Bologna Italy

Scoliosis Research Society

53rd Annual Meeting & Course

OCTOBER 10-13, 2018

Bologna Polo Congressuale • Piazza Costituzione 3, 40128, Bologna, Italy

Final Program

www.srs.org

Sponsored by the Scoliosis Research Society

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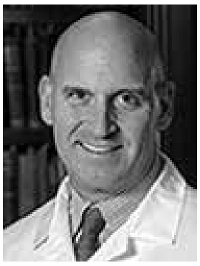
President's Message



Welcome to the 53rd Annual Meeting of the Scoliosis Research Society in Bologna. For the past 52 years this meeting has been the flagship event of the Society, and a meeting where spinal surgeons from around the world come to learn the most innovative research and information in our field. This year will be no different, as it will be a superb program. There were 1,617 submitted abstracts, approximately half from the United States and half from outside the United States. This resulted in 147 podium presentations, 103 e-posters, and 18 e-presentations, which are abstracts not presented on the podium but are considered excellent and will be recorded for future viewing on the SRS website after the meeting and are included in the final program. Additionally, there will be 12 case discussions, presented on Wednesday afternoon.

Highlights for this year's meeting include abstract sessions that start on Wednesday, allowing us 18 more abstracts to be presented than last year. With the new registration rates, your base registration includes both the Pre-Meeting Course on Wednesday and the Half-Day Courses, so no additional tickets are required for any of the educational or scientific sessions. Another change this year is that there are two member business meetings instead of three, being held Thursday at lunch and Friday at breakfast.

Thank you to Greg Mundis for putting together, along with his Program Committee, a superb scientific program. Also owed a debt of gratitude is Suken Shah, our Education Committee chair, for all his help overseeing the meeting, the Pre-Meeting Course and Half-Day Courses. The Pre-Meeting Course will run from 8:00-13:00 on Wednesday and is entitled "Physician Well Being for the Benefit of the Patient: How Can we be Better for Everyone Else?" This is an increasingly important topic and one that is being recognized as a significant issue in our field. The Pre-Meeting Course will be followed by lunchtime symposia, the first abstract session, "Session 1A: Adult Spinal Deformity" and case discussion sessions. After the educational content, do not miss the Opening Ceremonies including the Blount Award presented to Dr. Richard Schwend and the Steele Lecture this year given by Kevin Zraly on Italian wine and food of the region.

Thursday will feature the Lifetime Achievement presentations to John. A. (Tony) Herring, MD, and Se-Il Suk, MD. The Harrington lecture will be given by James Kerr focusing on insights into the success of the New Zealand All Blacks rugby team, the most successful team in sports history. We also will offer three Half-Day Courses on Thursday afternoon from 15:00-18:00.

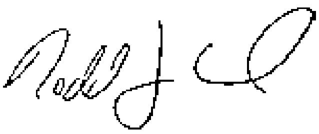
Friday will offer 2019 meeting previews, the Presidential Address and an excellent Farewell Reception at Palazzo Re Enzo located in Bologna's main square, the Piazza Maggiore. This historic palace dates back to the 13th century and offers unique views of the Piazza Maggiore and the famous Neptune Fountain. Cocktail attire is appropriate for the Farewell Reception. We will finish the meeting on Saturday with a half day of scientific sessions.

I want to personally thank our local members, Marco Brayda-Bruno, Mario Di Silvestre and Alberto Ponte, who have done much to bring the meeting to Bologna. They have been incredibly involved and supportive.

The SRS staff, lead by executive director Tressa Goulding, deserves special recognition for their incredible efforts in running this Society and making the work of the SRS president seamless and easy.

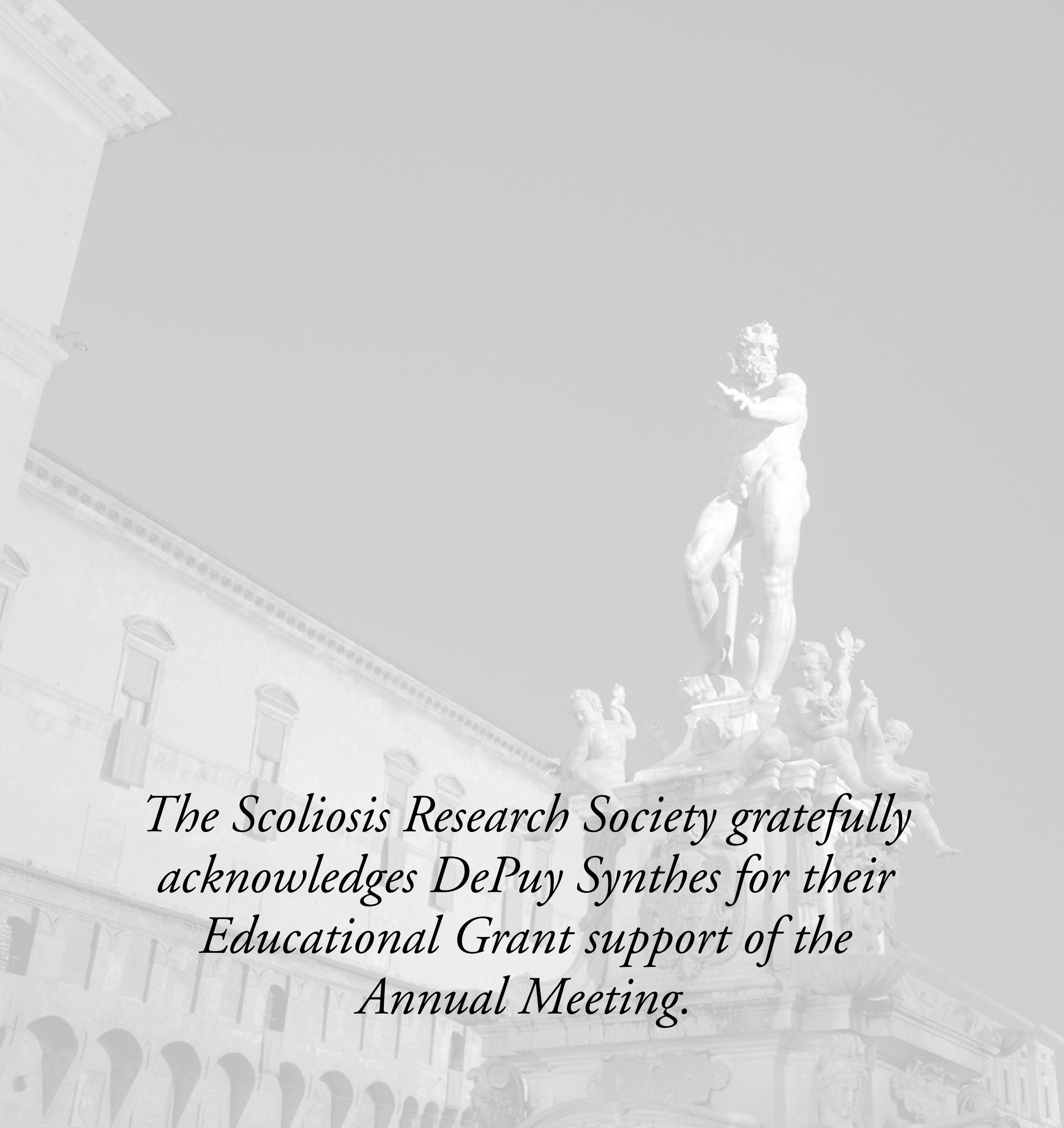
It has been an honor to serve you this year as president of an amazing society. I want to especially thank my close teammates on the presidential line and colleagues who supported me over the last three years: Past President II David Polly, Immediate Past President Ken Cheung, President Elect Peter Newton and Vice President Paul Sponseller. I am confident that the Society will rise to even greater levels of success under the leadership of Peter Newton and I am excited to see the changes forthcoming.

Sincerely,



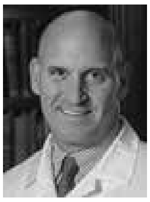
Todd J. Albert, M.D.

General Meeting Information



The Scoliosis Research Society gratefully acknowledges DePuy Synthes for their Educational Grant support of the Annual Meeting.

Board of Directors - 2017-2018



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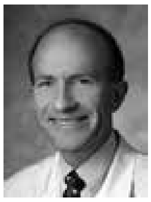

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Vincent C. Traynelis, MD
Surya Prakash Voleti, MD, DNB
Kota Watanabe, MD, PhD
Yat Wa Wong, MD

General Meeting Information

Venue Information

Bologna Polo Congressuale
Piazza Costituzione 3, 40128, Bologna

Abstract Volume

All abstracts accepted for presentation at the 53rd Annual Meeting have been published in the final program. Each attendee will receive one copy of the program along with their registration materials. Abstracts have also been posted online to the Program tab of the SRS Annual Meeting website (www.srs.org/am18/program).

Admission To Sessions

Official name badges will be required for admission to all sessions. All Annual Meeting attendees receive a name badge with their registration materials. Name badges should be worn at all time inside the congress center, as badges will be used to control access to sessions and activities. Attendees are cautioned against wearing their name badges while away from the venue, as badges draw unwanted attention to your status as visitors to the city.

Admission By Tickets

Tickets will be required for admission to the Farewell Reception. The Farewell Reception will take place at the Palazzo Re Enzo, at an additional $50 fee per ticket for registered delegates and $175 for registered guests. If you pre-registered, tickets will be distributed with your registration materials and name badge. A limited number of tickets may be available for purchase at the Registration Desk.

Attire

Business casual (polo or dress shirts, sports coats) is appropriate for all Annual Meeting sessions; ties are not required. The Farewell Reception dress code is cocktail attire.

Cell Phone Protocol

Please ensure that cell phone ringers, pagers and electronic devices are silenced or turned off during all sessions.

Emergency & First Aid

The Bologna Polo Congressuale is fully prepared to handle emergency requests and first aid. Contact an SRS staff person for support. Remember to note all emergency exits within the venue.

E-Posters

There are over 100 E-Posters available for your review on the E-Poster kiosks in the Foyer Europa on the ground floor of the Bologna Polo Congressule. The E-Posters are also available on the USB included with your registration materials.

E-Poster USBs are supported, in part, by a grant from NuVasive.

E-Presentations

E-Presentations will be recorded onsite at the Annual Meeting and will be available for attendees to view online approximately two weeks after the meeting. The 18 E-Presentation abstracts are also included in the abstract volume in the final program.

Evaluations

Please take time to complete the online evaluation forms provided for each session you attend. Evaluations can be found on the mobile app or online; for more information, see page 7 of the final program. Your input and comments are essential in planning future Annual Meetings.

Wireless Internet

Wireless Internet access is available throughout the meeting space, to log on use:

Network: srs2018
Password: scoliosis

Language

English will be the official language of the SRS Annual Meeting.

Lost & Found

Please feel free to stop by the SRS Registration Desk if you have lost or found an item during the course of the Annual Meeting.

Announcement Board

A self-service announcement board (non-electronic) will be available in the registration area for attendees to post notes or leave messages for other attendees. SRS staff will also post meeting updates and announcements on the board.

The announcement board is supported, in part, by a grant from NuVasive.

Members Business Meetings

Location: Hall 19

All SRS members are invited to attend the Members Business Meetings, at the following times:

- Thursday, October 11 – 13:30-14:45 (hot lunch buffet)
- Friday, October 12 – 7:30-8:45 (hot breakfast buffet)

Agendas will include reports from the various SRS committees, presentations by the 2018 Travelling Fellows and updates on SRS activities and programs.

Registration Desk

Location: Sala Maggiore Foyer

Tuesday, October 9	12:00 – 17:00
Wednesday, October 10	7:30 – 19:00
Thursday, October 11	7:30 – 17:00
Friday, October 12	7:30 – 17:00
Saturday, October 13	7:45 – 11:00

General Meeting Information

Presentation Upload Area

Location: Foyer Europa Office

Presenters may upload their PowerPoint presentations in the Presentation Upload Area, located on the ground level in the Foyer Europa Office.

Presentations may not be uploaded in individual rooms, but must be uploaded in the Presentation Upload Area.

Wednesday, October 10	7:30 – 20:00
Thursday, October 11	7:30 – 18:00
Friday, October 12	7:30 – 18:30
Saturday, October 13	7:30 – 13:30

Smoking Policy

Smoking is not permitted during any meeting activity or event.

Photography Policy

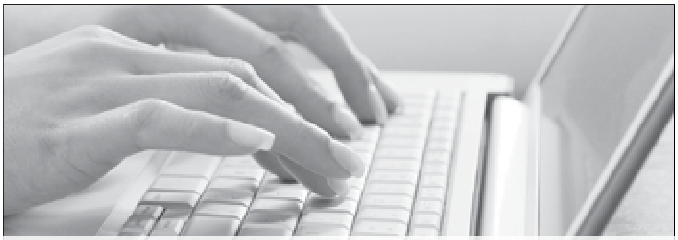
SRS will be taking photographs throughout the Annual Meeting. SRS will use these photos in publications and to produce related literature and products for public release. Individuals photographed will not receive compensation for the use and release of these photos and will be deemed to have consented to the use and release of photos in which they appear. If you are opposed to being photographed, please immediately notify the photographer or an SRS staff member if your picture is taken. Thank you for your cooperation.

Video Recording Prohibited

SRS does not allow personal video recording of the presentations of any kind. SRS holds the right to confiscate any and all recordings taken of any of the presentations. All session rooms will be recorded and will be available to delegates after the meeting on the SRS website.

Special Needs

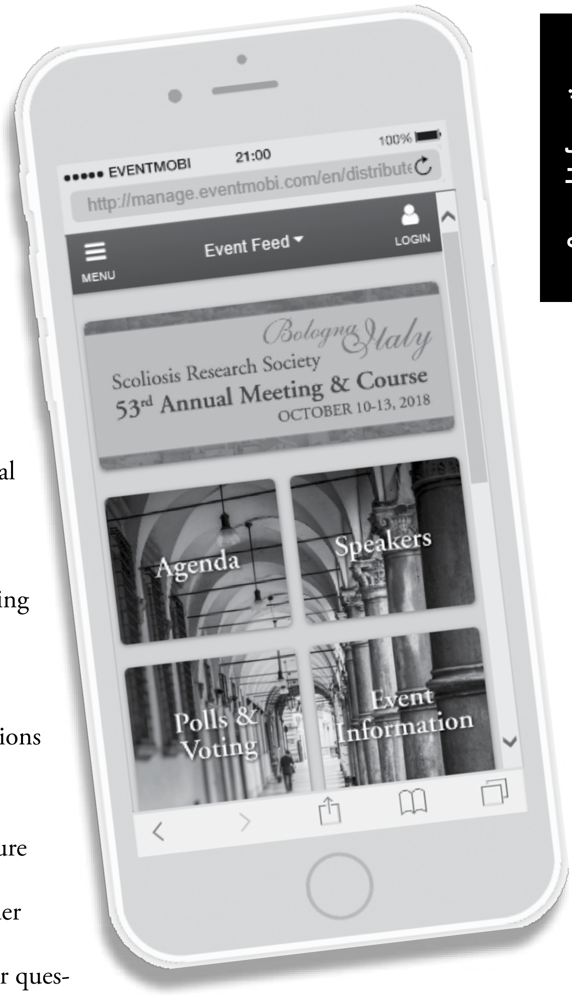
If you have any health issues for which you may require special accommodations or assistance, please notify the SRS staff at the Registration Desk. We will make every effort to accommodate any special needs.



VIDEO ARCHIVES

Video archives will be available to all meeting delegates on the SRS website (www.srs.org/professionals/online-education-and-resources/past-meeting-archives) four to six weeks after the meeting. All session rooms are being recorded. If you were unable to attend a concurrent session, don't forget to watch it on the website!

SRS Annual Meeting Mobile App



A mobile app will be available to all delegates during the 53rd Annual Meeting. The app is designed to enhance the attendee experience by providing all the information about the Annual Meeting in one convenient location that can be accessed from any smart phone or tablet with an internet connection.

To download the 53rd Annual Meeting Mobile App:

1. Search for “SRS AM 2018” in the App Store or Google Play Store and install
2. Open the downloaded app to begin using the app right away!
3. To take full advantage of the app, login with your email address

Once downloaded, delegates can access all static content on the app without an internet connection, including:

- A detailed Annual Meeting agenda that allows delegates to create a personalized schedule (must login with an email address)
- Maps of the meeting space
- An alert system for real-time updates from SRS – program changes, tour and social event notifications, and breaking news as it happens
- Session and overall meeting evaluations
- Session handouts created by faculty
- Live polls and the “Ask a Question” feature allowing you to submit questions during specific sessions

New This Year: Ask A Question In The App

Delegates will be able to ask questions, directly through the mobile app, during sessions held in the Europauditorium (designated by “?” in the agenda).

To ask a question:

1. Click on “Meeting Agenda” and select a session with the “Ask a Question” feature enabled.
2. Scroll to the bottom of the session information and click “Ask a Question” under Session Engagement. Questions already asked by attendees will be listed.
3. Type your question in the text box provided and click "Submit Question". Your question will appear within the question list.
4. If someone else has already asked your question, you can upvote the question by clicking the button to the right of the question in the list. When questions get upvoted they will be pushed higher up on the page as the number of votes increase.

Participate In Live Session Polls

Live session polls will be used in the Pre-Meeting Course on Wednesday, October 10 and the Adult Deformity Half-Day Course on Thursday, October 11.

To patriciate in a poll, select the session from the meeting agenda in the mobile app. Scroll down to the bottom of the session page and click, “Join Live Poll” under Session Engagement.

Once you've started a session poll, you can move from question to question by selecting your answers and clicking “Submit” or by clicking on the navigation arrows to the left and right of the Submit button. Moderators will display the live results on screen for the entire audience to view.

Please remember to activate your wireless access on your mobile device or tablet to utilize the mobile app without incurring international fees and charges.

Network: srs2018 Password: scoliosis

Stay up to date with SRS during the Annual Meeting and share your experiences.

#SRSAM18

@srs_org Scoliosis Research Society @srs_org ® Scoliosis Research Society

CME Information

Meeting Description

The Scoliosis Research Society (SRS) Annual Meeting is a forum for the realization of the Society's mission and goals, the improvement of patient care for those with spinal deformities. Over 145 papers will be presented on an array of topics, including adolescent idiopathic scoliosis, growing spine, kyphosis, adult deformity, trauma, neuromuscular scoliosis and tumors.

Learning Objectives

Upon completion of the Annual Meeting, participants should be able to:

- Identify symptoms of professional burnout and take appropriate action to improve mental and physical health for benefit of the patient.
- Classify and integrate preoperative planning into surgical plans to optimize patient outcomes.
- Combine understanding of pediatric and adult natural history and pathology to strengthen best practices.
- Assess innovative evidence-based research for appropriate incorporation into the clinical environment.
- Promote safe practices and complication reduction in the treatment of complex spine deformity.

Target Audience

Spine surgeons (orthopaedic and neurological surgeons), residents, fellows, nurses, nurse practitioners, physician assistants, engineers and company personnel.

Accreditation Statement

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education (ACCME) through the sponsorship of the Scoliosis Research Society (SRS). SRS is accredited by the ACCME to provide continuing medical education for physicians.

Credit Designation

SRS designates this live activity for a maximum of 28 AMA PRA Category 1 Credit(s)TM. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Disclosure of Conflict of Interest

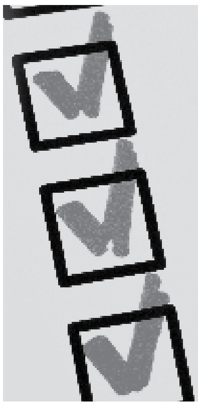
It is the policy of SRS to insure balance, independence, objectivity and scientific rigor in all of their educational activities. In accordance with this policy, SRS identifies conflicts of interest with instructors, content managers and other individuals who are in a position to control the content of an activity. Conflicts are resolved by SRS to ensure that all scientific research referred to, reported or used in a CME activity conforms to the generally accepted standards of experimental design, data collection and analysis. Complete faculty disclosures will be included in the final program.

FDA Statement (United States)

Some drugs and medical devices demonstrated during this course have limited FDA labeling and marketing clearance. It is the responsibility of the physician to be aware of drug or device FDA labeling and marketing status.

Insurance/Liabilities and Disclaimer

SRS will not be held liable for personal injuries or for loss or damage to property incurred by participants or guests at the Annual Meeting including those participating in tours and social events. Participants and guests are encouraged to take out insurance to cover loss incurred in the event of cancellation, medical expenses or damage to or loss of personal effects when traveling outside of their own countries. SRS cannot be held liable for any hindrance or disruption of the Annual Meeting proceedings arising from natural, political, social or economic events or other unforeseen incidents beyond its control. Registration of a participant or guest implies acceptance of this condition. The materials presented at this Continuing Medical Education activity are made available for educational purposes only. The material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement or opinion of the faculty that may be helpful to others who face similar situations. SRS disclaims any and all liability for injury or other damages resulting to any individual attending a scientific meeting and for all claims that may arise out of the use of techniques demonstrated therein by such individuals, whether these claims shall be asserted by a physician or any other person.



EVALUATIONS

WE NEED YOUR FEEDBACK!

Complete the session and overall meeting evaluations on the app or online.

If you have questions, contact SRS at cme@srs.org

On the App: Session Evaluations:

1. Select "Meeting Agenda" from the home screen
2. Select the Session you want to evaluate
3. Scroll to the bottom of the session description to find the evaluation

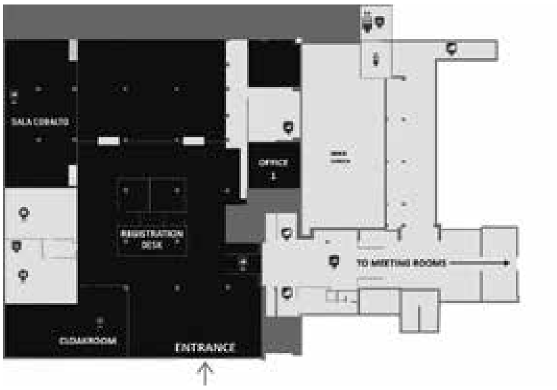
Overall Meeting Evaluation:

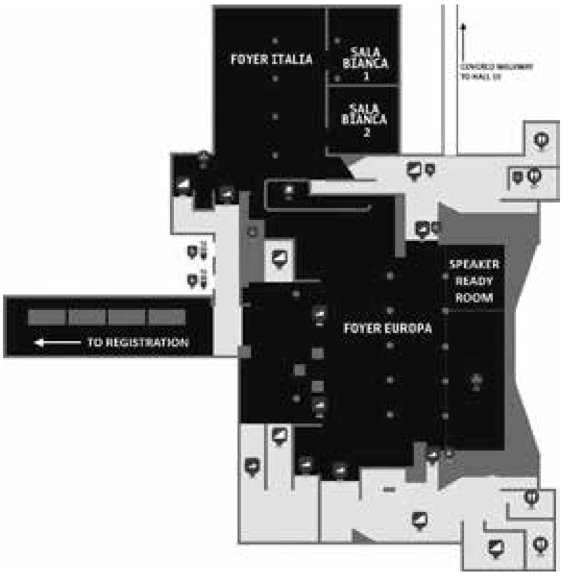
1. Select "Polls & Voting" from the home screen
2. Select the Annual Meeting Evaluation

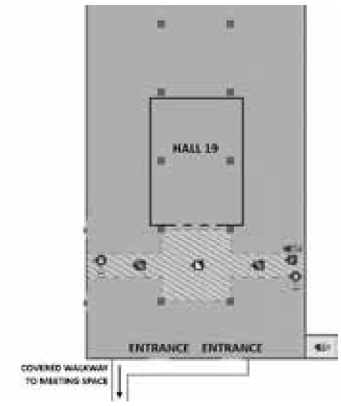
Online: www.srs.org/am18/cme-evaluations

Meeting Space Floorplans

Ground Floor:

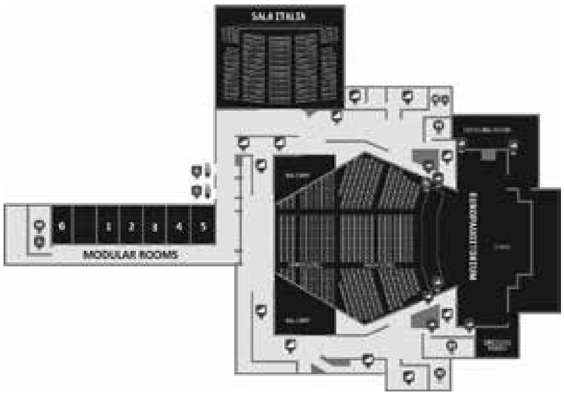






Ground Floor:
Sala Maggiore Foyer – Registration Desk
Foyer Europa – E-Posters, Catering (Breaks & Lunch)
Foyer Europa Office - Presentation Upload Area
Sala Bianca Room 1 – Pop-Up Committee Room
Sala Bianca Room 2 – Pop-Up Committee Room
Hall 19 – Concurrent Sessions (PMC, HDC, LTS) & Member Business Meetings

1st Floor:



1st Floor:
Europauditorium – General Session
Sala Italia – Concurrent Sessions, Hibbs Society Meeting
Plazza dei Congressi Modular Rooms 1-6 – Committee Meeting Rooms & Corporate Hospitality Rooms

Bologna Transportation

Getting to the Congress Center (Bologna Polo Congressuale)

The Bologna Polo Congressuale is located 5km from the city center. Attendees staying in the city center can get to the Polo Congressuale by taxi or bus.

Taxi

There will be an increased rotation of taxi's at the Polo Congressuale during the days of the meeting.

Taxi Bologna
Telephone: +39 051 4590

Cotabo Taxi Bologna
Telephone: +39 051 372727

Bus

Polo Congressuale Bus Stop: Fiera Palazzo Congressi
Bologna Polo Congressuale Address: Piazza Costituzione 3, 40128, Bologna

Bus	City Center → Polo Congressuale	Polo Congressuale → City Center
N. 28	From Via Indipendenza San Pietro bus stop to Fiera Palazzo Congressi bus stop *Schedule: Monday-Friday from 5:57-21:00* *Bus departs every 12-15 minutes* *Ride Time: 20-25 minutes* *(On Saturday buses depart from via dei Mille bus stop instead.)*	From Fiera Palazzo Congressi bus stop to Via Indipendenza San Pietro bus stop *Schedule: Monday-Friday* *Bus departs every 12-15 minutes* *Ride Time: 18-20 minutes* *(Last bus departs at 20:40)*
N. 35	From the Satzione Centrale bus stop to Fiera Palazzo Congressi bus stop *Schedule: Monday-Friday from 5:33-20:00* *Bus departs every 5-10 minutes* *Ride time: 11-15 minutes* *(Last bus on Saturday departs at 14:00)*	From Fiera Palazzo Congressi bus stop to Satzione Centrale bus stop *Schedule: Monday-Friday* *Bus departs every 15 minutes* *Ride time: 10-15 minutes* *(Last bus Monday-Friday departs at 20:18; last bus on Saturday departs at 14:20)*
N. 38	From the Satzione Centrale bus stop to Fiera Palazzo Congressi bus stop *Schedule: Monday-Friday from 5:37-20:28* *Bus departs every 20 minutes* *Ride time: 10-15 minutes* *(Last bus on Saturday departs at 20:27)*	From Fiera Palazzo Congressi bus stop to Satzione Centrale bus stop *Schedule: Monday-Friday from 5:37-20:32* *Bus departs every 20 minutes* *Ride time: 10-15 minutes* *(Last bus Monday-Friday departs at 20:32; last bus on Saturday departs at 20:37)*

Ticket Options

1. Timed tickets: Valid for 75 minutes - € 1.30/ ticket (€ 1.50/ticket if purchased on board)
2. 24 hours daily ticket: Valid for 24 hours - € 5.00/ticket (must be purchased before getting on board)
3. Citypass: 10 ticket pack, each ticket is valid for 75 minutes - € 12.00/10 ticket pack (must be purchased before getting on board)

Meeting Outline

Monday, October 8, 2018	
8:00-16:00	Board of Directors Meeting*
Tuesday, October 9, 2018	
7:00-17:00	SRS Committee Meetings*
12:00-17:00	Registration Open
13:00-17:00	Hibbs Society Meeting*
19:00-22:00	SRS Leadership Dinner* (by invitation only)
Wednesday, October 10, 2018	
7:30-19:00	Registration Open / E-Posters* Open
7:30-20:00	Presentation Upload Area Open
9:00-13:00	Pre-Meeting Course
13:15-14:15	Lunchtime Symposia
14:30-17:20	Scientific Program
17:30-18:30	Case Discussions
18:45-20:00	Opening Ceremonies*
20:00-22:00	Welcome Reception*
Thursday, October 11, 2018	
7:00-8:30	2018-2019 Committee Chair Breakfast* (by invitation only)
7:30-17:00	Registration Open / E-Posters* Open
7:30-18:00	Presentation Upload Area Open
8:55-13:30	Scientific Program
13:30-14:45	Member Business Meeting & Lunch*
13:45-14:45	Non-Member Lunch Session*
15:00-18:00	Half-Day Courses
18:00-18:30	Member Info Session*
Friday, October 12, 2018	
7:30-8:45	Member Business Meeting & Breakfast*
7:30-17:00	Registration Open / E-Posters* Open
7:30-18:30	Presentation Upload Area Open
8:55-12:45	Scientific Program
13:00-14:00	Lunchtime Symposia
14:15-18:14	Scientific Program
20:00-23:00	Farewell Reception*
Saturday, October 13, 2018	
7:30-13:30	Presentation Upload Area Open
7:45-11:00	Registration Open / E-Posters* Open
8:55-13:30	Scientific Program
14:00-16:30	Board of Directors Meeting*

*denotes non-CME

Guest Lectures & Award Recipients

Howard Steel Lecture

Wednesday, October 10, 2018
A Glass Half Full
Kevin Zraly

Internationally acclaimed wine educator, best-selling author, James Beard Lifetime Achievement Award Recipient Kevin Zraly has been described as a naturally gifted speaker who is both refreshingly humble and candid. His passion for wine and food and his engaging teaching style help demystify the ever-changing world of wine.

After graduating college and studying wine by visiting vineyards and winemakers, Kevin had a chance meeting with legendary restaurateur Joe Baum which led to his being hired as the first cellar master and eventually wine director of the renowned Windows on the World Restaurant atop One World Trade Center. Windows soon became the country's top grossing restaurant and, with Kevin at the helm of its highly recognized wine list, sold more wine than any restaurant in the world. It was there that he established his Windows on the World Wine School which lasted forty years and graduated more than 20,000 students ranging from wine novices and aficionados to top chefs and culinary professionals. Kevin worked at the Windows on the World Restaurant for 25 years, from the day it opened in 1976 until September 11, 2001.

He has been featured in such publications as The New York Times, People magazine The Wall Street Journal, GQ magazine, Newsweek and USA Today and has been featured on the Regis and Kelly Show and other syndicated television and radio shows He co-hosted the Food Networks ''Wine A to Z," captivating his audience with his signature charisma and enthusiasm.

He is a member of the Board of Trustees of the Culinary Institute of America (since 1990) and director of the Sherry-Lehmann/ Kevin Zraly Master Wine Classes, the Sherry-Lehmann/Kevin Zraly Wine Club, and the Kevin Zraly Advanced Wine Classes in New York City.

Kevin presents corporate and private One Hour Wine Expert Tastings and Wine Paired Dinners along with his teaching at the Kevin Zraly Advanced Wine Classes.

Kevin is the author of the best selling Windows on the World Complete Wine Course, now in its 31st edition with more than 4 million copies sold. He is also the author of the first book that covers wineries and vineyards in all 50 states, Kevin Zraly's American Wine Guide, The Ultimate Wine Companion, a compilation of 40 world-renowned wine writers, and Red Wine (2017) which has won the Gourmand 2017 Best Wine Book in the U.S.

Harrington Lecture

Thursday, October 11, 2018
A Legacy of Leadership
James Kerr

James Kerr is a bestselling author, speaker and business consultant specializing in defining, designing and delivering change for leaders of world-class teams and organizations. His latest book, Legacy, reveals 15 leadership lessons from the All Blacks, the world's most successful sporting team, and his corporate clients include HSBC, Boeing, Raffles, UBS and Shell. In the sporting arena he has also worked with UEFA, Team Origin, the RFU, Adidas and the Australian Kangaroos. His Key message is that "higher purpose leads to higher performance" and that successful change begins with a values-based, vision-led, purpose driven mindset – and ends without it.

Walter P. Blount Humanitarian Award Recipient

The 2018 Walter P. Blount Humanitarian Award will be presented on Wednesday, October 10, acknowledging outstanding service to those with spinal deformity, and for generosity to the profession and society.

Richard M. Schwend, MD

Richard M. Schwend MD, is Chief of Orthopaedic Research at the Children's Mercy Hospital, and is Professor of Orthopaedics and Pediatrics, University of Missouri, Kansas City and University of Kansas Medical Center.

Dr. Schwend graduated with BA Biochemistry from the University of California, MD from St. Louis University Medical School, general pediatric residency training at Children's Mercy Hospital, orthopaedic residency at Harvard Combined Orthopaedic Residency and pediatric orthopaedic fellowship at Children's Hospital, Boston, under the mentorship of his chief, Dr. John Hall, finishing training in 1992. In 1993 he received the Harvard University Cave Travelling Fellowship to Bern, Switzerland. He recently completed the Global Clinical Research Training Program, Harvard University. His board certification is in pediatrics and orthopaedics.

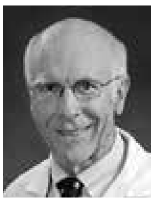
Early in his career he was introduced to global health care. As a fourth-year medical student he had to try hard to convince his Dean of Students to be able to do a 3-month elective in rural Liberia, West Africa, after he had already been awarded a Wheaton College Fellowship. After initial training in pediatrics he spent 3 years in the Indian Health Service as a general medical officer in Zuni, New Mexico. As Clinical Director he helped to make the hospital the first government health care facility to be completely non-smoking, not very popular back then, but did receive a commendation from the Surgeon General. During his pediatric orthopaedic fellowship in 1992, his staff mentor, Peter Waters, invited him and generously paid for the 2-week trip to Romania, just after the fall of the communist dictator Chauchescu. Dr. Schwend learned from Peter the importance to "pay forward" and of mentoring young people interested in this type of work. For many years he returned to Romania for service trips. After fellowship Dr. Schwend returned to the Indian Health Service as the first pediatric orthopaedic surgeon employed by USPHS, this time on the Navajo Reservation. For much of his career he continued to have outreach clinics in Shiprock New Mexico. In 2002 while deployed with the USAF because of 9/11 he was asked to join a humanitarian project in Guayaquil, Ecuador. He met Sister Annie Credidio, Catholic nun caring for the poor of Ecuador, who convinced him to come back the next year, and the next… This was the first of 18 years of continuous service to the Children of Ecuador. Begun as a pediatric orthopaedic program, the largest unmet need was identified by local staff to be pediatric spine deformity. After several years of infrastructure assistance and education, the Pediatric Spine Project was begun in 2008 and has continued to grow since then in cooperation with the Roberto Gilbert Hospital and local staff. Since day one it has been based on the principles of Safety always, staff mentoring, team ownership, and infrastructure development.

Dr. Schwend is immediate past president of POSNA and was Chair of the Orthopaedic Section of the American Academy of Pediatrics 2010-2014. While Chair he helped to develop the AAP scholarship program for residents to have international global experiences under the guidance of a mentor. He was a 2001 Scoliosis Research Society Travelling Fellow. He chaired POSNA COUR committee 2009-2011 as well as POSNA Advocacy Committee and Practice Management Committee. He is chair of SRS Health Policy Committee. Dr. Schwend received the POSNA Humanitarian award 2014 and the POSNA Special Effort award in 2013. He is Medical Director of the Project Perfect World, Ecuador, which sponsors the Ecuador Spine Project. His research interests involve program development in regions with limited resources, pediatric spine and chest anatomy and surgical safety. After 23 years in the USPHS and USAF he is a retired Colonel, United States Air Force Reserves. Rick and his wife Colleen have two children, Ryan and Meghan and now one granddaughter, 2 year-old Ada. Fun Facts: born in Hollywood CA, in his spare time he enjoys family time, bicycling to work, open water swimming, fly fishing, reading anything history, airplanes and travelling the world to see his friends.

Lifetime Achievement Award Recipients

The 2018 Lifetime Achievement Awards will be presented on Thursday, October 11. The Lifetime Achievement Award Recipients were chosen from among the SRS membership, based on long and distinguished service to the Society and spinal deformity research and care.

John A. (Tony) Herring, MD



Dr. Herring was born and grew up in Vernon, Texas, attended The University of Texas, graduated Phi Beta Kappa after 3 years. He graduated AOA from Baylor College of Medicine in Houston, Texas, and began his medical career as an intern in internal medicine at the Peter Bent Brigham Hospital. In his last semester in medical school he developed an interest in orthopedic surgery. After his internship and a year's training as a junior resident in surgery he served his residency in the Harvard Combined Orthopedic Program where he worked under Dr. John Hall. He then served two years in the United States Navy in San Diego where he did primarily pediatric orthopedics with Dr. Alvin Crawford.

He was awarded a travelling fellowship in pediatric orthopedic surgery by the Orthopedic Research and Education Foundation. During that fellowship he and Dr. Crawford were the first American orthopedists to visit Dr. Eduardo Luque in Mexico City. He then returned to begin his career at the Texas Scottish Rite Hospital for Children in Dallas, Texas, where he became Chief of Staff, a position he held for 44 years.

In the late 1970's he was a leader in the application of the segmental fixation techniques of Luque, and also noted many of the associated risks. He was awarded the first Hibbs Clinical and Hibbs Research awards by the SRS for his related research in 1981. Dr. Herring had a busy spinal deformity practice and was an early user of the Cotrel-Dubouset instrumentation, and was part of the team that developed the TSRH instrumentation system. Dr. Herring assisted Dr. Dubousset in his work describing the Crankshaft Phenomenon. Dr. Herring and his group published the first paper showing a direct relationship between hours of brace wear and control of idiopathic scoliosis progression. He was the program chairman of the TSRH Fellowship in Pediatric Orthopedics and Scoliosis for 44 years and oversaw the training of more than 160 North American fellows and numerous international fellows. Dr. Herring feels that the training of future spinal deformity surgeons is his most important legacy.

Dr. Herring has overseen and participated in the clinical portions of molecular genetic research at TSRH which has identified several genes related to the development of idiopathic scoliosis, and this group has been awarded two Hibbs Awards by the SRS. In addition Dr. Herring has received the Award for Distinguished Achievement from the Pediatric Orthopedic Association of North America (POSNA), the Lifetime Achievement Award Ehrenmedaile from the Pediatric Orthopedic Society of the German Speaking Countries, Honorary Fellowship in the Royal College of Surgeons in Ireland, the Benjamin Rush Award from the American Medical Association, the Clinical Scientific Paper Award from POSNA, and delivered the Shands Lecture for the American Orthopedic Association. For the SRS he has served on the board of directors and has chaired the Instrumentation and Research Committees, and served on the Etiology and Subspecialty Certification Committees. He has published more than 150 scientific papers and is the editor of Tachdjian Textbook of Pediatric Orthopedics, 4th, 5th, and 6th editions.

Dr. Herring is a devoted family member to his wife of 48 years, 3 daughters, and 10 grandchildren. His hobbies include cycling, photography, piano. He has ridden his bicycle to work for more than 40 years and competes in the Senior Olympics in cycling.

Se-Il Suk, MD

Known to every single member of the society as "Prof. Suk", there is no one more influential to the clinical and academic practice of spinal deformity surgery around the world the past 25 years than he has been. His clinical experience began the slow transition around the world to making thoracic pedicle screws the gold standard for all spinal deformity operations, which has stood the test of time with so many patients worldwide.

Se-Il Suk, MD, graduated from Seoul University Medical School in 1958 and PhD in 1964. He had orthopedic resident training in 1964-1968 at University of Rochester, NY, under his mentor, Dr. Louis A. Goldstein. Prof. Suk returned to Seoul University in 1968 as faculty and stayed there as a professor until 1997. He then moved to Inje University Sanggye-Paik Hospital where he organized Spine Center in 1997 and still works there.

Prof. Suk served as Presidents for many national and international organizations; Korean Orthopedic Association in 1980, Korean Spine Society in 1988, Korean Orthopedic Research Society in 1995, International Orthopedic Research Society (SIROT) in 2002-2005, as well as others. He trained many Korean/International Spine Fellows as well as invited them every year to visit through the SRS office. He has hosted SRS Traveling Fellows since 1998 as well as an SRS Asia-Pacific Spine Meeting, Jeju in 2005.

Prof. Suk reported many new procedures in correction of spine deformity. When he reported thoracic pedicle screw (TPS) fixation for thoracic AIS at SRS in 1994, many surgeons did not believe it. Countless members can now agree that this was probably the greatest change to occur in spinal deformity surgery following the introduction and universal usage of CD instrumentation in the 1980s. He also reported only Posterior Vertebral Column Resection (PVCR) in 1997 which was risky but now widely applied. He was the first to both demonstrate and report that this extremely difficult but beneficial operation could be performed through an all posterior approach. He reported Direct Vertebral Rotation (DVR), a new technique of 3-dimensional deformity correction with segmental pedicle screw fixation in AIS in 2004.

On top of being a pioneer in the industry, a highly skilled surgeon, a leading academician, and a genuinely personable and professional man, Prof. Suk has also published more than 200 papers and many textbooks.

Social Events

Opening Ceremonies & Welcome Reception

Wednesday, October 10, 2018
18:45-22:00

Open to all registered delegates and their registered guests at no additional fee. Name badges are required.

The Annual Meeting will officially begin with the Opening Ceremonies and this year's Howard Steel Lecture, presented by Kevin Zraly. All delegates and registered guests are invited and encouraged to attend the Opening Ceremonies. Following the Opening Ceremonies, we will move to a hosted reception featuring heavy hors d'oeuvres, cocktails, and plenty of lively conversations and reunions with colleagues and friends.

The Welcome Reception is supported, in part, by grants from Medtronic, NuVasive, and OrthoPediatrics.

Farewell Reception

Friday, October 12, 2018
20:00-23:00

The 53rd Annual Meeting will culminate with a Reception at the Palazzo Re Enzo located in Bologna's main square, Piazza Maggiore. This historic palace dates back to the 13th century and offers unique views of the Piazza Maggiore and famous Neptune Fountain.

The Reception is open to all registered delegates and registered guests. Tickets are $50 each for registered delegates and $175 for registered guests, and should be purchased in advance. A limited number of tickets may be available for purchase onsite. SRS strongly urges delegates and guests to purchase tickets at the time of registration. Cocktail dress is appropriate for the Farewell Reception.

Optional Tours

The following tours are available to registered delegates and guests through Bologna Welcome.

The following tours must be pre-booked through Bologna Welcome. Please note, tours with a minimum number of persons listed will only operate if the minimum number of persons book the tour.

Tour	Date	Time	Departure Location
Bologna City Walking Tour	Every day	16:45-18:45 *2 hrs.*	Bologna Welcome Tourist Center *Piazza Maggiore 1/e - 40124*
Tower Break Food Experience *15 person minimum*	October 10	11:00-13:00 *3 hrs.*	Piazza del Nettuno
Enjoy Bologna Food Tour *10 person minimum*	October 11	17:00-19:00 *2 hrs.*	Piazza del Nettuno
Gelatology *15 person minimum*	October 12	10:00-13:00 *3 hrs.*	Bologna Welcome Tourist Center *Piazza Maggiore 1/e - 40124*
Flavors of Emilia Experience *4 person minimum*	October 9 October 13	10:00-20:00 *10 hrs.*	Hotel Pick-up
Truffle Hunting Experience *4 person minimum*	October 9 October 13	15:30-22:00 *8 hrs.*	Hotel Pick-up

If you did not pre-book a tour, additional tour options are available online at www.bolognawelcome.com/en/home/find-book/tour/ or in person at the Bologna Welcome Tourist Center, located in the Piazza Maggiore (Piazza Maggiore 1/e – 40124).

Restaurant Recommendations

Ristorante Al Sangiovese
www.alsangiovese.com/en/index.html
Vicolo del Falcone, 2, 40124 Bologna BO, Italy

Taverna del Postiglione
www.tavernadelpostiglione.it/
Bologna Via Marchesana, 6/e, 40124 Bologna BO, Italy

Osteria de' Poeti
www.osteriadepoeti.it/eng/events-winebar-bologna.html
Via de' Poeti, 1/B, 40124 Bologna BO, Italy

Trattoria Battibecco
www.battibecco.com/index.aspx
Via Battibecco, 4, 40123 Bologna BO, Italy

Ristorante da Nello
www.ristorantedanello.com/Home_Page_en.html
Via Monte Grappa, 2, 40100 Bologna BO, Italy

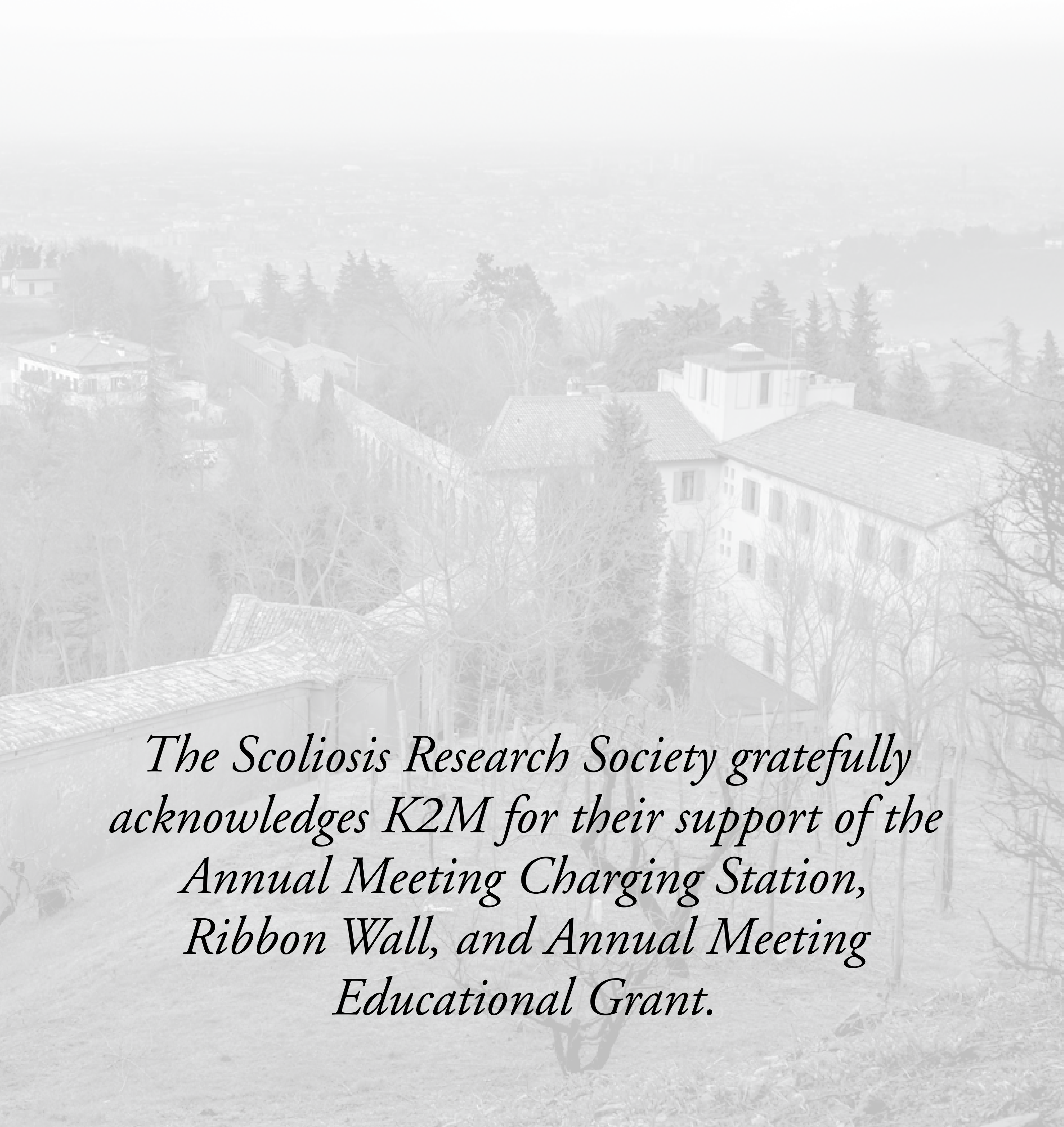
Il Posto
www.ilposto.bo.it/
Via Massarenti, 37, 40138 Bologna BO, Italy

da Silvio
www.dasilvio.it/en/restaurant/
Via S. Petronio Vecchio, 34, 40125 Bologna BO, Italy

Osteria Bartolini
www.osteriabartolinibologna.com/
Piazza Malpighi, 16, 40123 Bologna BO, Italy

Quanto Basta
Via del Pratello, 103, 40122 Bologna BO, Italy

Conflict of Interest Disclosures



The Scoliosis Research Society gratefully acknowledges K2M for their support of the Annual Meeting Charging Station, Ribbon Wall, and Annual Meeting Educational Grant.

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Nobuyuki Fujita, MD	Japan	No Relationships
Rohan B. Gala, MS	India	No Relationships
Eduardo Galaretto, MD	Argentina	No Relationships
Jesse M. Galina, BS	United States	No Relationships
Shashank V. Gandhi, MD	United States	No Relationships
Bilwaj Gaonkar, PhD	United States	No Relationships
Sumeet Garg, MD	United States	Medtronic (b); Mighty Oak Medical (b)
Enrique Garrido, MD, FRCS	United Kingdom	No Relationships
Martin Gehrchen, MD, PhD	Denmark	K2M (a); Medtronic (a)
Stephen G. George, MD	United States	No Relationships
Paul Gerdhem, MD, PhD	Sweden	No Relationships
Michael C. Gerling, MD	United States	Wolf (b)

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Ismat B. Ghanem, MD, MBBS	Lebanon	No Relationships
Alexander Gibson, FRCS	United Kingdom	BIEDERMANN (b); DePuy Synthes (d)
Sarah Gilday, PA-C, MS	United States	No Relationships
Olivier Gille, MD, PhD	France	Spineway (a)
Federico P. Girardi, MD	United States	Centinial Spine (e, g); DePuy Synthes (a, g); Ethicon (b); Healthpoint Capital (b, c, e); LANX (b, c, g); Liventa Bioscience (c); MiMedx Group (a); NuVasive (b, g); Paradigm Spine LLC (c, e, g); Spinal KInetics Inc (c, e)
Joseph P. Gjolaj, MD	United States	DePuy Synthes (b)
Juliane D. Glaeser, PhD	United States	No Relationships
Steven D. Glassman, MD	United States	Intellirod (a); ISSG (a); Medtronic (b, g); OREF (a); PFIZER (a)
Massimiliano Gobbo, MD	Italy	No Relationships
Vijay K.Goel, PhD	United States	No Relationships
Saw Huan Goh, MBBS,	Malaysia	No Relationships
Ariana Goldstein, BA	United States	No Relationships
Jeffrey Andrew Goldstein, MD	United States	Altus Spine (b); NuVasive (g); RTI (b, g)
Jaime A. Gomez, MD	United States	No Relationships
Susan M. Goobie, MD, FRCPC	United States	No Relationships
Ankur Goswami, MD	India	No Relationships
Pawel Grabala, MD	Poland	DePuy Synthes (a); Medtronic (a); NuVasive (a)
Zachary J. Grabel, MD	United States	No Relationships
Robert J. Graham, MD	United States	No Relationships
Anna Grauers, MD, PhD	Sweden	No Relationships
Daniel W. Green, MD	United States	No Relationships
Tiziana Greggi, MD	Italy	No Relationships
Michael P. Grevitt, MBBS, FRCS	United Kingdom	No Relationships
Growing Spine Study Group	United States	NuVasive (a)
Qi Gu, MS	China	No Relationships
Kenneth J. Guidera, MD	United States	No Relationships
Umit Ozgur Guler, MD	Turkey	No Relationships
Mahir Gulsen, MD	Turkey	No Relationships
Kee-Yong Ha, MD, PhD	Korea, South	No Relationships
Matthew J. Hadad, BS	United States	No Relationships
Sleiman Haddad, MD	Spain	No Relationships
Regis W. Haid Jr., MD	United States	Elsevier, Inc. (g); Globus Medical (g); Medtronic (g); NuVasive (b, c); Spine Wave (c); Vertical Health (c)
Matthew F. Halsey, MD	United States	No Relationships
D. Kojo Hamilton, MD	United States	No Relationships
Kim W. Hammerberg, MD	United States	No Relationships
Sanghyun Han, MD	Korea, South	No Relationships
Maged Hanna, MD, PhD	United States	No Relationships
Regina Hanstein, PhD	United States	No Relationships
Katsumi Harimaya, MD, PhD	Japan	No Relationships
Harms Study Group	United States	Allied Orthopedic Associates, Inc. (g); C.D. Denison Orthoaedic Appliance Corp. (g); CHU Sainte Justine (g); DePuy Synthes (a); Ellipse (g); EOS Imaging (a); Globus Medical (a); Johnson & Johnson Medical (a); K2M (a); Lawall Prosthetic & Orthotic Services (g); Mazor Robotics (a); Medtronic (a); NuVasive (a); OrthoPediatrics (a); SpineGuard (g); Stryker Spine (a); Theraplay (g); Thieme Publishing (g); Zimmer Biomet (a)
Robert A. Hart, MD	United States	No Relationships
Mohd Shahnaz Hasan, MAnaes	Malaysia	No Relationships
Kazuhiro Hasegawa, MD	Japan	No Relationships
Tomohiko Hasegawa, MD, PhD	Japan	No Relationships

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Hiroshi Hashizume, MD	Japan	No Relationships
Amani Hassan, PhD	Canada	No Relationships
Hamid Hassanzadeh, MD	United States	Medtronic (d); NuVasive (b, c); Orthofix (a, b); Pfizer (a, e)
Shun Hatsushikano, BS	Japan	No Relationships
Rune Hedlund, MD, PhD	Sweden	K2M (b, g); Zimmer Biomet (d, g)
John A. Heflin, MD	United States	Globus Medical (b)
John Heller, MD	United States	Medtronic (b, c, d, g)
Julie Herfkens, BSc	Netherlands	No Relationships
Thibault Hernandez, MD	France	No Relationships
Jose A. Herrera-Soto, MD	United States	OrthoPediatrics (b); SpineGuard (b); Zimmer Biomet (b, g)
Oded Hershkovich, MD, MHA	United Kingdom	No Relationships
Jan Herzog	United Kingdom	No Relationships
Karen M. Heskett, MSI	United States	No Relationships
Eduardo Hevia, MD	Spain	No Relationships
Hwee Weng Dennis Hey, MD	Singapore	No Relationships
Toru Hirano, MD, PhD	Japan	No Relationships
Aaron Hockley, MD, FRCS(C)	United States	No Relationships
Jelle Frederik Homans, MD	Netherlands	No Relationships
Michio Hongo, MD, PhD	Japan	No Relationships
Jennifer Hope, CPNP	United States	No Relationships
Samantha R. Horn, BA	United States	No Relationships
Jason A. Horowitz, BA	United States	No Relationships
Pooria Hosseini, MD	United States	No Relationships
Richard Hostin, MD	United States	DePuy Synthes (b)
Michiel L. Houben, MD, PhD	Netherlands	No Relationships
Michael T. Hresko, MD	United States	Boston Orthotics and Prosthetics (b); Medtronic (a); NuVasive (g)
Ming-Hsiao Hu, MD	Taiwan	No Relationships
Alexander P. Hughes, MD	United States	Altus Spine (b); Mallinckrodt Pharmaceuticals (a); MiMedx Group, Inc. (a); NuVasive (a); Pfizer, Inc. (a)
Jessica L. Hughes, MD	United States	No Relationships
Andrew J. Huh, BS	United States	No Relationships
Chun Wai Hung	United States	No Relationships
Lik Hang Alec Hung, FRCS	Hong Kong	No Relationships
Awais K. Hussain, BS	United States	No Relationships
Steven Hwang, MD	United States	Zimmer Biomet (d)
Joshua Hyman, MD	United States	No Relationships
Seung-Jae Hyun, MD, PhD	Korea, South	No Relationships
Stephanie Ihnow, MD	United States	No Relationships
Takuya Iimura, MD	Japan	No Relationships
Tamás S. Illés, MD, PhD	Belgium	No Relationships
Kenneth D. Illingworth, MD	United States	No Relationships
Kazuhide Inage, MD, PhD	Japan	No Relationships
Satoshi Inami, MD, PhD	Japan	No Relationships
Masatake Ino, MD	Japan	No Relationships
Masatoshi Inoue, MD	Japan	No Relationships
International Spine Study Group	United States	DePuy Synthes (a); K2M (a); Medtronic (a); NuVasive (a); Orthofix (a); Stryker Spine (a)
Yoshinori Ishikawa, MD, PhD	Japan	No Relationships
Hiroshi Iwasaki, MD, PhD	Japan	No Relationships
Henry J. Iwinski, MD	United States	No Relationships
Sravisht Iyer, MD	United States	No Relationships

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Amit Jain, MD	United States	No Relationships
Viral V. Jain, MD	United States	No Relationships
Cyrus Jalai,	United States	No Relationships
M. Burhan Janjua, MD	United States	No Relationships
Andrew Jea, MD	United States	No Relationships
Kelly A. Jeans, MS	United States	No Relationships
Megan Jeffords, MS	United States	No Relationships
Enze Jiang, MD, PhD	China	No Relationships
Jun Jiang, MD	China	No Relationships
Weiwei Jiang, PhD	China	No Relationships
Anders Joelson, MD	Sweden	No Relationships
Bradley C. Johnson, MD	United States	No Relationships
Julie Joncas, RN	Canada	No Relationships
Tej Joshi, BS	United States	No Relationships
Nima Kabirian, MD	United States	No Relationships
Sinan Kahraman, MD	Turkey	No Relationships
Takashi Kaito, MD, PhD	Japan	AO Spine (a); Asahi-Kasei Pharma (a, b); Kyocera (b); Lilly (a); Medacta (b); Medtronic (d); NuVasive (b, d); Pip (a); Rohto (a); Two-cell (a)
Antony Kallur, MD	United States	No Relationships
Pankaj Kandwal, MD, MBBS	India	No Relationships
Linda E. A. Kanim, MA	United States	Medtronic (c)
Rishi M. Kanna, MBBS, MS	India	No Relationships
Adam S. Kanter, MD	United States	NuVasive (b, g); Zimmer Biomet (b, g)
Umut Can Karaarslan	Turkey	No Relationships
Selhan Karadereler, MD	Turkey	No Relationships
Isik Karalok, MD	Turkey	No Relationships
Mohammad Karam, MS	Lebanon	No Relationships
Mohsen Karami, MD	Iran	No Relationships
Remzi Karaokur, MD	Turkey	No Relationships
Judson W. Karlen, MD	United States	No Relationships
Yuji Kasukawa, MD, PhD	Japan	No Relationships
Fumihiko Kato, MD	Japan	No Relationships
Kazuki Kawakami, B.Kin	Japan	DePuy Synthes (b); Japan Spinal Deformity Institute (e); Kisco (b); Medtronic (b)
Emel Kaya Aumann, MD	Turkey	No Relationships
Floreana N. Kebaish, MD	United States	DePuy Synthes (b, g); K2M (b, g); Orthofix (g); SpineCraft (g)
Keio Spine Research Group	Japan	No Relationships
John J. Kelly, BA	Grenada	No Relationships
Tanya S. Kenkre, PhD	United States	No Relationships
Paul F. Kent, MD, PhD	United States	No Relationships
Jeffrey Kessler, MD	United States	No Relationships
Nour Khalil, BS	Lebanon	No Relationships
Yehia H. Khalil, PhD	United States	No Relationships
Khalil Emile Kharrat, MD	Lebanon	No Relationships
Morsi Khashan, MD	United States	No Relationships
Michael Kheir, MD	United States	Kleu (c)
Sara Khoyratty, MRCS	United Kingdom	No Relationships
David C. Kieser, PhD, MBChB, FRACS, FNZOA	New Zealand	No Relationships
Jin-Hyok Kim, MD, PhD	Korea, South	No Relationships
Sang-il Kim, MD	Korea, South	No Relationships

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Whoan Jeang Kim, MD, PhD	Korea, South	No Relationships
Yongjung J. Kim, MD	United States	No Relationships
Young-Hoon Kim, MD, PhD	Korea, South	No Relationships
Peri Kindan	Turkey	No Relationships
Esat Kiter, MD	Turkey	No Relationships
Christopher J. Kleck, MD	United States	Globus Medical (a); Medacta (b); Medicrea (a, b); Medtronic (b); Orthofix (a); Premia (a); SI Bone (a); Spinal Kinetics (a)
Frank S. Kleinstueck, MD	Switzerland	DePuy Synthes (a)
Yuval Kluger, PhD	United States	Alexion (e); BioDesix (e); Bristol Myers Squib (a); Corvus (e); Genentec (e); Merck (a); Nectar (e); Pfizer (b)
Walter Klyce, BA	United States	No Relationships
Dennis Raymond Knapp, Jr, MD	United States	No Relationships
Sho Kobayashi, MD, PhD	Japan	No Relationships
Toshiaki Kotani, MD, PhD	Japan	No Relationships
Joseph Ivan Krajbich, MD, FRCS(C)	United States	K2M (d)
Gabi Kreichati, MD	Lebanon	No Relationships
Daisuke Kudo, MD	Japan	No Relationships
Naresh Kumar, MBBS, FRCS, MS, DNB(Orth)FRCS (Orth)DM(Orth),	Singapore	No Relationships
Tomas K. Kuprys, MD	United States	No Relationships
Swamy Kurra, MBBS	United States	No Relationships
Duygu Kuzu, MA	Turkey	No Relationships
Mun Keong Kwan, MBBS, MS	Malaysia	No Relationships
Hubert Labelle, MD, FRCS(C)	Canada	Canadian Institute of Health Research (a); DePuy Synthes (a); Spinologics (c, g)
Renaud Lafage, MS	United States	No Relationships
Virginie Lafage, PhD	United States	AO Spine (g); DePuy Synthes (a, g); K2M (a); Nemaris (c, e); NuVasive (a); Stryker Spine (a)
Suna Lahut, PhD	Turkey	No Relationships
Kelly Ka-Lee LAI, BS	Hong Kong	No Relationships
Tsz-Ping Lam, MBBS	Hong Kong	Telefield Medical Imaging Limited (a)
Sarah T. Lander, MD	United States	No Relationships
Daniel Larrieu, PhD	France	No Relationships
A. Noelle Larson, MD	United States	K2M (a); OrthoPediatrics (a)
Ahmad Latefi, DO	United States	K2M (b); Medtronic (b); Stryker Spine (b)
Leok-Lim Lau, FRCS	Singapore	No Relationships
Scheherazade Le, MD	United States	No Relationships
Chong-Suh Lee, MD, PhD	Korea, South	No Relationships
Jae Won Lee, MD	Korea, South	No Relationships
Jung Sub Lee, MD, PhD	Korea, South	No Relationships
Jung-Hee Lee, MD, PhD	Korea, South	No Relationships
Keong Joo Lee, MBBS	Malaysia	No Relationships
Ki Young Lee, MD	Korea, South	No Relationships
Leslie Lee, MD	United States	No Relationships
Sang-Ho Lee, MD, PhD	Korea, South	No Relationships
Tin Yan Lee, MS	Hong Kong	No Relationships
Yuan-Fuu Lee, MD	Taiwan	No Relationships
Xin Yi Ler, MBBS	Malaysia	No Relationships
Thamrong Lertudomphonwanit, MD	Thailand	No Relationships
Eric Leung	United States	No Relationships
Jean-Christophe A. Leveque, MD	United States	K2M (e); NuVasive (d)
Eric Lewallen, PhD	Uzbekistan	No Relationships

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Don Li	United States	Merck (f)
Eric Li	United States	No Relationships
Tao Li, MD	China	No Relationships
Wenbo Li	China	No Relationships
Xingye Li, MD	China	No Relationships
Ying Li, MD	United States	Medtronic (d)
Zheng Li, MD	China	No Relationships
Benita Liao, MD	United States	No Relationships
Dong-Ju Lim, MD, PhD	Korea, South	No Relationships
Joel Louis Lim, MBBS, MRCS (Glasgow)	Singapore	No Relationships
James D. Lin, MD, MS	United States	No Relationships
Youxi Lin, MD	China	No Relationships
Martin Lindberg-Larsen, MD, PhD	Denmark	No Relationships
George Linderman, BS	United States	No Relationships
Breton G. Line, BS	United States	International Spine Study Group Foundation (f)
Quanfei Liu, MD	China	No Relationships
Raymond W. Liu, MD	United States	OrthoPediatrics (g)
Zhen Liu, MD	China	No Relationships
Zhuojie Liu, MD	China	No Relationships
Yungtai Lo, PhD	United States	No Relationships
Ling Hui Loh, MBBS	Malaysia	No Relationships
Ji Keon Looi, MAnaes	Malaysia	No Relationships
Alejandro Lorente, PhD	Spain	No Relationships
Rafael Lorente, PhD	Spain	No Relationships
Zac Lovato, DO	United States	No Relationships
Scott John Luhmann, MD	United States	Globus Medical (g); Medtronic (b, d); NuVasive (b); OrthoPediatrics (b, d); Stryker Spine (b, d); Wishbone Medical (b); Wolters (g)
Darren F. Lui, MBBS, FRCS	United Kingdom	No Relationships
Keith D K Luk, FRCS	Hong Kong	No Relationships
Jinmei Luo, MD	China	No Relationships
Jon D. Lurie, MD	United States	NewVert (b, c)
Hong Ma, MD	China	No Relationships
Bruce A. MacWilliams, PhD	United States	No Relationships
Luke Macyszyn, MD, MS	United States	No Relationships
Kathleen Maguire, MD	United States	No Relationships
Vijay Mahalingam Rajamani, MS	United Kingdom	No Relationships
Rufai Mahmud, MD	Ghana	No Relationships
Takahiro Makino, MD	Japan	No Relationships
Karan Malhotra, FRCS	United Kingdom	No Relationships
Shoba Malviya, MD	United States	No Relationships
Carol A. Mancuso, MD	United States	No Relationships
Sai-hu Mao, MD	China	No Relationships
Sami Mardam-Bey, MD	United States	No Relationships
Dan Mihai Mardare, MD, MSc	United Kingdom	No Relationships
Adam Margalit, MD	United States	No Relationships
Michelle Claire Marks, MS, PT	United States	No Relationships
Konstantinos Martikos, MD	Italy	No Relationships
Hiroko Matsumoto, PhDc	United States	No Relationships
Morio Matsumoto, MD, PhD	Japan	Kyocera (b); NuVasive (b)
David G. Mayers, RN (Child)	United Kingdom	No Relationships

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Antonio Mazzotti, MD	Italy	No Relationships
Eoin M. McAughey, MS	United Kingdom	Covance Inc (f); Medtronic (b)
Richard E. McCarthy, MD	United States	Medtronic (b, g)
Jamal McClendon Jr, MD	United States	No Relationships
Anna McClung, RN, BSN	United States	No Relationships
Donna McDonald-McGinn, MS	United States	Natera (d)
Amy Lynn McIntosh, MD	United States	Globus Medical (d)
William J. McKinnon, MD	United States	No Relationships
Rogelio Medina, BA	United States	No Relationships
Charles T. Mehlman, DO	United States	National Institutes of Health (a); Oakstone Medical Publishing (a, g)
Anil Mendiratta, MD	United States	No Relationships
Addisu Mesfin, MD	United States	AO Spine (a); Corelink (a); Globus Medical (a); LES Society (a)
Zachary Messer, MPH	United States	No Relationships
Yuki Mihara, MD	Japan	No Relationships
Todd Milbrandt, MD	United States	Broadwater (e); OrthoPediatrics (b); viking scientific (c)
Andrew H. Milby, MD	United States	No Relationships
Daniel J. Miller, MD	United States	No Relationships
Patricia E. Miller, MS	United States	No Relationships
Shohei Minami, MD, PhD	Japan	No Relationships
Akihito Minamide, MD, PhD	Japan	No Relationships
Daniela N. Minecan, MD	United States	No Relationships
Minimize Implants Maximize Outcomes Study Group	United States	No Relationships
Naohisa Miyakoshi, MD, PhD	Japan	No Relationships
Tatsuki Mizouchi, MD	Japan	No Relationships
Mohamed A. Moawad, MPH	United States	No Relationships
Arfah Hanim Mohamad, MAnaes	Malaysia	No Relationships
Florina Moldovan, MD, PhD	Canada	No Relationships
Sirinart Molidperee,	Canada	No Relationships
Sean Molloy, MBBS, FRCS, MSc (eng)	United Kingdom	Medtronic (a, b, d)
Hong Joo Moon, MD, PhD	United States	No Relationships
John Moon, BS	United States	No Relationships
Jessica V. Morgan, BS	United States	No Relationships
Hiroshi Moridaira, MD, PhD	Japan	No Relationships
MJ Mulcahey, PhD, OTR/L	United States	No Relationships
Rajan R. Murgai, BS	United States	No Relationships
Joshua S. Murphy, MD	United States	DePuy Synthes (b)
Daniel P. Murray, BS	United States	No Relationships
Vasantha Murthy, MD	United States	No Relationships
Karen S. Myung, MD, PhD	United States	No Relationships
Vugar Nabiyev, MD	Turkey	No Relationships
Narihito Nagoshi, MD	Japan	No Relationships
Masaya Nakamura, MD, PhD	Japan	No Relationships
Yoshinori Nakata, MD	Japan	No Relationships
Keita Nakayama, MD	Japan	No Relationships
Zachary M. NaPier, MD	United States	No Relationships
Unni G. Narayanan, MBBS, FRCS(C), MSc	Canada	No Relationships
J. Naresh-Babu, MD	India	No Relationships
Luigi A. Nasto, MD, PhD	Italy	No Relationships
Alexander Nazareth, MS, BS	United States	No Relationships

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Qais Naziri, MD	United States	No Relationships
Brian J. Neuman, MD	United States	DePuy Synthes (a); ISGGF (a)
Jared M. Newman, MD	United States	No Relationships
Bobby Kinwah Ng, MD	Hong Kong	No Relationships
Sherwin Johan Ng, MBBS	Malaysia	No Relationships
Yun Hui Ng, MBBS	Malaysia	No Relationships
Annie Tram Anh N. Nguyen	United States	No Relationships
Cynthia V. Nguyen, MD	United States	No Relationships
Viet Nguyen, MD	United States	No Relationships
Derek T. Nhan, BS	United States	No Relationships
Allen Nicholson, MD	United States	No Relationships
Alexandra N Nielson, BS	United States	No Relationships
Dimitrios Nikas, MD	United States	No Relationships
Tianyi Niu, MD	United States	No Relationships
Krista Noble, BS	United States	No Relationships
Russ P. Nockels, MD, FAANS	United States	Medtronic (b, g)
Mariano Augusto Noel, MD	Argentina	No Relationships
Ayato Nohara, MD	Japan	No Relationships
Kellen Nold, PA-C	United States	No Relationships
Andriy Noshchenko, PhD	United States	No Relationships
Pierce D. Nunley, MD	United States	Amedica (c); K2M (b, d, g); Paradigm Spine (c); Spineology (c); Zimmer Biomet (d, g)
Ibrahim Obeid, MD, MS	France	Alphatec Spine (g); clariance (g); DePuy Synthes (a, b); Medtronic (a, b); spineart (g)
Don Daniel Ocay, BS	Canada	No Relationships
Shin Oe, MD	Japan	Japan Medical Dynamic Marketing (g); Medtronic (g); Meitoku Institution Jyuzen Memorial Hosipital (g)
Matthew E. Oetgen, MD	United States	No Relationships
Henry Ofori Duah, RN	Ghana	No Relationships
Gerhard Ofori-Amankwah, MD	Ghana	No Relationships
Cheongeun Oh, PhD	United States	No Relationships
Tetsuya Ohara, MD	Japan	No Relationships
Masayuki Ohashi, MD, PhD	Japan	No Relationships
Soren Ohrt-Nissen, MD, PhD	Denmark	K2M (a)
Seiji Ohtori, MD, PhD	Japan	No Relationships
Nusret Ok, MD	Turkey	No Relationships
Eijiro Okada, MD, PhD	Japan	No Relationships
Masashi Okamoto, MS	Japan	No Relationships
David O. Okonkwo, MD, PhD	United States	NuVasive (g); Zimmer Biomet (g)
Z. Deniz Olgun, MD	United States	No Relationships
J. Casey Olson, PhD	United States	No Relationships
Asli Oncel, MD	Turkey	No Relationships
Sumihisa Orita, MD, PhD	Japan	No Relationships
Henry Osei Tutu, BS	Ghana	No Relationships
Joeffroy Otayek, MS	Lebanon	No Relationships
Audrey A.F Oteng-Yeboah, MD	Ghana	No Relationships
Robert Owen, MD	United States	No Relationships
Kirk Owens, MD	United States	DePuy Synthes (g); Intellirod (a); ISSG (a); K2M (g); Medtronic (b, g); NuVasive (b, g); OREF (a); Pfizer (a)
Mabel Owiredu,	Ghana	No Relationships
Metin Ozalay, MD	Turkey	No Relationships
Anil Murat Ozturk, MD	Turkey	No Relationships

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Seniz Ozusta, PhD	Turkey	No Relationships
Selcuk Palaoglu, MD, PhD	Turkey	No Relationships
Zhimin Pan, MD	China	No Relationships
Janit Pandya, BS	United States	No Relationships
Tejbir S. Pannu, MD, MS	United States	No Relationships
Francesco Pardo, MD	Italy	No Relationships
Hyung-Youl Park, MD	Korea, South	No Relationships
Jong-Hwa Park, MD	Korea, South	No Relationships
Kun Young Park, MD, PhD	Korea, South	No Relationships
Paul Park, MD	United States	Allosource (b); Globus Medical (b, g); Medtronic (b); NuVasive (b); Pfizer (a); Vertex (a)
Saba Pasha, PhD	United States	No Relationships
Peter G. Passias, MD	United States	Allosource (e); CSRS (a); DePuy Synthes (a); Medicrea (b); SpineWave (b); Zimmer Biomet (d)
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Meeting Agenda

The Scoliosis Research Society gratefully acknowledges Medtronic for their support of the Annual Meeting Charging Station, Half-Day Courses, Newsletter, Pre-Meeting Course, and Welcome Reception.

Hibbs Society Meeting: Innovation and New Ideas in the Treatment of Spinal Deformity, the European Perspective

13:00-17:00
Room: Sala Italia

13:00-13:05	**Introduction** *Richard E. McCarthy, MD*
13:05-13:08	**Background of the Hibbs Society** *Robert W. Gaines, Jr., MD*

Session 1

Moderators: Han Jo Kim, MD & Joshua M. Pahys, MD

13:08-13:18	**What Works Best in Outreach Sites for Spinal Deformity Treatment** *Francisco Javier Sanchez Perez Grueso, Sr., MD*
13:18-13:23	**An Especially Instructive Case** *Francisco Javier Sanchez Perez Grueso, Sr., MD*
13:23-13:33	**What is Most Pertinent in Evaluating Adult Deformity – Pre and Post Op** *Ferran Pellise, MD, PhD*
13:33-13:38	**An Especially Instructive Case** *Ferran Pellise, MD, PhD*
13:38-13:48	**A Peak into the Hospital of Tomorrow: How Al-trained Robots will Treat you Using Blockchained Data from loTs"** *Samuel K. Cho, MD*
13:48-13:53	**Discussion**
13:53-14:03	**Innovative Solutions to Challenging Cervical Deformities** *Michael Ruf, MD*
14:03-14:08	**An Especially Instructive Case** *Michael Ruf, MD*
14:08-14:18	**Challenges of Complex Spinal Treatment in Russia** *Sergey Kolesov, MD, PhD*
14:18-14:23	**An Especially Instructive Case** *Sergey Kolesov, MD, PhD*
14:23-14:33	**Growth Guidance through Shilla** *Richard E. McCarthy, MD*
14:33-14:38	**Discussion**
14:38-15:00	**Break**

Session 2

Moderators: Samuel K. Cho & Richard E. McCarthy, MD

15:00-15:10	**Developing Innovative and Cost Efficient Treatments for Spinal Deformities in the Future** *Henry F. H. Halm, MD*
15:10-15:15	**An Especially Instructive Case** *Henry F. H. Halm, MD*
15:15-15:25	**The Importance of the Pelvic Platform in Balancing the Spine in Deformity** *Pierre Roussouly, MD*
15:25-15:40	**An Especially Instructive Case** *Pierre Roussouly, MD*
15:40-15:50	**PJK: Multimodal Prevention Strategies for a Multifactorial Issue** *Han Jo Kim, MD*
15:50-15:55	**Discussion**
15:55-16:05	**History of French Spinal Surgery** *Daniel H. Chopin, MD*

16:05-16:10	**An Especially Instructive Case** *Daniel H. Chopin, MD*
16:10-16:20	**How to Mind the GAP in Spinal Deformity** *Ahmet Alanay, MD*
16:20-16:25	**An Especially Instructive Case** *Ahmet Alanay, MD*
16:25-16:35	**Vertebral Body Tethering: Successes and Failures** *Joshua M. Pahys, MD*
16:35-16:40	**Discussion**
16:40-16:50	**Growth Guidance in Turkey – Results of Treatment** *Azmi Hamzaoglu, MD*
16:50-16:55	**An Especially Instructive Case** *Azmi Hamzaoglu, MD*
16:55-17:05	**Role of Flexibility Assessment in the Treatment of Complex Deformity** *Meric Enercan, MD*
17:05-17:10	**Discussion**
17:10-17:15	**Conclusion** *Richard E. McCarthy, MD*

Pre-Meeting Course: Physician Well Being for the Benefit of the Patient: How Can We Be Better for Everyone Else?

9:00-13:00
Room: Europauditorium

Chair: Suken A. Shah, MD
Co-Chairs: Michael D. Daubs, MD; John R. Dimar, II, MD; Burt Yaszay, MD

See page 69 for Pre-Meeting Course materials and handouts.

Session 1: Physician Preservation

Moderators: Kenneth MC Cheung, MD & Peter O. Newton, MD

9:00-9:04	**Introduction** *Todd J. Albert, MD; Suken A Shah, MD*
9:04-9:12	**Professional Burnout: Scope of the Problem and Avoidance** *Todd J. Albert, MD*
9:12-9:18	**Substance Abuse & Bad Behavior…Coping Mechanisms?** *David Hanscom, MD*
9:18-9:24	**Time Management, Getting Enough Rest and Avoiding Sleep Deprivation** *John M. Flynn, MD*
9:24-9:36	**Discussion**
9:36-9:42	**Overuse Syndromes and New Technology to Prevent Them** *Baron S. Lonner, MD*
9:42-9:48	**Reduction of Radiation Exposure to Surgeon and Patient** *John R. Dimar, II, MD*
9:48-9:54	**Other Environmental Hazards of the O/R** *Christopher I. Shaffrey, MD*
9:54-10:00	**Developing Emotional Discipline in Dealing with Complications Reduces Personal Stress and Clarifies Responsibility** *David S. Marks, FRCS, FRCS(Orth)*
10:00-10:12	**Discussion**
10:12-10:18	**The Benefits of Mindfulness/Meditation and Yoga** *David Skaggs, MD*
10:18-10:26	**Getting Fit after 40** *Abhay Nene, MD*
10:26-10:34	**Peak Performance – Lessons Learned from Science and Sociology** *Michael G. Vitale, MD*
10:34-10:44	**Discussion**
10:44-11:02	**Refreshment Break**

Session 2: Physician Growth

Moderators: Suken A. Shah, MD & Michael D. Daubs, MD

11:02-11:22	**Coaching / Mentoring – The Surgeon as a Professional Athlete** ***Mentor Panel*** *–Behrooz A. Akbarnia, MD; Laurel C. Blakemore, MD; Alvin H. Crawford, MD; Ferran Pellisé, MD; Vernon Tolo, MD* ***Mentee Panel*** *– Lindsay Andras, MD; Robert Cho, MD; Charles Crawford, MD; Han Jo Kim, MD; Kota Watanabe, MD*
11:22-11:28	**Surgeon Leadership is Essential to the Future of Spine Surgery** *David W. Polly, Jr., MD*
11:28-11:34	**Lifelong Learning and How to Stay Current** *Lawrence G. Lenke, MD*
11:34-11:40	**Building High Functioning, Resilient Teams** *Rajiv K. Sethi, MD*
11:40-11:50	**Discussion**

11:50-11:56 **Getting Through the Mid-Career Blues**
Michael D. Daubs, MD

11:56-12:02 **Working in a Toxic Environment: Have that Courageous Conversation**
Paul Rubery, MD

12:02-12:08 **The Benefits of Global Outreach and Philanthropy**
Gregory M. Mundis, Jr., MD

12:08-12:18 **Discussion**

12:18-12:24 **Managing Family Relationships and Work-Life Balance**
Serena S Hu, MD

12:24-12:30 **Work-Life Balance: Perspective from Europe to America**
Benny T. Dahl, MD, PhD, DMSci

12:30-12:36 **The Path: Teachings from Asian Philosophy**
Kenneth MC Cheung, MD, FRCS

12:36-12:43 **Discussion**

12:43-12:58 **Panel: Hobbies and Passions: How to Really Relax After Work**
Alvin Crawford, MD; James Sanders, MD; Frank J. Schwab, MD; Michael Vitale, MD; Burt Yaszay, MD

12:58-13:00 **Closing Remarks/Final Thoughts**
Suken A. Shah, MD

Break & Boxed Lunch Pick-up

13:00-13:15

Lunchtime Symposia *(Two Concurrent Sessions)*

13:15-14:15

From Pre- to Post-Op, an International Perspective on Patient Expectations and Pain Management Protocols

Chairs: Sanjeev Suratwala, MD, FACS, FAAOS & David Hanscom, MD
Room: Hall 19

13:15-13:19 **Introduction and Brief Report on Patient Expectations**
Sanjeev Suratwala, MD, FACS, FAAOS

13:19-13:25 **An International Perspective on Patient Expectations of the Scoliosis Surgeons**
Hani Mhaidli, MD, PhD

13:25-13:33 **Understanding the Neurological Nature of Chronic Pain**
David Hanscom, MD

13:33-13:47 **Perioperative Protocols For Pain Management**
Ryan Goodwin, MD

13:47-13:53 **Multi-Pronged Approach for Post-Op Pain Management**
Benny Dahl, MD, PhD, DMSci

13:53-13:57 **Alternative (Non-Pharmacologic) Options that are Popular and Locally Accepted**
Mark Lee, MD

13:57-14:13 **Discussion**

14:13-14:15 **Closing Remarks**
David Hanscom, MD

Early Onset Scoliosis – Expert Roundtable

Chairs: Ron El-Hawary, MD & James O. Sanders, MD
Panelists: *Teresa Bas, MD, PhD; Colin Nnadi, FRCS (Orth); Amer Samdani, MD; Suken A. Shah, MD*
Room: *Sala Italia*

13:15-13:30 **Cases and Discussion: When is Growth Modification a Reasonable Consideration and When Should it Definitely not be Used?**

13:30-13:45 **Cases and Discussion: What Strategies can Prevent PJK, and How Should you Treat it When it Does Occur?**

13:45 – 14:00 **Cases and Discussion: What is Proper Sagittal Alignment for Various Children's Deformities and When is it Reasonable to be "OK" Rather than Perfect?**

14:00 – 14:15 **General Discussion and Questions**

Break
14:15-14:30

Abstract Session 1A: Adult Spinal Deformity
14:30-15:35
Room: Europauditorium

Moderators: David W. Polly, Jr., MD & Marinus de Kleuver, MD

14:30-14:34 **Paper #1: Can Pelvic Incidence Change after Surgical Correction in Adult Spinal Deformity Patients with use of S2 Alar Iliac Screws and Cantilever Correction of the Sagittal Plane?**
Chao Wei, MD; James D. Lin, MD, MS; Hong Ma, MD; Ming Yang, MD, PhD; Suomao Yuan, MD; Meghan Cerpa, BS, MPH; J. Alex Sielatycki, MD; Suthipas Pongmanee, MD; Zachary Messer, MPH; Eric Leung; Takayoshi Shimizu, MD, PhD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

14:34-14:38 **Paper #2: Evaluation of Pelvic Incidence (PI) Constancy at Different Physiologic Postures, and Assessment of Confounding Factors That May Affect Stability of This Parameter**
Christopher J Kleck, MD; Andriy Noshchenko, PhD; Christopher MJ Cain, MD, PhD; Evalina L. Burger, MD; Vikas V Patel, MD, BS, MA

14:38-14:42 **Paper #3: Sagittal Vertical Axis: A Poor Instrument for Measuring Inappropriate Spinal Correction**
Derek T Cawley, FRCS; Louis Boissiere, MD; Takashi Fujishiro, MD; Daniel Larrieu, PhD; Ferran Pellisé, MD; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Emre R Acaroglu, MD; Ahmet Alanay, MD; Jean-Marc Vital, MD; Olivier Gille, MD, PhD; Ibrahim Obeid, MD, MS

14:42-14:51 **Discussion**

14:52-14:56 **Paper #4: The Effect of Open versus Minimally Invasive Approach (MIS) in Instrumentation of the Proximal Spinal Segment in Long Posterior Fusion on the Incidence of Proximal Junctional Kyphosis (PJK): A Prospective Randomized Controlled Study with Minimum 2 year Follow Up**
Floreana N Kebaish, MD; Micheal Raad, MD; Khaled M. Kebaish, MD, FRCS(C)

14:56-15:00 **Paper #5: The Offset of the Upper Instrumented Vertebrae to the Gravity Line is a Risk Factor for PJK Onset after 6 Weeks**
Jonathan Charles Elysée, BS; Renaud Lafage, MS; Han Jo Kim, MD; Robert A. A Hart, MD; Breton G. Line, BS; Christopher I. Shaffrey, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Gregory M Mundis, MD; Richard Hostin, MD; Shay Bess, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

15:00-15:04 **Paper #6: Tether Constructs Used to Prevent Proximal Junctional Kyphosis (PJK) Should Incorporate the UIV+1 and UIV+2; A Finite Element Analysis (FEA)**
Shay Bess, MD; Ming Xu, PhD, MS, BS; Virginie Lafage, PhD; Breton G. Line, BS; Regis W. Haid Jr., MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S Smith, MD, PhD; International Spine Study Group

15:04-15:13 **Discussion**

15:14-15:18 **Paper #7: Does Preoperative Opioid Use lead to Poorer Outcomes and Continued Opioid Abuse at 2 Years Postoperative?**
Robert Owen, MD; Sami Mardam-Bey, MD; Lawrence G. Lenke, MD; Jeffrey L Gum, MD; Michael P. Kelly, MD, MS

15:18-15:22 **Paper #8: The Impact of Surgical Invasiveness and Patient Factors on Long-Term Opioid Use in ASD Surgery**
Brian J Neuman, MD; Micheal Raad, MD; Daniel M. Sciubba, MD; Peter G Passias, MD; Eric O. Klineberg, MD; Hamid Hassanzadeh, MD; Themistocles S. Protopsaltis, MD; Munish C Gupta, MD, Chief of Spine; Gregory M Mundis, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Jeffrey L Gum, MD; Justin S Smith, MD, PhD; Virginie Lafage, PhD; Shay Bess, MD; Khaled M. Kebaish, MD, FRCS(C); International Spine Study Group

15:22-15:26 **Paper #9: Immediate Postoperative Narcotic Use is Not Associated with Preoperative Opiate Use or Surgery Invasiveness**
Portia A Steele, MS; Jeffrey L Gum, MD; Charles H Crawford III, MD; Kirk Owens, MD; Mladen Djurasovic, MD; Morgan Brown, MS; Steven D Glassman, MD; Leah Yacat Carreon, MD, MS

15:26-15:35 **Discussion**

Refreshment Break
15:35-15:50

Abstract Session 1B: Adolescent Idiopathic Deformity
15:50-17:10
Room: Europauditorium

Moderators: Kenneth MC Cheung, MD, FRCS & Amer F. Samdani, MD

15:50-15:54 **Paper #10: Sagittal Balance in Hyperkyphotic Patients with Growing Rods and the Effect of Preoperative Halo Gravity Traction**
Cynthia V Nguyen, MD; Henry Ofori Duah, RN; Mabel Owiredu; Henry Osei Tutu, BS; Kwadwo Poku Yankey, MD; Irene Wulff, MD; Harry Akoto, MB ChB; Oheneba Boachie-Adjei, MD; FOCOS Spine Research Group

15:54-15:58 **Paper #11: Surgical Treatment of Segmental Spinal Dysgenesis: A Report of 18 Cases**
Rodrigo G. Remondino, MD; Carlos A. Tello, MD, PhD; Lucas Piantoni, MD; Eduardo Galaretto, MD; Ida Alejandra Francheri Wilson, MD; Mariano Augusto Noel, MD

15:58-16:02 **Paper #12: Vertebral Column Resection for Early-Onset Scoliosis: Indications, Utilization and Outcome**
Anna McClung, RN, BSN; Gregory M Mundis, MD; Jeff Pawelek, BS; Sumeet Garg, MD; Burt Yaszay, MD; Oheneba Boachie-Adjei, MD; James O. Sanders, MD; Paul D. Sponseller, MD; Francisco Javier Sanchez Perez-Grueso, MD; William F Lavelle, MD; John B. Emans, MD; Charles E Johnston, MD; Behrooz A. Akbarnia, MD; Children's Spine Study Group; Growing Spine Study Group

16:02-16:11 **Discussion**

16:11-16:15 **Paper #13: "Less is More" - Significant Coronal Correction of AIS Deformity Predicts Thoracic Hypokyphosis**
Oded Hershkovich, MD, MHA; Areena D'Souza, MBBS, MS; Paul RP Rushton; Michael P. Grevitt, MBBS, FRCS

16:15-16:19 **Paper #14: The Impact of Posterior Spinal Fusion (PSF) on Coronal Balance in Adolescent Idiopathic Scoliosis (AIS): A New Classification and Trends in the Post-operative Period**
Jason Brett Anari, MD; Aaron Tatad, MPH; Patrick J. Cahill, MD; John M. Flynn, MD; Harms Study Group

16:19-16:23 **Paper #15: It's Not Just About the Frontal Plane: Spinopelvic Parameters Impact Curve Progression in AIS Patients Undergoing Brace Treatment**
Hiroko Matsumoto, PhDc; Shay Warren, BS; Megan Campbell, BA; John Tunney, BOCPO; Nicole Bainton, RN, CPNP; Joshua Hyman, MD; Benjamin D. Roye, MD, MPH; David Roye, MD; Michael G Vitale, MD

16:23-16:32 **Discussion**

16:32-16:36 **Paper #16: Sagittal Balance and Health-Related Quality of Life Three Decades after Fusion in Situ for High-Grade Isthmic Spondylolisthesis**
Anders Joelson, MD; Barbro I Danielson, MD, PhD; Rune Hedlund, MD, PhD; Per Wretenberg, MD, PhD; Karin Frennered, MD, PhD

16:36-16:40 **Paper #17: High Grade Spondylolisthesis (HGS) in Adolescents: Reduction and Circumferential Fusion Improves HRQoL and Sagittal Balance**
Hubert Labelle, MD, FRCS(C); Stefan Parent, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD; Julie Joncas, RN; Soraya Barchi, BS

16:40-16:44 **Paper #18: Spondylolisthesis Classification Based On Prognostic and Treatment Principles**
Farhaan Altaf, MBBS, FRCS; Amer Sebaaly, MD, BS; Pierre Roussouly, MD

16:44-16:53 **Discussion**

16:53-16:57 **Paper #19: The Surgical Volume, More Than the Number of Surgeons or Surgeon Experience, Drives Patient Outcomes in Pediatric Scoliosis**
Vishal Sarwahi, MBBS; Jesse M Galina, BS; Stephen F Wendolowski, BS; Jon-Paul DiMauro, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

16:57-17:01 **Paper #20: Variation in Adolescent Idiopathic Scoliosis (AIS) Surgery: Implications for Improving Healthcare Value**
John T Smith, MD; Angela P Presson, PhD; John A. A Heflin, MD

17:01-17:10 **Discussion**

Break
17:10-17:30

Case Discussion Sessions *(Three Concurrent Sessions)*

17:30-18:30

Case Discussion 1

Moderator: Rajiv K. Sethi, MD
Panelists: Han Jo Kim, MD & Kota Watanabe, MD
Room: Europauditorium

17:30-17:45 **1A: Occiput-to-Pelvis Spinal Arthrodesis: A Case Series Discussion**
Matthew J. Hadad, BS; Oussama Abousamra, MD; Brian T. Sullivan, BS; Paul D. Sponseller, MD

17:45-18:00 **1B: The Challenges of Restoring Sagittal Alignment in Circumferential Minimally Invasive Surgery (MIS) Fusions**
Vishal Sarwahi, MBBS; Ahmad Latefi, DO; Stephen F Wendolowski, BS; Jesse Galina, BS; Melanie Smith, cPNP; Terry D. Amaral, MD

18:00-18:15 **1C: "SI Joint at Risk" After Lumbosacral Fixations: Identification Of Risk Factors And Role Of Prophylactic Management For SI Joint Dysfunction.**
Naresh-Babu J, MD; Arun Kumar Viswanadha, MBBS, MS

18:15-18:30 **1D: Neurologic Deficit During Halo-Gravity Traction in the Treatment of Severe Thoracic Kyphoscoliotic Spinal Deformity**
Martin H Pham, MD; Meghan Cerpa, BS, MPH; Lawrence G. Lenke, MD

Case Discussion 2

Moderator: Muharrem Yazici, MD
Panelists: Brice Illharreborde, MD, PhD & John T. Smith, MD
Room: Sala Italia

17:30-17:45 **2A: Surgical Management of Atlantoaxial Dislocation and Cervical Spinal Cord Injury in Craniopagus Twins**
Russ P. Nockels, MD, FAANS

17:45-18:00 **2B: Single-Stage Management of a Tumor-Related Curve with Improvement in IONM**
Brandon J Toll, BA; Amer F. Samdani, MD; Joshua M. Pahys, MD; Steven Hwang, MD

18:00-18:15 **2C: Preoperative Traction, Riluzole, and 3D Modeling Optimizes the Safety of Correction of a Stiff 150-Degree Kyphoscoliosis Deformity**
Michael To, MBBS, FRCS; Jason Pui Yin Cheung, MBBS, FRCS, MS; Feng Zhu, MD, PhD; Kenneth Cheung, MD, FRCS

18:15-18:30 **2D: Prune Belly Syndrome: Importance of Anterior Abdominal Musculature in Maintenance of Thoracic Kyphosis**
Derek T. Nhan, BS; Paul D. Sponseller, MD

Case Discussion 3

Moderator: Francisco Javier Sanchez Perez-Grueso, Sr., MD
Panelists: Laurel C. Blakemore, MD & Michael Glotzbecker, MD
Room: Hall 19

17:30-17:45 **3A: A Motion-Preserving Surgical Treatment for Neuromuscular Scoliosis: Proof of Concept**
Laury A Cuddihy, MD; M. Darryl Antonacci, MD; Awais K. Hussain, BS; Khushdeep S Vig, BS; MJ Mulcahey, PhD, OTR/L; Randal R. Betz, MD

17:45-18:00 **3B: Outpatient Distraction for Severe Adolescent Idiopathic Scoliosis**
Selina C. Poon, MD; Paul D Choi, MD

18:00-18:15 **3C: Complete Loss of Motor Sensory With Motor Deficits with Instrumentation and Fusion of Severe Juvenile Scoliosis**
Terry D. Amaral, MD; Jesse Galina, BS; Stephen F Wendolowski, BS; Melanie Smith, cPNP; Vishal Sarwahi, MBBS

18:15-18:30 **3D: Staged Minimally Invasive Neuromuscular Scoliosis Surgery in the Jehovah's Witness Patient Can Safely Achieve Surgical Correction**
Vishal Sarwahi, MBBS; Jesse M Galina, BS; Stephen F Wendolowski, BS; Benita Liao, MD; Terry D. Amaral, MD

Break

18:30-18:45

Meeting Agenda — Wednesday, October 10, 2018

Opening Ceremonies

18:45-20:00

Room: Europauditorium

18:45-18:50	**Welcome to Bologna** *Marco Brayda-Bruno, MD & Mario Di Silvestre, MD, Local Hosts*
18:50-18:55	**Presidential Welcome** *Todd J. Albert, MD*
18:55-19:00	**Recognition of Alberto Ponte, MD** *Todd J. Albert, MD*
19:00-19:10	**Presentation of Blount Humanitarian Award** *Introduction by Todd J. Albert, MD* *Presentation by Michael T. Hresko, MD, Awards & Scholarships Committee Chair*
19:10-19:20	**Acknowledgement of Corporate Supporters** *Introduction by Todd J. Albert, MD* *Presentation by Kenneth MC Cheung, MD, Past President & Corporate Relations Committee Chair*
19:20-19:25	**Introduction of Howard Steel Lecturer** *Todd J. Albert, MD*
19:25-19:55	**Howard Steel Lecture: A Glass Half Full** *Kevin Zraly*
19:55-20:00	**Closing Remarks** *Todd J. Albert, MD*

Welcome Reception

20:00-22:00

Room: Foyer Europa

The Welcome Reception is supported, in part, by grants from Medtronic, NuVasive, and OrthoPediatrics.

Abstract Session 2: Adolescent Idiopathic Scoliosis II

8:55-10:49
Room: Europauditorium

Moderators: Paul D. Sponseller, MD, MBA & Burt Yaszay, MD

8:55-9:00	**Welcome**
9:00-9:04	**Paper #21: The "Touched Vertebra" Method and Progression of the Non-Fused Lumbar Curve in Patients with Lenke Type I in AIS: A Prospective Randomized Study** *Giedrius Bernotavicius, MD, PhD; Vykintas Sabaliauskas, MD; Dominykas Varnas, MD; Rimantas Zagorskis, MD; Irena Zagorskienė, MD; Kestutis Saniukas, MD, PhD*
9:04-9:08	**Paper #22: Touched Vertebra (TV) on Standing XR is a Good Predictor for Lowest Instrumented Vertebra (LIV): TV on Prone XR is Better** *Vishal Sarwahi, MBBS; Stephen F Wendolowski, BS; Jesse M Galina, BS; Yungtai Lo, PhD; Beverly Thornhill, MD; Kathleen Maguire, MD; Terry D. Amaral, MD*
9:08-9:12	**Paper #23: Defining Two Subtypes of Lenke 1 Curve: An Analysis of Pre-Operative Shoulder Balance and Post-Operative Outcome Following Posterior Spinal Fusion (PSF) in Adolescent Idiopathic Scoliosis (AIS) Patient** *Chris Yin Wei Chan, MD, MS; Chee Kidd Chiu, MBBS, MS; Yun Hui Ng, MBBS; Saw Huan Goh, MBBS; Xin Yi Ler, MBBS; Sherwin Johan Ng, MBBS; Xue Han Chian, MBBS; Pheng Hian Tan, MBBS; Mun Keong Kwan, MBBS, MS*
9:12-9:21	**Discussion**
9:22-9:26	**Paper #24: The Comparison between Cervical Supine Side Bending versus Cervical Supine Traction Radiographs in Predicting Proximal Thoracic Flexibility for Lenke 1 and 2 Adolescent Idiopathic Scoliosis** *Chee Kidd Chiu, MBBS, MS; Chris Yin Wei Chan, MD, MS; Mun Keong Kwan, MBBS, MS*
9:26-9:30	**Paper #25: Pre-operative Prone Radiographs can Reliably Determine Spinal Curve Flexibility in Adolescent Idiopathic Scoliosis** *Tej Joshi, BS; Regina Hanstein, PhD; Jaime A Gomez, MD; Jacob F Schulz, MD*
9:30-9:34	**Paper #26: The Supine Flexibility: Prediction of Flexibility in Adolescent Idiopathic Scoliosis Using Standard Standing and Supine Radiographs** *Caglar Yilgor, MD; Kenny Kwan, FRCS; Kadir Abul, MD; Suna Lahut, PhD; Umut Can Karaarslan; Peri Kindan; Yasemin Yavuz, PhD; Kenneth Cheung, MD, FRCS; Ahmet Alanay, MD*
9:34-9:43	**Discussion**
9:44-9:48	**Paper #27: Brace Wearing Time is the Strongest Predictor of Final Results: A Regression Model in 1457 High Risk Consecutive Adolescents with Idiopathic Scoliosis** *Stefano Negrini, MD; Sabrina Donzelli, MD; Francesca Di Felice, MD; Fabio Zaina, MD*
9:48-9:52	**Paper #28: SRS Survey: Brace Management in Adolescent Idiopathic Scoliosis** *Matthew F Halsey, MD; Lori A. Dolan, PhD; Richard Hostin, MD; Raphael D. Adobor, MD, PhD; Romain Dayer, MD; Eugenio Dema, MD; Olavo B Letaif, MD, MSc*
9:52-9:56	**Paper #29: Optimizing Non-Operative Management in Adolescent Idiopathic Scoliosis: Increased Body Mass Associated with Decreased Bracing Outcomes** *Adam Margalit, MD; Derek T. Nhan, BS; Walter Klyce, BA; Kristen Venuti, MS; Paul D. Sponseller, MD*
9:56-10:05	**Discussion**
10:06-10:10	**Paper #30: The Demographics and Epidemiology of Idiopathic Scoliosis in Children and Incidence of Scoliosis in the U.S.** *Jeffrey Kessler, MD; Kevin Bondar; Annie Tram Anh N Nguyen; Jasmine Vatani, BS*
10:10-10:14	**Paper #31: Determination of Growth Remaining From Humeral Head Periphyseal Ossification** *Stephen G DeVries, BS; Don Li; Allen Nicholson, MD; Eric Li; Jonathan Cui, BS; James O. Sanders, MD; Raymond W Liu, MD; Daniel R Cooperman, MD; Brian G. Smith, MD*
10:14-10:18	**Paper #32: Cervical Vertebral Maturation (CVM) Stage in Adolescent Idiopathic Scoliosis: Is it an Alternative Option in Determining Peak Height Velocity (PHV)?** *Hongda Bao, MD, PhD; Shibin Shu, PhD; Yuancheng Zhang, MS; Qi Gu, MS; Zezhang Zhu, MD; Zhen Liu, MD; Yong Qiu, MD*
10:18-10:27	**Discussion**

10:28-10:32 **Paper #33: Predictive Capability of a Surgical Planning Tool for Anterior Vertebral Body Growth Modulation: Two-Year Follow-Up**
Nikita Cobetto, PhD; Stefan Parent, MD, PhD; Carl-Eric Aubin, PhD

10:32-10:36 **Paper #34: Tridimensional Changes Following Anterior Vertebral Growth Modulation after Two Years of Follow-Up**
Olivier Turcot, BS; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BS; Christian Bellefleur, MSCA; Vincent Cunin, MD; Stefan Parent, MD, PhD

10:36-10:40 **Paper #35: Non-fusion Thoracoscopic Anterior Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Preliminary Results of a Single European Center**
Caglar Yilgor, MD; Barbaros O Cebeci; Kadir Abul, MD; Suna Lahut, PhD; Gokhan Ergene, MD; Sahin Senay, MD; Ahmet Alanay, MD

10:40-10:49 **Discussion**

Refreshment Break

10:50-11:10

Abstract Session 3: Complex Adult Deformity & Complications

11:10-13:30
Room: Europauditorium

Moderators: Michael Ruf, MD & Frank J. Schwab, MD

11:10-11:14 **Paper #36: In the Relationship between Change in Kyphosis and Change in Lordosis: Which Drives Which?**
Renaud Lafage, MS; Tejbir S Pannu, MD, MS; Jonathan Charles Elysée, BS; Brandon B Carlson, MD, MPH; Frank J. Schwab, MD; Han Jo Kim, MD; Virginie Lafage, PhD

11:14-11:18 **Paper #37: The Role of the Fractional Lumbosacral Curve in Persistent Coronal Malalignment following Adult Thoracolumbar Deformity Surgery**
Alekos A. Theologis, MD; Thamrong Lertudomphonwanit, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Munish C. Gupta, MD

11:18-11:22 **Paper #38: A Radiographic Analysis of Lumbar Fusion Status after Complex Adult Spinal Deformity Surgery: Subanalysis of the Scoli-Risk-1 Database**
Takayoshi Shimizu, MD, PhD; Eduardo C. Beauchamp, MD; Leah Yacat Carreon, MD, MS; Christopher I. Shaffrey, MD; Kenneth MC Cheung, MD, FRCS; Meghan Cerpa, BS, MPH; Lawrence G. Lenke, MD

11:22-11:31 **Discussion**

11:32-11:36 **Paper #39: Spinal Deformity Surgery in Patients ≥ 75 Years Old: How Do the Outcomes Compare with Younger Patients?**
Zac Lovato, DO; Andrew Chung, DO; Dennis G Crandall, MD; Jan Revella, RN; Michael S Chang, MD

11:36-11:40 **Paper #40: Probability of Severe Frailty Development Among Operative and Non-Operative Adult Spinal Deformity Patients: An Actuarial Survivorship Analysis over a 3-Year Period**
Peter G Passias, MD; Frank A. Segreto, BS; Cheongeun Oh, PhD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S Smith, MD, PhD; Alan H Daniels, MD; Breton G. Line, BS; Han Jo Kim, MD; Juan S. Uribe, MD; Robert K. Eastlack, MD; D. Kojo Hamilton, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. A Hart, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Shay Bess, MD; International Spine Study Group

11:40-11:44 **Paper #41: Frailty Phenotype Correlates with EQ5D and ODI Scores in Patients with Spinal Disorders**
Shane Burch, MD, MS, FRCS(C); Sigurd H. Berven, MD

11:44-11:53 **Discussion**

11:54-11:58 **Paper #42: Effects of Restoring Individualized Sagittal Shape and Alignment on Mechanical Complications and Patient-Reported Outcomes in Elderly Patients Fused To Pelvis**
Caglar Yilgor, MD; Suna Lahut, PhD; Yasemin Yavuz, PhD; Kadir Abul, MD; İrem Ekin Sayın; Javier Pizones, MD, PhD; Ibrahim Obeid, MD, MS; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Emre R Acaroglu, MD; Ferran Pellisé, MD; Ahmet Alanay, MD; European Spine Study Group

11:58-12:02 **Paper #43: Ability of the Global Alignment and Proportion Score to Predict Mechanical Failure in ASD: Validation in 149 patients with Two-years Follow-up**
Tanvir Johanning Bari, MD; Soren Ohrt-Nissen, MD, PhD; Benny T. Dahl, MD, PhD; Martin Gehrchen, MD, PhD

12:02-12:06 **Paper #44: Comparison of a Lumbar GAP Score to PI-LL Mismatch to Predict Adjacent Segment Disease in the Degenerative Lumbar Spine**
Dominique A. Rothenfluh, MD, PhD; Étienne Bourassa-Moreau, MD, FRCS(C), MSc; Ahmet Alanay, MD; Caglar Yilgor, MD

12:06-12:10 **Paper #45: Results from an External Validation of the Global Alignment and Proportion Score (GAP): Can it Predict Proximal Junctional Kyphosis?**
Frank J. Schwab MD, Han Jo Kim MD, Munish C. Gupta MD, Chief of Spine, Jeffrey L. Gum MD, Christopher I. Shaffrey MD, Douglas C. Burton MD, Christopher P. Ames MD, Gregory M. Mundis MD, Richard Hostin MD, Shay Bess MD, Eric O. Klineberg MD, Justin S. Smith MD, PhD, Renaud Lafage MS, Virginie Lafage PhD, International Spine Study Group

12:10-12:20 **Discussion**

12:20-12:24 **Paper #46: Preliminary Review of an ISSG AO Multi-Domain Spinal Deformity Complication Classification System**
Eric O. Klineberg, MD; Virginie Lafage, PhD; Alex Soroceanu, MD, FRCS(C), MPH; Ferran Pellisé, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Jeffrey L. Gum, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Tejbir S Pannu, MD, MS; Marinus de Kleuver, MD, PhD; Christopher P. Ames, MD; Shay Bess, MD; Lawrence G. Lenke, MD; Sigurd H. Berven, MD; International Spine Study Group

12:24-12:28 **Paper #47: Impact of Serious Adverse Events on Health-Related Quality of Life Measures Following Surgery for Adult Symptomatic Lumbar Scoliosis**
Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Michael P. Kelly, MD, MS; Elizabeth L. Yanik, PhD, MS; Jon D. Lurie, MD; Charles Cannon Edwards, MD; Steven D Glassman, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; Jacob M. Buchowski, MD, MS; Leah Yacat Carreon, MD, MS; Charles H Crawford III, MD; Thomas J. Errico, MD; Stephen J. Lewis, MD, FRCS(C); Tyler Koski, MD; Stefan Parent, MD, PhD; Han Jo Kim, MD; Shay Bess, MD; Frank J. Schwab, MD; Keith H. Bridwell, MD; Christine Baldus, RN, MS

12:28-12:37 **Discussion**

12:38-12:43 **Harrington Lecture Introduction**
Todd J. Albert, MD

12:43-13:03 **Harrington Lecture: A Legacy of Leadership**
James Kerr

13:03-13:30 **Presentation of Lifetime Achievement Awards**
See page 13 for additional information.

Break
13:30-13:45

Lunch Sessions *(Two Concurrent Sessions)*
13:45 -14:45

Member Business Meeting
Room: Hall 19

Non-Member Lunchtime Symposium (Non-CME)
The Ponte Osteotomy
Chairs: Giuseppe Costanzo, MD & Daniele A. Fabris-Monterumici, MD
Room: Sala Italia

3:45-13:50 **Introduction**
Daniele A. Fabris-Monterumici, MD

13:50-13:57 **The True Ponte Osteotomy: Technical Pearls and Tricks**
Gian Luigi Siccardi, MD

13:57-14:04 **Its Use in Paediatric and Adolescent Deformities**
Massimo Balsano, MD

14:04-14:11 **Its Use Together With Magnetically Controlled GR for Posterior-Only Correction of Severe AIS**
Mario Di Silvestre, MD

14:11-14:18 **Its Use in Severe Adult Deformities**
Roberto Bassani, MD

14:18-14:25 **Complications, Warnings and Pitfalls: How to Prevent**
PierPaolo Mura, MD

14:25-14:45 **Discussion**
Marco Brayda Bruno, MD, Moderator

Break
14:45-15:00

Half-Day Courses *(Three Concurrent Sessions)*
15:00-18:00
See page 100 for Half-Day Course materials and handouts.

Achieving Excellence in the Management of Severe Pediatric Spinal Deformity
Chairs: Patrick J. Cahill, MD & Burt Yaszay, MD
Room: Hall 19

Part I: Understanding the Development of Severe Scoliosis
Moderators: Patrick J. Cahill, MD & Burt Yaszay, MD

15:00-15:10 **Quantification of Growth in the Early Years**
James O. Sanders, MD

15:10-15:20 **Understanding and Quantifying Peri-pubertal Growth**
James O. Sanders, MD

15:20-15:28 **Looking at Growth in 3D**
Stefan Parent, MD, PhD

15:28-15:38 **Discussion**

Part II: Prevention of Severe Scoliosis
Moderators: Patrick J. Cahill, MD & Burt Yaszay, MD

15:39-15:47 **Early Intervention – Casting/Bracing**
Noriaki Kawakami, MD, DMSc

15:47-15:55 **Distraction Based**
Kenneth MC Cheung, MD, FRCS

15:55-16:03 **Growth Guidance**
Jean Ouellet, MD, FRSC

16:03-16:11 **Tether**
Patrick J. Cahill, MD

16:11-16:21 **Discussion**

Part III: Treatment of Severe Scoliosis: Avoiding the VCR
Moderators: Amer F. Samdani, MD & Suken A Shah, MD

16:22-16:32 **Anterior Surgery**
Peter O. Newton, MD

16:32-16:42 **Skeletal Traction/Internal Distraction**
Joshua M. Pahys, MD

16:42-16:52 **Posterior Releases (including asymmetric resection/post. discectomy)**
Harry L. Shufflebarger, MD

16:52-17:02 **Discussion**

Part IV: Treatment of Severe Scoliosis: Performing the VCR
Moderators: Amer F. Samdani, MD & Suken A Shah, MD

17:03-17:13 **Surgical Technique**
Lawrence G. Lenke, MD

17:13-17:21 **Preop Construct Planning**
Brice Ilharreborde, MD, PhD

17:21-17:29 **Preop Optimization**
Gregory M. Mundis, Jr., MD

17:29-17:39 **Discussion**

Part V: Case Based Discussions

Moderators: Patrick J. Cahill, MD & Burt Yaszay, MD
Panelists: *Lawrence G. Lenke, MD; Amer F Samdani, MD; Paul D. Sponseller, MD; Muharrem Yazici, MD*

17:40-17:45 **Case 1: Cervical-Thoracic Congenital Scoliosis**

17:45-17:50 **Case 2: Neuromonitoring Loss – Apical Pedicle Screw Insertion**

17:50-17:55 **Case 3: Severe Scoliosis → Anterior Release**

17:55-18:00 **Case 4: Delayed Onset of Neurologic Deficit**

Adult Spinal Deformity: An International Exchange on the Safety and Efficacy of Current Techniques

Chairs and Moderators: Munish C. Gupta, MD & Yan Wang, MD
Room: Europauditorium

Part I: Preoperative and Intraoperative Safety

15:00-15:10 **Preoperative Assessment and Optimization of a Patient with a Complex Deformity**
Jason W. Savage, MD

15:10-15:20 **Preoperative Planning for Treatment: Imaging and use of Halo Traction**
Harry Akoto, MD

15:20-15:30 **Intraoperative Positioning and Neuro-Monitoring to Avoid Complications: Intraoperative Traction**
Stephen J. Lewis, MD, MSc, FRCSC

15:30-15:40 **Discussion**

Part II: MIS Options for Deformity Correction: Safety First

15:41-15:51 **Lateral Approach Can Avoid 3 Column Osteotomies**
Juan Uribe, MD

15:51-16:01 **MIS Adult Deformity: On the Cutting Edge**
Neel Anand, MD

16:01-16:11 **MIS Long Constructs for Spinal Deformity**
Praveen Mummaneni, MD

16:11-16:21 **Discussion**

Part III: Open Spinal Osteotomy Techniques: Detailed Description with Videos: Pitfalls and Tips

16:22-16:32 **Smith Petersen Osteotomy**
Go Yoshida, MD

16:32-16:42 **Corner Osteotomy**
Claudio Lamartina, MD

16:42-16:52 **Pedicle Subtraction Osteotomy**
Yong Qiu, MD

16:52-17:02 **Vertebral Column Decancellation**
Yan Wang, MD

17:02-17:12 **Posterior Vertebral Column Resection**
Azmi Hamzaoglu, MD

17:12-17:27 **Discussion**

Part IV: Case Panel

17:28-17:58 **Four Complex Adult Deformity Cases**
Moderator: Munish Gupta, MD

Panel: *Christopher P. Ames, MD; Saumyajit Basu, MD; Marco Brayda Bruno, MD; David Clements, MD; ZeZhang Zhu, MD*

17:58-18:00 **Closing Remarks**
Munish Gupta, MD

Sharing Our Best Global Algorithms for the Treatment of Complex Spinal Deformity

Chairs: Ahmet Alanay, MD & Rajiv K. Sethi, MD
Room: Sala Italia

Part I: Challenges in the Delivery of Complex Spine Care around the World

Moderator: Rajiv K. Sethi, MD

15:00-15:01 **Introduction to the New Paradigms in Global Complex Spine Care**
Rajiv K. Sethi, MD

15:01-15:06 **Perspectives of the SRS Worldwide Course Committee Chair**
Benny T. Dahl, MD, PhD, DMSci

15:06-15:11 **Perspectives of the SRS Safety and Value Committee Chair**
Michael G. Vitale, MD, MPH

15:11-15:16 **The Global Burden of Advanced Spinal Disease: Challenges and Strategies to Increase Access.**
Theodore A. Wagner, MD

15:16-15:21 **When Good Intentions Lead to Bad Results: Avoiding Pitfalls in Global Outreach**
J. Michael Wattenbarger, MD

15:21-15:25 **Discussion**

Establishing Care with Limited Resources: Learning from BRIC

15:25-15:29 **Brazil**
Luis Munhoz Da Rocha, MD

15:29-15:33 **Russia**
Sergey Kolesov, MD, PhD

15:33-15:37 **India**
Sajan K. Hegde, MD

15:37-15:41 **China**
Bangping Qian, MD

15:41-15:55 **BRIC Panel Discussion**
Panel: Sajan K. Hegde, MD; Luis Munhoz Da Rocha, MD; Kenny Kwan, BMBCh(Oxon), FRCSEd; Bangping Qian, MD; Sergey Kolesov, MD, PhD

Part II: What Can We Learn From Each Other on Best Practices? A Case Based Discussion

Moderator: Ahmet Alanay, MD

15:55-16:15 **Congenital Scoliosis Case Presentation**
Panel: John R. Dimar, II, MD; Ron El-Hawary, MD; Sajan K. Hegde, MD, Nicholas Fletcher, MD; J. Michael Wattenbarger, MD

16:15-16:35 **AIS Case**
Panel: Luis Munhoz Da Rocha, MD; Mario Di Silvestre, MD; Michael P. Kelly, MD; Francisco Javier Sanchez Perez-Grueso, MD

16:35-16:55 **Adult Deformity Case**
Panel: Todd J. Albert, MD; Kushagra Verma, MD, MS; Eric O. Klineberg, MD; Jwalant Mehta, FRCS

Part III: Maintaining Quality and Value Despite Declining Budgets

Moderator: Rajiv K. Sethi, MD

16:55-17:00 **Maintaining High Quality Spine Care Despite Declining Budget: The NHS Example**
David S. Marks, FRCS, FRCS(Orth)

17:00-17:05 **What Are the Challenges for Quality and Value in a High Performing European Health Care System?**
Marinus De Kleuver, MD, PhD

17:05-17:10 **What Are the Challenges for Quality and Value in a High Performing Asian Health Care System?**
Manabu Ito, MD, PhD

17:10-17:15 **What Are the Challenges for Quality and Value in a High Performing North American Health Care System?**
Han Jo Kim, MD

17:15-17:20 **What Are Some Strategies for Managing AIS in a Bundled System?**
Suken A. Shah, MD

17:20-17:25 **What Are Some Strategies for Managing ASD in a Bundled System?**
Rajiv K. Sethi, MD

17:25-18:00 **Panel Discussion/Audience Discussion**
Panel: *Todd J. Albert, MD; Benny T. Dahl, MD, PhD, DMSci; Marinus De Kleuver, MD, PhD; Manabu Ito, MD, PhD; Han Jo Kim, MD; David S. Marks, FRCS, FRCS(Orth); Suken A. Shah, MD*

Member Business Meeting
7:30-8:45
Room: Hall 19

Abstract Session 4A: Hibbs Basic Research Award Nominees
8:55-9:33
Room: Europauditorium

Moderators: Todd J. Albert, MD & Gregory M. Mundis, Jr., MD

8:55-9:00 **Welcome**

9:00-9:04 **Paper #48: Topical Vancomycin Eliminates Staphylococcus epidermidis in Experimental Chronic Spinal Implant-Associated Infection†**
Chenghao Zhang, PhD, MBBS, MS; Todd Milbrandt, MD; A. Noelle Larson, MD; Andre Van Wijnen, PhD; Thomas Boyce, MD; Robin Patel, MD

9:04-9:08 **Paper #49: A Novel Axial MRI Classification of Spinal Cord Shape and CSF Presence at the Curve Apex to Assess Risk of Intraoperative Neuromonitoring Data Loss with Thoracic Spinal Deformity Correction†**
J. Alex Sielatycki, MD; Meghan Cerpa, BS, MPH; Martin H Pham, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

9:08-9:16 **Discussion**

9:16-9:20 **Paper #50 NF-κB Inhibitor Reduces the Inflammatory Response and Improves Bone Formation in rhBMP-2-Mediated Spine Fusion†**
Juliane D Glaeser, PhD; Phillip H Behrens, MD; Khosrowdad Salehi, BS; Linda E. A. Kanim, MA; Dmitriy Sheyn, PhD; Zachary M NaPier, MD; Jason M Cuellar, MD, PhD; Hyun W. Bae, MD

9:20-9:24 **Paper #51: POC5 and Cilia Anomalies in Adolescent Idiopathic Scoliosis†**
Amani Hassan, PhD; Stefan Parent, MD, PhD; Sirinart Molidperee; Soraya Barchi, BS; Kessen Patten, PhD; Florina Moldovan, MD, PhD

9:24-9:33 **Discussion**

Abstract Session 4B: Hibbs Clinical Research Award Nominees
9:34-10:39
Room: Europauditorium

Moderators: Firoz Miyanji, MD, FRCSC & Ferran Pellisé, MD

9:34-9:40 **Paper #52: Increased Radiation but No Benefits in Pedicle Screw Accuracy Using Intraoperative CT-Based Navigation Compared to Freehand Technique in Idiopathic Scoliosis Surgery***
Wiktor Urbanski, MD, PhD

9:40-9:44 **Paper #53: The Use of Tranexamic Acid in Adult Spinal Deformity: Is There an Optimal Dosing Strategy?***
Tina Raman, MD; Peter L Zhou, BS; Dennis Vasquez-Montes, MS; John Moon, BS; Aaron J. Buckland, MBBS, FRACS; Thomas J. Errico, MD

9:44-9:48 **Paper #54: Unfulfilled Expectations after Surgery for Adult Lumbar Scoliosis Compared to Other Degenerative Conditions***
Carol A Mancuso, MD; Roland B Duculan, MD; Frank P Cammisa Jr, MD; Andrew A Sama, MD; Alexander P Hughes, MD; Federico P Girardi, MD

9:48-9:57 **Discussion**

9:57-10:01 **Paper #55: A High Degree of Variability Exists in How "Safety and Efficacy" is Defined and Reported in Growing Rod Surgery for Early-Onset Scoliosis: A Systematic Review***
Pooria Hosseini, MD; Areian Eghbali; Jeff Pawelek, BS; Karen M Heskett, MSI; Gregory M Mundis, MD; Behrooz A. Akbarnia, MD

10:01-10:05 **Paper #56: A Prospective, Multicenter Analysis of the Efficacy of Anterior Vertebral Body Tethering (AVBT) in the Treatment of Idiopathic Scoliosis***
Firoz Miyanji, MD, FRCS(C); Jeff Pawelek, BS; Luigi A Nasto, MD, PhD; Stefan Parent, MD, PhD

Cast your vote for the Hibbs Awards in the mobile app:
1. Select "Polls & Voting" from the app home screen; 2. Select the Hibbs Awards poll; 3. Cast your vote
*= Hibbs Award Nominee for Best Clinical Paper, †= Hibbs Award Nominee for Best Basic Research Paper

10:05-10:09 **Paper #57: 10-Year Natural History of the Uninstrumented Compensatory Curve in Selectively Fused AIS***
Burt Yaszay, MD; Madeline Cross, MPH; Carrie E. Bartley, MA; Tracey P. Bastrom, MA; Suken A. Shah, MD; Baron S. Lonner, MD; Patrick J. Cahill, MD; Amer F. Samdani, MD; Vidyadhar V Upasani, MD; Peter O. Newton, MD

10:09-10:18 **Discussion**

10:18-10:22 **Paper #58: Can TGR Change the Natural History of Pulmonary Functions in EOS? Is Radiological Straightness Correlated with Normal Lung Development?***
Ebru Celebioglu, MD; Alper Huseyin Yataganbaba, MD; Asli Oncel, MD; Ceren Degirmenci, MD; Senol Bekmez, MD; Fatih Tekin, MD; Gokhan Halil Demirkiran, MD; Elmas Ebru Yalcin, MD; Ahmet Ugur Demir, MD; Muharrem Yazici, MD

10:22-10:26 **Paper #59: Distal Fusion Level Determines the Prevalence of Back Pain and Risk of Cesarean Section in Pregnant Women Who Have Had Scoliosis Surgery***
Suken A. Shah, MD; Pawel Grabala, MD

10:26-10:30 **Paper #60: Health-Related Quality of Life in Patients With AIS at Average 45 Years After Instrumented Fusion Compared to the Age Matched US Population.***
Sarah T. Lander, MD; Caroline Thirukumaran, PhD, MBBS, MS; Krista Noble, BS; Ahmed Saleh, MD; Addisu Mesfin, MD; Paul T Rubery, MD; James O. Sanders, MD

10:30-10:39 **Discussion**

Refreshment Break
10:40-11:00

Abstract Session 5: Across the Ages
11:00-12:46
Room: Europauditorium

Moderators: Marco Brayda-Bruno, MD & Peter O. Newton, MD

11:00-11:04 **Paper #61: Liposomal Bupivacaine Reduces Narcotic Consumption in Adult Deformity Surgery**
Michael S Chang, MD; Andrew Chung, DO; Jan Revella, RN; Dennis G Crandall, MD; Yu-Hui H. Chang, PhD, MPH

11:04-11:08 **Paper #62: The Effect of Balanced Preemptive Analgesia on Postoperative Pain in Spine Surgery": A Double Blinded Prospective Randomized Study**
Ajoy Prasad Shetty, MS, DNB; Dilip Chand Raja S, MBBS, MS; Rishi M Kanna, MBBS, MS; S. Rajasekaran, PhD

11:08-11:12 **Paper #63: Prophylactic Alvimopan to Prevent Ileus in Adult Spinal Deformity Surgery: A Double-Blind, Placebo-Controlled, Randomized Feasibility Trial**
Eric Feuchtbaum, MD; David B. Bumpass, MD; Lukas P. Zebala, MD; Robert Owen, MD; Michael P. Kelly, MD, MS

11:12-11:21 **Discussion**

11:21-11:25 **Paper #64: The Safety and Efficacy of Intraoperative Acute Normovolaemic Haemodilution (ANH) in Complex Spine Surgery at an SRS GOP Site in Ghana: A Prospective Study**
Irene Wulff, MD; Audrey A.F Oteng-Yeboah, MD; Henry Ofori Duah, RN; Henry Osei Tutu, BS; Kwadwo Poku Yankey, MD; Oheneba Boachie-Adjei, MD; FOCOS Spine Research Group; Harry Akoto, MD

11:25-11:29 **Paper #65: Blood Loss Estimates and Risk Factors for Excessive Blood Loss in AIS Surgery: Have we Been Fooling Ourselves?**
Baron S. Lonner, MD; Yuan Ren, PhD; Nicholas D Fletcher, MD; Paul D. Sponseller, MD; Peter O. Newton, MD

11:29-11:33 **Paper #66: Clinical Outcome of Intraoperative Lumbosacral Nerve Root Monitoring Changes Using Motor Evoked Potential Warning Criteria**
Anil Mendiratta; Lawrence G. Lenke, MD; Lee A. Tan, MD; Meghan Cerpa, MPH; Ronald A. Lehman, MD; Mark Weidenbaum, MD; Yongjung J. Kim, MD; Charla R Fischer, MD; Paul F. Kent; Earl D Thuet

Cast your vote for the Hibbs Awards in the mobile app:
1. Select "Polls & Voting" from the app home screen; 2. Select the Hibbs Awards poll; 3. Cast your vote
*= Hibbs Award Nominee for Best Clinical Paper, †= Hibbs Award Nominee for Best Basic Research Paper

11:33-11:37 **Paper #67: Surgical Teams Surgery Improve Quality, Safety and Value in Surgery for Adolescent Idiopathic Scoliosis (AIS)**
John T Smith, MD; John A. A Heflin, MD; Cynthia V Nguyen, MD; Jessica V. V Morgan, BS; Graham T. Fedorak, MD, FRCS(C)

11:37-11:49 **Discussion**

11:49-11:53 **Paper #68: Preoperative Hemoglobin Levels and Risk for Transfusion after Adult Spinal Deformity Surgery: Analysis of Predictive Factors**
Tina Raman, MD; Peter L Zhou, BS; John Moon, BS; Dennis Vasquez-Montes, MS; Aaron J. Buckland, MBBS, FRACS; Thomas J. Errico, MD

11:53-11:57 **#69: Cobalt Chromium-Titanium versus Both Titanium Rods for Surgical Treatment of Adolescent Idiopathic Scoliosis (AIS); Which Has Better Correction?**
Mohammadreza Etemadifar, MD; Abbas Rahimian, MD

11:57-12:01 **Paper #70: A 10-Year Radiographic Outcome Study of Anterior and Posterior Instrumented Spinal Fusion in Patients with Lenke Type 5 Adolescent Idiopathic Scoliosis: Are We Preparing Our Patients for Adult Deformity Targets?**
Hwee Weng Dennis Hey, MD; Joel Louis Lim, MBBS, MRCS (Glasgow); Leok-Lim Lau, FRCS; Joseph Thambiah, MBBS, FRCS, FAMSOrth; Naresh Kumar, MBBS, FRCS, MS, DNB(Orth), FRCS (Orth), DM(Orth); Gabriel KP Liu, FRCS; Hee-Kit Wong, FRCS

12:01-12:05 **Paper #71: Trends in Complications in Operative Adolescent and Adult Idiopathic Scoliosis from the SRS Morbidity and Mortality Database**
Swamy Kurra, MBBS; Baron S. Lonner, MD; Katherine Sullivan; Isador H Lieberman, MD, FRCS(C); Shay Bess, MD; William F Lavelle, MD

12:05-12:14 **Discussion**

12:14-12:17 **Genealogy Project Presentation**
Serena S. Hu, MD & Joshua M. Pahys, MD

12:17-12:20 **26th IMAST Preview – Amsterdam**
Marinus de Kleuver, MD

12:20-12:23 **54th Annual Meeting Preview – Montréal**
Stefan Parent, MD, PhD

12:23-12:26 **2019 Worldwide Courses Preview**
Benny T. Dahl, MD, PhD, DMSci

12:26-12:31 **Introduction of the President**
Peter O. Newton, MD

12:31-12:46 **Presidential Address**
Todd J. Albert, MD

Break & Boxed Lunch Pick-up
12:46-13:00

Lunchtime Symposia *(Two Concurrent Sessions)*
13:00-14:00

Current Trends in Bracing for AIS
Chairs: Marco Brayda-Bruno & Howard Place, MD
Room: Hall 19

13:00-13:10 **Introduction and Rationale For Considering An AIS Non-Operative Treatment**
Marco Brayda-Bruno & Howard Place, MD

13:10-13:20 **North American Perspective on AIS Bracing**
Stefan Parent, MD, PhD

13:20-13:30 **European Perspective on AIS Bracing**
Theodoros Grivas, MD, PhD

13:30-13:40 **Multidisciplinary and Comprehensive Approach to Bracing for Better Compliance and Results**
Stefano Negrini, MD

13:40-14:00 **Discussion**

Neuromuscular Spine Deformities: The Spine is Only a Small Piece of the Big Puzzle!

Chairs: *Olavo Letaif, MD, MSc & Muharrem Yazici, MD*
Room: Sala Italia

13:00-13:02 **Introduction**
Olavo Letaif, MD, MSc & Muharrem Yazici, MD

13:02-13:08 **Are Preoperative Workups in Neuromuscular Patients Same With Idiopathic Deformities?**
Olavo Letaif, MD, MSc

13:08-13:14 **Can We Apply General Pediatric Deformity Principles to NM Deformities?**
Muharrem Yazici, MD

13:14-13:20 **What Effect Do Comorbidities Have on the Decision-Making in Spinal Deformity Surgery for CP?**
Suken A. Shah, MD

13:20-13:30 **Discussion**

13:30-13:36 **How Can Spinal Reconstruction Make Low-Thoracic/High Lumbar MMC Patients Happy?**
Paul D. Sponseller, MD, MBA

13:36-13:42 **The Dream of Disease-Modifying Treatment Has Come True: But did it Open a New Page in Low-Tone NM Deformities?**
Michael G. Vitale, MD, MPH

13:42-13:48 **Should We Manage Neuromuscular Patients Postoperatively As AIS?**
Michael P. Glotzbecker, MD

13:48-13:58 **Discussion**

13:58-14:00 **Closing Remarks**
Olavo Letaif, MD, MSc & Muharrem Yazici, MD

Break

14:00-14:15

Abstract Session 6: Early Onset and Neuromuscular Scoliosis (Runs Concurrently with Session 7)

14:15-16:04
Room: Europauditorium

Moderators: Behrooz A. Akbarnia, MD & Cristina Sacramento Dominguez, MD, PhD

14:15-14:19 **Paper #72: Magnetically Controlled Growing Rod Systems Have Higher Hazard of Adverse Events Compared to Prosthetic Rib Constructs**
Chun Wai Hung; Hiroko Matsumoto, PhDc; Megan Campbell, BA; Michael G Vitale, MD; David Roye, MD; Benjamin D. Roye, MD, MPH

14:19-14:23 **Paper #73: Diminishing Returns of Magnetically Controlled Growing Rod Lengthenings Over Time**
Stephanie Ihnow, MD; Viral V Jain, MD; Sarah Gilday, PA-C, MS; William J McKinnon, MD; Peter F. Sturm, MD

14:23-14:27 **Paper #74: The Oxford 5 year Observational Study of 31 patients with Magnetically Controlled Growing Rods (MGCR)**
Thejasvi Subramanian, BABMBCh; Adil Ahmad, MBBS, BSc MRCS; Dan Mihai Mardare, MD, MSc; David C. Kieser, PhD, MBChB, FRACS, FNZOA; David G. Mayers, RN; Colin Nnadi, MBBS, FRCS

14:27-14:36 **Discussion**

14:37-14:41 **Paper #75: Minimum 5 year Follow-up of Mehta Casting to Treat Early-Onset Scoliosis: Correction in the First Cast Predicts Outcome**
Graham T. Fedorak, MD, FRCS(C); Jacques L. D'Astous, MD, FRCS(C); Alexandra N. Nielson, BS; Bruce A. MacWilliams, PhD; John A. Heflin, MD

14:41-14:45 **Paper #76: Non-Anesthetized Alternatively-Repetitive Cast/Brace Treatment for Early Onset Scoliosis**
Kazuki Kawakami, B. Kin; Toshiki Saito, MD; Ryoji Tauchi, MD; Tetsuya Ohara, MD; Noriaki Kawakami, MD

14:45-14:49 **Paper #77: Analysis of Chest and Diaphragm Motion in Early Onset Scoliosis with Thoracic Insufficiency Syndrome using Dynamic MRI**
Toshiaki Kotani, MD, PhD; Noriaki Kawakami, MD; Taichi Tsuji, MD; Toshiki Saito, MD; Ryoji Tauchi, MD; Tetsuya Ohara, MD; Tsuyoshi Sakuma, MD, PhD; Keita Nakayama, MD; Tsutomu Akazawa, MD, PhD; Seiji Ohtori, MD, PhD; Shohei Minami, MD, PhD

14:49-14:58 **Discussion**

14:59-15:03 **Paper #78: Does Decreased Surgical Stress Really Improve the Psychosocial Health of EOS Patients? A Comparison of TGR and MCGR Patients Reveals Disappointing Results**
Cihan Aslan, MD; Gokhan Ayik, MD; Z. Deniz Olgun, MD; Remzi Karaokur, MD; Seniz Ozusta, PhD; Gokhan Halil Demirkiran, MD; Fatih Ünal, MD; Muharrem Yazici, MD

15:03-15:07 **Paper #79: 15 year Trend Analysis of Early Onset Idiopathic Scoliosis Surgeries**
Swamy Kurra, MBBS; Katherine Sullivan; Ravi Dhawan; William F Lavelle, MD

15:07-15:11 **Paper #80: Vertebral Growth Can Be Influenced by Distraction Force from Dual Growing Rods Technique: An Imaging Study over 10 years**
Tianhua Rong, MD; Haining Tan, MD; Youxi Lin, MD; Chong Chen, MD; Xingye Li, MD; Zheng Li, MD; Jianxiong Shen, MD

15:11-15:20 **Discussion**

15:21-15:25 **Paper #81: Reoperation in Patients with Cerebral Palsy After Spinal Fusion: Incidence, Reasons, and Impact on HRQoL**
James Bennett, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Baron S. Lonner, MD; Peter O. Newton, MD; Firoz Miyanji, MD, FRCS(C); Suken A. Shah, MD; Burt Yaszay, MD; Paul D. Sponseller, MD; Patrick J. Cahill, MD; Harms Study Group; Steven Hwang, MD

15:25-15:29 **Paper #82: Assessing HRQOL in Cerebral Palsy following Scoliosis Surgery**
Firoz Miyanji, MD, FRCS(C); Luigi A Nasto, MD, PhD; Tracey P. Bastrom, MA; Paul D. Sponseller, MD; Amer F. Samdani, MD; Suken A. Shah, MD; David H. H Clements III, MD; Burt Yaszay, MD; Unni G. Narayanan, MBBS, FRCS(C), MSc; Peter O. Newton, MD

15:29-15:33 **Paper #83: Pelvic Fixation Improves Coronal Balance, Decreases Pelvic Obliquity, But is Not Essential in Neuromuscular Scoliosis (NMS)**
Vishal Sarwahi, MBBS; Stephen F. Wendolowski, BS; Jesse M Galina, BS; Beverly Thornhill, MD; Saankritya Ayan, MD, MS; Yungtai Lo, PhD; Terry D. Amaral, MD

15:33-15:42 **Discussion**

15:43-15:47 **Paper #84: Neural Axis Abnormalities in EOS Patients Can Be Detected With Limited MRI Sequences**
Rajan R. Murgai, BS; Benita Tamrazi MD, MD; Lindsay M. Andras, MD; Kenneth D. Illingworth, MD; David L. Skaggs, MD, MMM

15:47-15:51 **Paper #85: Corrective Surgery for Scoliosis Associated With Spinal Cord Malformation: Is Neurosurgical Intervention Always Necessary?**
Hongqi Zhang, MD; Yuxiang Wang, MD

15:51-15:55 **Paper #86: Is Prophylactic Surgery for Chiari I Malformation Necessary Previous to Scoliosis Correction?**
Victor Vasquez Rodriguez, MD; Carlos Tello, MD, PhD; Lucas Piantoni, MD; Rodrigo G. Remondino, MD; Ida Alejandra Francheri Wilson, MD; Eduardo Galaretto, MD; Mariano Augusto Noel, MD

15:55-16:04 **Discussion**

Abstract Session 7: Sagittal Alignment and PJK (Runs Concurrently with Session 6)

14:15-16:04
Room: Sala Italia

Moderators: Steven D. Glassman, MD & Pierre Roussouly, MD

14:15-14:19 **Paper #87: Spinal Correction Surgery Enables Long-Term Relief of Gastroesophageal Reflux Disease Symptoms in Adult Spinal Deformity**
Tomohiko Hasegawa, MD, PhD; Yu Yamato, MD, PhD; Daisuke Togawa, MD, PhD; Go Yoshida, MD, PhD; Sho Kobayashi, MD, PhD; Tatsuya Yasuda, MD; Tomohiro Banno, MD, PhD; Hideyuki Arima, MD, PhD; Shin Oe, MD; Yuki Mihara, MD; Hiroki Ushirozako, MD; Yukihiro Matsuyama, MD, PhD

14:19-14:23 **Paper #88: Patient Expectations about Relief of Back Pain are Predictive of Pain Levels at Long Term Follow Up in Adult Spinal Deformity Surgery**
Micheal Raad, MD; Varun Puvanesarajah, MD; Mostafa H. El Dafrawy, MD; Floreana N. Kebaish, MD; Brian J. Neuman, MD; Richard L. Skolasky, Sc.D.; Khaled M. Kebaish, MD, FRCS(C)

14:23-14:27 **Paper #89: Gait Analysis to Evaluate Global Compensatory Mechanisms Including Spine, Pelvis, and Lower Extremities in Patients with Fixed Sagittal Imbalance**
Yo Shiba, MD, PhD; Satoshi Inami, MD, PhD; Hiroshi Moridaira, MD, PhD; Daisaku Takeuchi, MD; Tsuyoshi Sorimachi, MD; Haruki Ueda, MD; Futoshi Asano, MD; Hiromichi Aoki, MD; Takuya Iimura, MD; Hiroshi Taneichi, MD, PhD

14:27-14:36 **Discussions**

14:37-14:41 **Paper #90: Restoring the Spinal Shape in Adult Spinal Deformity According To the Roussouly Classification and Its Effect on Mechanical Complications: A Multicentric Study**
Amer Sebaaly, MD, BS; Martin Gehrchen, MD, PhD; Clément Silvestre, MD; Khalil Emile Kharrat, MD; Tanvir Johanning Bari, MD; Gabi Kreichati, MD; Maroun Rizkallah, MD; Pierre Roussouly, MD

14:41-14:45 **Paper #91: Is it Possible to Classify Adult Scoliosis Patients by Roussouly´s Classification?**
Montserrat Baldan Martin, PhD; Javier Pizones, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; Caglar Yilgor, MD; Ibrahim Obeid, MD, MS; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Emre R Acaroglu, MD; Ferran Pellisé, MD; European Spine Study Group

14:45-14:49 **Paper #92: Any Vertebral Segment May Be Chosen as Upper-Instrumented Vertebra If Ideal Individualized Sagittal Shape and Alignment is Reached**
Caglar Yilgor, MD; Suna Lahut, PhD; Yasemin Yavuz, PhD; Kadir Abul, MD; Hatice Hatun Tanriover; Javier Pizones, MD, PhD; Ibrahim Obeid, MD, MS; Frank S. Kleinstueck, MD; Francisco Javier Sanchez Perez-Grueso, MD; Emre R. Acaroglu, MD; Ferran Pellisé, MD; Ahmet Alanay, MD; European Spine Study Group

14:49-14:58 **Discussion**

14:59-15:03 **Paper #93: Spinal Sagittal Realignment after Osteotomy on Healed Thoracolumbar Osteoporotic Fracture-related Kyphosis**
Kai Cao, MD, PhD; Junlong Zhong, MD; Zhimin Pan, MD; Yiwei Chen, MD; Zhaoxun Zeng, MD; Zhi-min Zeng, MD; Zongyao Duan, MD; Quanfei Liu, MD

15:03-15:07 **Paper #94: Comparison of 3 Lumbopelvic Fixation Techniques in Long Fusion to the Sacrum in Osteoporotic Adult Spinal Deformity Pts (>60 Yrs): Clinical and Radiological Outcomes**
Emel Kaya Aumann, MD; Sinan Kahraman, MD; Isik Karalok, MD; Cem Sever, MD; Yunus Emre Akman, MD; Tunay Sanli, MA; Meric Enercan, MD; Azmi Hamzaoglu, MD

15:07-15:11 **Paper #95: Outcome Evaluation: HRQoL vs Patient Satisfaction**
Miquel Serra-Burriel, PhD; Alba Vila-Casademunt, MS; Sleiman Haddad, MD; Francesca Soler-Santasusagna, BS; Juan Bago, MD, PhD; Francisco Javier Sanchez Perez-Grueso, MD; Emre R. Acaroglu, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD, MS; Ahmet Alanay, MD; Ferran Pellisé, MD; European Spine Study Group

15:11-15:20 **Discussion**

15:21-15:25 **Paper #96: Impact of Paraspinal Muscle Degeneration on Fatigue of Spinopelvic Compensatory Mechanism in Sagittal Plane Adult Spinal Deformity: Quantitative Assessment of MRI and Sagittal Parameters after 10 Minutes of Walking**
Junseok Bae, MD; Alekos A. Theologis, MD; Verdat Deviren, MD; Sang-Ho Lee, MD, PhD

15:25-15:29 **Paper #97: Both Bone and Muscle Quality Influence Reciprocal Change In the Thoracic Spine**
Renaud Lafage, MS; Jonathan Charles Elysée, BS; Jeffrey J Varghese, BS; Tejbir S Pannu, MD, MS; Frank J. Schwab, MD; Han Jo Kim, MD; Virginie Lafage, PhD

15:29-15:33 **Paper #98: 5 Year Outcomes of Three Column Osteotomies for Correction of Adult Spinal Deformity in Elderly Patients**
Varun Puvanesarajah, MD; Micheal Raad, MD; Mostafa H. El Dafrawy, MD; Morsi Khashan, MD; Sandesh S. Rao, MD; Hamid Hassanzadeh, MD; Khaled M. Kebaish, MD, FRCS(C)

15:33-15:42 **Discussion**

15:43-15:47 **Paper #99: Unaltered Upper Instrumented Vertebra Reduces Risk of Proximal Junctional Failure Following Surgery for Adult Spinal Deformity**
Alan H Daniels, MD; Breton G. Line, BS; Peter G Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Daniel Reid, MD; D. Kojo Hamilton, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Virginie Lafage, PhD; Robert A. Hart, MD; International Spine Study Group

15:47-15:51 **Paper #100: Cervical, Thoracic and Spinopelvic Compensation after Proximal Junctional Kyphosis: Does Location of PJK Matter?**
Han Jo Kim, MD; Renaud Lafage, MS; Jonathan Charles Elysée, BS; Christopher I. Shaffrey, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Gregory M Mundis, MD; Richard Hostin, MD; Shay Bess, MD; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Peter G Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

15:51-15:55 **Paper #101: Effective Prevention of Proximal Junctional Failure (PJF) in Adult Spinal Deformity (ASD) Surgery Requires a Combination of Surgical Implant Prophylaxis and Avoidance of Overcorrection of Age Adjusted Sagittal Parameters**
Shay Bess, MD; Breton G. Line, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Christopher P. Ames, MD; Douglas C. Burton, MD; Richard Hostin, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Robert A. Hart, MD; Munish C. Gupta, MD; Michael P. Kelly, MD, MS; Eric O. Klineberg, MD; Khaled M. Kebaish, MD, FRCS(C); Han Jo Kim, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S.Smith, MD, PhD; International Spine Study Group

15:55-16:04 **Discussion**

Refreshment Break
16:04-16:25

Abstract Session 8: AIS Techniques/Scheuermann's Kyphosis
16:25-18:14
Room: Europauditorium

Moderators: Lawrence G. Lenke, MD & Suken Shah, MD

16:25-16:29 **Paper #102: Selective Thoracic Fusion of Lenke 3, 4 Curves: Rule Breakers or New Rule Makers?**
David H. Clements III, MD; Lawrence G. Lenke, MD; Peter O. Newton, MD; Randal R. Betz, MD; Michelle Claire Marks, MS, PT; Tracey P. Bastrom, MA

16:29-16:33 **Paper #103: How to Determine Distal Fusion Level in the Major Thoracolumbar and Lumbar Adolescent Idiopathic Scoliosis Treated by Rod Derotation and Direct Vertebral Rotation**
Dong-Gune Chang, MD, PhD; Se-Il Suk, MD, PhD; Jin-Hyok Kim, MD, PhD; Dong-Ju Lim, MD, PhD; Jae Hyuk Yang, MD, PhD; Seoung Woo Suh, MD, PhD; Jung-Hee Lee, MD, PhD; Kee-Yong Ha, MD, PhD; Young-Hoon Kim, MD, PhD; Sang-il Kim, MD; Hyung-Youl Park, MD; Jung Sub Lee, MD, PhD; Ki Young Lee, MD; Whoan Jeang Kim, MD, PhD; Chong-Suh Lee, MD, PhD

16:33-16:37 **Paper #104: Re-evaluating the "1.2 Ratio Rule" for Successful Selective Thoracic Fusion for C Lumbar Modifier Curves in Adolescent Idiopathic Scoliosis: Two- to Five-Year Follow-up of All Pedicle Screw Constructs**
Joshua M. Pahys, MD; Steven Hwang, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Peter O. Newton, MD; Jahangir K. Asghar, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Harms Study Group; Lawrence G. Lenke, MD

16:37-16:46 **Discussion**

16:47-16:51 **Paper #105: L4 Tilt at Skeletal Maturity can Predict Lumbar Disc Degeneration and Low Back Pain in Adults Treated Non-Operatively for Adolescent Idiopathic Scoliosis with Thoracolumbar/Lumbar Curve: A Mean 25-Year Follow-up Study**
Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD; Naoto Endo, MD, PhD

16:51-16:55 **Paper #106: Novel Ossification Markers from a Single AP of the Spine, Combined with Demographics, Accurately Predict Peak Height Velocity in Children**
George Linderman, BS; Don Li; Allen Nicholson, MD; Eric Li; Jonathan Cui, BS; Stephen G DeVries, BS; Yuval Kluger, PhD; Daniel R Cooperman, MD; Brian G. Smith, MD

16:55-16:59 **Paper #107: Is Radiation-free Ultrasound Accurate for Quantitative Assessment of Spinal Deformity in Adolescent Idiopathic Scoliosis (AIS): A Detailed Analysis with Radiography for 952 Patients**
Tsz-Ping Lam, MBBS; Yi-Shun Wong, BSc (Hons); Kelly Ka-Lee LAI, BS; Yong-Ping Zheng, PhD; Lyn Lee-Ning WONG, ; Bobby Kinwah Ng, MD; Lik Hang Alec Hung, FRCS; Benjamin Hon Kei Yip, PhD; Yong Qiu, MD; Jack C.Y. Cheng, MD

16:59-17:08 **Discussion**
Moderators: Michael P. Kelly, MD & Stephen J. Lewis, MD, MSc, FRCS

17:09-17:13 **Paper #108: The Prevalence of Adding-On or Distal Junctional Kyphosis in Adolescent Idiopathic Scoliosis Treated by Anterior Spinal Fusion to L3 was Significantly Higher than By Posterior Spinal Fusion to L3**
Seung-Jae Hyun, MD, PhD; Lawrence G. Lenke, MD; Yongjung J. Kim, MD; Keith H. Bridwell, MD; Kathleen M. Blanke, RN

17:13-17:17 **Paper #109: Do Patients with "Less than Ideal" Outcomes at 2 Years Continue to Have Suboptimal Outcomes in the Long-Term Following Surgery of Adolescent Idiopathic Scoliosis?**
Jessica L Hughes, MD; Burt Yaszay, MD; Tracey P. Bastrom, MA; Carrie E. Bartley, MA; Stefan Parent, MD, PhD; Patrick J. Cahill, MD; Baron S. Lonner, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Harms Study Group

17:17-17:21 **Paper #110: Predictive Factors for Postoperative Medial and Lateral Shoulder Imbalance Following Posterior Spinal Fusion (PSF) in Lenke 1 and 2 Adolescent Idiopathic Scoliosis (AIS) Patients**
Mun Keong Kwan, MBBS, MS; Yukihiro Matsuyama, MD, PhD; Yu Yamato, MD, PhD; Tomohiro Banno, MD, PhD; Shin Oe, MD; Chee Kidd Chiu, MBBS, MS; Xin Yi Ler, MBBS; Sherwin Johan Ng, MBBS; Saw Huan Goh, MBBS; Chris Yin Wei Chan, MD, MS

17:21-17:30 **Discussion**

17:31-17:35 **Paper #111: The Three-Dimensional Deformity in AIS Depends on the Type of Curvature**
Ayman Assi, PhD; Mohammad Karam, MS; Wafa Skalli, PhD; Claudio Vergari, PhD; Ziad Bakouny, MS; Joeffroy Otayek, MS; Aren Joe Bizdikian, MS; Fares Yared, MS; Nour Khalil, BS; Khalil Emile Kharrat, MD; Ismat B Ghanem, MD, MBBS

17:35-17:39 **Paper #112: The Effect of Idiopathic Thoracic Scoliosis on the Tracheobronchial Tree**
Enrique Garrido, MD, FRCS; James Farrell

17:39-17:43 **Paper #113: Negative Impacts of Postoperative Thoracic Hypokyphosis in Adolescent Idiopathic Scoliosis: A 10-year Follow-up**
Ayato Nohara, MD; Ryoji Tauchi, MD; Toshiki Saito, MD; Kazuki Kawakami, B.Kin; Tetsuya Ohara, MD; Noriaki Kawakami, MD

17:43-17:52 **Discussion**

17:53-17:57 **Paper #114: Radiological and Clinical Evaluation of the Use of Low and High Density Screw Systems in Scheurmann Kyphosis**
Metin Ozalay, MD; Umit Ozgur Guler, MD; Alpaslan Senkoylu, MD; Ismail Daldal, MD; Murat Bezer, MD; Akif Albayrak, MD; Mustafa Celiktas, MD; Mahir Gulsen, MD; Akin Ugras, MD; Serkan Erkan, MD; Esat Kiter, MD; Nusret Ok, MD; Yetkin Soyuncu, MD; Omer Akcali, MD; Ali Asma, MD; Anil Murat Ozturk, MD; Burak Akesen, MD

17:57-18:01 **Paper #115: A New Classification for Scheuermann's Kyphosis**
David B. Bumpass, MD; Lawrence G. Lenke, MD; Michael P. Kelly, MD, MS; Ronald A. Lehman, MD; Richard E McCarthy, MD; Michael G Vitale, MD; Baron S. Lonner, MD

18:01-18:05 **Paper #116: Severe Hyperkyphosis Harms Aerobic Capacity and Maximal Exercise Tolerance in Patients with Scheuermann Disease**
Carlos Barrios, MD, PhD; Jesus Burgos Flores, MD, PhD; Alejandro Lorente, PhD; Rocio Tamariz-Martel Moreno, MD; Eduardo Hevia, MD; Luis Miguel Anton Rodrigalvarez, PhD; Rafael Lorente, PhD

18:05-18:14 **Discussion**

Farewell Reception

20:00-23:00
Palazzo Re Enzo

Abstract Session 9A: Basic Science/Infection

8:55-10:05
Room: Europauditorium

Moderators: Luis Munhoz Da Rocha, MD & A. Noelle Larson, MD

8:55-9:00 **Welcome**

9:00-9:04 **Paper #117: Asymmetric Expression of Wnt/ß-catenin Pathway in AIS: Primary or Secondary to the Curve?**
Lei-Lei Xu, PhD; Chao Xia, PhD; Fei Sheng, PhD; Bingchuan Xue, PhD; Xiaodong Qin, PhD; Weiguo Zhu, PhD; Yong Qiu, MD; Zezhang Zhu, MD

9:04-9:08 **Paper #118: Blockade of Osteoclast-Mediated Bone Resorption with a RANKL Inhibitor Enhances Spinal Fusion in a Rat Model**
Evalina L. Burger, MD; Nichole Marie Shaw, BS; Christopher Erickson, BS; Peter Yarger, BS; Yangyi Yu, MD; Todd Baldini, MS; Christopher J Kleck, MD; Vikas V Patel, MD, BS, MA; Karin A. Payne, PhD

9:08-9:12 **Paper #119: Differentially Expressed ceRNA Networks in Vitamin-A Deficiency Induced Congenital Scoliosis**
Chong Chen, MD; Zheng Li, MD; Haining Tan, MD; Tianhua Rong, MD; Youxi Lin, MD; Xingye Li, MD; Jianxiong Shen, MD

9:12-9:21 **Discussion**

9:22-9:26 **Paper #120: Intra-wound Application of Vancomycin Powder May Increase Gr (-) Wound Infections: A Case-control Study**
Prashant Adhikari, MS; Vugar Nabiyev, MD; Selim Ayhan, MD; Selcen Yuksel, PhD; Selcuk Palaoglu, MD, PhD; Emre R Acaroglu, MD

9:26-9:30 **Paper #121: Topical Vancomycin in Concentrations over 5 mg/ml is Toxic to Stem Cell**
Chenghao Zhang, PhD, MBBS, MS; Eric Lewallen, PhD; A. Noelle Larson, MD; Andre Van Wijnen, PhD; Thomas Boyce, MD; Robin Patel, MD; Todd Milbrandt, MD

9:30-9:34 **Paper #122: The Impact of Prophylactic Intraoperative Vancomycin Powder on Microbial Profile, Antibiotic Regimen, Length of Stay, And Reoperation Rate in Elective Spine Surgery**
Zachary J Grabel, MD; Allison L. Boden, BA; Dale Segal, MD; Stephanie Boden; Andrew H. Milby, MD; John Heller, MD

9:34-9:42 **Discussion**

9:43-9:47 **Paper #123: Using Lean/Six Sigma Reaches Target Zero for Surgical Site Infections (SSIs) in Pediatric Spinal Fusion Surgery for Over 100 Consecutive Cases**
Karen S. Myung, MD, PhD; Brock D Reiter, MD; Michael Kheir, MD

9:47-9:51 **Paper #124: Single-Stage Implant Exchange Provides Less Correction Loss than Implant Removal Only Following Late Infections After Posterior Spinal Fusion for AIS**
Derek T. Nhan, BS; Paul D. Sponseller, MD; Harry L. Shufflebarger, MD; Suken A. Shah, MD; Burt Yaszay, MD; Michelle Claire Marks, MS, PT; Peter O. Newton, MD; Harms Study Group

9:51-9:55 **Paper #125: The Treatment of SSI in Severe Spinal Deformity Received PVCR: Hard Choices of Removing Implants**
Tao Li, MD; Yingsong Wang, MD; Jingming Xie, MD; Ying Zhang, MD; Zhi Zhao, MD; Zhiyue Shi, MD; Ni Bi, MD

9:55-10:05 **Discussion**

Abstract Session 9B: Complications, MIS and Cervical Deformity

10:06-11:45
Room: Europauditorium

Moderators: Eric O. Klineberg, MD & Ibrahim Obeid, MD

10:06-10:10 **Paper #126: Flat Bed Rest vs. Immediate Mobilization after Incidental Durotomy in Spine Surgery: Preliminary Results of a Randomized Controlled Trial**
Mazda Farshad, MD; Alexander Aichmair, MD; Michael Betz, MD; José Miguel Spirig, MD; David Ephraim Bauer, MD

10:10-10:14 **Paper #127: Revision Rate after Primary Adult Spinal Deformity Surgery**
Frederik Taylor Pitter, MD; Martin Lindberg-Larsen, MD, PhD; Alma Becic Pedersen, MD, PhD, DMSc; Benny T. Dahl, MD, PhD, DMSci; Martin Gehrchen, MD, PhD

10:14-10:18 **Paper #128: Intra-Operative Neuromonitoring for Pediatric Deformity: A 12 Year Experience from a Single Institution**
John S Vorhies, MD; Kali Tileston, MD; Lawrence Rinsky, MD; Leslie Lee, MD; Scheherazade Le, MD; S. Charles Cho, MD; Viet Nguyen, MD

10:18-10:27 **Discussion**

10:28-10:32 **Paper #129: Minimally Invasive Versus Standard Surgery in Idiopathic Scoliosis Patients: A Comparative Study**
Vishal Sarwahi, MBBS; Romain Dayer, MD; Charlotte De Bodman, MD; Alexandre Ansorge, MD; Stephen F Wendolowski, BS; Jesse M Galina, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

10:32-10:36 **Paper #130: Neurologic Injury in Complex Adult Spinal Deformity surgery: Multilevel Oblique Lumbar Interbody Fusion (MOLIF) Ssing Hyperlordotic Porous Metal Cages Versus Pedicle Subtraction Osteotomy (PSO)**
Darren F. Lui, MBBS, FRCS; Haiming Yu, MD; Jan Herzog; Joseph S. Butler, PhD FRCS; Karan Malhotra, FRCS; Susanne Spure Selvadurai, BSc(Hons); Sean Molloy, MBBS, FRCS, MSc (eng)

10:36-10:40 **Paper #131: Is Achieving Optimal Spinopelvic Parameters Necessary to Obtain Substantial Clinical Benefit: Analysis of Patients Who Underwent Circumferential MIS or Hybrid Surgery with Open Posterior Instrumentation**
Paul Park, MD; Robert K. Eastlack, MD; Kai-Ming Gregory Fu, MD, PhD; Stacie Tran, MPH; Gregory M Mundis, MD; Juan S. Uribe, MD; Michael Y. Wang, MD; Khoi D. Than, MD; David O Okonkwo, MD, PhD; Adam S. Kanter, MD; Pierce D. Nunley, MD; Neel Anand, MD; Richard G. Fessler, MD, PhD; Dean Chou, MD; Praveen V. Mummaneni, MD; International Spine Study Group

10:40-10:49 **Discussion**

10:50-10:54 **Paper #132: Assessment of T1 Slope Minus Cervical Lordosis and C2-7 Sagittal Vertical Axis Criteria of a Cervical Spine Deformity Classification System Using a Long-term Follow-Up Data After Multilevel Posterior Cervical Fusion Surgery**
Seung-Jae Hyun, MD, PhD; Sanghyun Han, MD; Jong-Hwa Park, MD

10:54-10:58 **Paper #133: Postoperative Recovery Kinetics: A Comparison of Primary and Revision Procedures for Cervical Deformity**
Frank A. Segreto, BS; Peter G Passias, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Breton G. Line, BS; Robert K. Eastlack, MD; Justin K. Scheer, MD; Dean Chou, MD; Nicholas J. Frangella, BS; Brian J Neuman, MD; Themistocles S. Protopsaltis, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

10:58-11:04 **Paper #134: Development of a Novel Cervical Deformity Surgical Invasiveness Index**
Peter G Passias, MD; Samantha R Horn, BA; Alex Soroceanu, MD, FRCS(C), MPH; Cheongeun Oh, PhD; Tamir T. Ailon, MD, FRCS(C), MPH; Brian J. Neuman, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Breton G. Line, BS; Robert K. Eastlack, MD; Themistocles S. Protopsaltis, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

11:04-11:08 **Paper #135: Indicators for Non-Routine Discharge Following Cervical Deformity-Corrective Surgery: Radiographic, Surgical, and Patient-related Predictors**
Cole Bortz, BA; Peter G. Passias, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Breton G. Line, BS; Gregory M. Mundis, MD; Khaled M. Kebaish, MD, FRCS(C); Michael P. Kelly, MD, MS; Themistocles S. Protopsaltis, MD; Daniel M. Sciubba, MD; Alex Soroceanu, MD, FRCS(C), MPH; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

11:08-11:20 **Discussion**

11:20-11:30 **Abstract Awards Presentation**
Gregory M. Mundis, Jr, MD

11:30-11:45 **Transfer of the Presidency**
Todd J. Albert, MD & Peter O. Newton, MD

Refreshment Break

11:45-12:05

Abstract Session 10: Complex Spine Across the Ages

12:05-13:30

Room: Europauditorium

Moderators: Bangping Qian, MD & Christopher I. Shaffrey, MD

12:05-12:09 **Paper #136: Continuous-Incremental-Heavy halo-gravity traction combined with posterior-only approach for cervical kyphosis correction in patients with neurofibromatosis-1.**
Hongqi Zhang, MD; Zhenhai Zhou, PhD

12:09-12:13 **Paper #137: Incidence and Risk Factors for Instrumentation-related Complications after Scoliosis Surgery in Pediatric Patients with NF-1**
Ziming Yao, MD, PhD; Xuejun Zhang, MD

12:13-12:17 **Paper #138: Two Staged Posterior Surgeries for Severe Idiopathic Scoliosis Using a Magnetically Controlled Growing Rod**
Mario Di Silvestre, MD; Tiziana Greggi, MD; Konstantinos Martikos, MD; Francesco Vommaro, MD; Gianluca Colella, MD

12:17-12:26 **Discussion**

12:26-12:30 **Paper #139: Postoperative Pulmonary Complications in Complex Paediatric Spine Deformity: A Retrospective Review of Consecutive Patients at SRS GOP Site in Ghana**
Irene Wulff, MD; Henry Ofori Duah, RN; Henry Osei Tutu, BS; Gerhard Ofori-Amankwah, MD; Kwadwo Poku Yankey, MD; Mabel Owiredu; Halima Bidemi Yahaya, MBBS; Oheneba Boachie-Adjei, MD; FOCOS Spine Research Group

12:30-12:34 **Paper #140: Halo Gravity Traction Can Mitigate Pre-Operative Risk Factors and Surgical Complications in Severe Spinal Deformity**
Sravisht Iyer, MD; Oheneba Boachie-Adjei, MD; Rufai Mahmud, MD; Irene Wulff, MD; Henry Ofori Duah, RN; Henry Osei Tutu, BS; Kwadwo Poku Yankey, MD; Harry Akoto, MB ChB; FOCOS Spine Research Group

12:34-12:38 **Paper #141: MIMO Adherence Study: Preliminary Results of a Randomized Controlled Trial**
Stefan Parent, MD, PhD; A. Noelle Larson, MD; Soraya Barchi, BS; Hubert Labelle, MD, FRCS(C); David W. Polly, MD; Minimize Implants Maximize Outcomes Study Group

12:38-12:47 **Discussion**

12:47-12:51 **Paper #142: Impact of Frailty and Comorbidities on Surgical Outcomes and Complications in Adult Spinal Disorders**
Mitsuru Yagi, MD, PhD; Nobuyuki Fujita, MD; Eijiro Okada, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD; Yoshiyuki Yato, MD, PhD; Takashi Asazuma, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD; Keio Spine Research Group

12:51-12:55 **Paper #143: Outcomes and Mechanical Complications by Roussouly-Type in Adult Spinal Deformity: A Single-Center Study**
Pooria Salari, MD; Hong Joo Moon, MD, PhD; Lawrence G. Lenke, MD; Munish C. Gupta, MD; Michael P. Kelly, MD, MS

12:55-12:59 **Paper #144: Reciprocal Change of Sagittal Profile in Unfused Spinal Segments and Lower Extremities after Complex Adult Spinal Deformity Surgery: A Full-Body Radipgraphic Analysis**
Takayoshi Shimizu, MD, PhD; Ronald A. Lehman, MD; J. Alex Sielatycki, MD; Suthipas Pongmanee, MD; Mitsuru Takemoto, MD, PhD; Lawrence G. Lenke, MD

12:59-13:08 **Discussion**

13:08-13:12 **Paper #145: 3D Printed Patient Specific Drill Guides for Pedicle Screw Insertion: A Retrospective Cohort Study**
Rajiv K. Sethi, MD; Sumeet Garg, MD; Jean-Christophe A. Leveque, MD; Joseph E DeWitt, MD, DO; Jacob F Schulz, MD; George A. Frey, MD; Dominick A. Tuason, MD; Ninh B. Doan, MD, PhD; Kellen Nold, PA-C; Alyssa Senz, MS

13:12-13:16 **Paper #146: 90 Day Return to Emergency Department (ED) Post-Spinal Deformity Surgery: Frequent Causes and Risk Factor**
Vishal Sarwahi, MBBS; Stephen F Wendolowski, BS; Jesse M Galina, BS; Shashank V. Gandhi, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

13:16-13:20 **Paper #147: Association Between Non-Modifiable Demographic Factors and Press Ganey Satisfaction Scores in Spine Surgery Clinics**
Bradley C Johnson, MD; Dennis Vasquez-Montes, MS; Aaron J. Buckland, MBBS, FRACS; John A. Bendo, MD; Jeffrey Andrew Goldstein, MD; Thomas J. Errico, MD; Charla R Fischer, MD

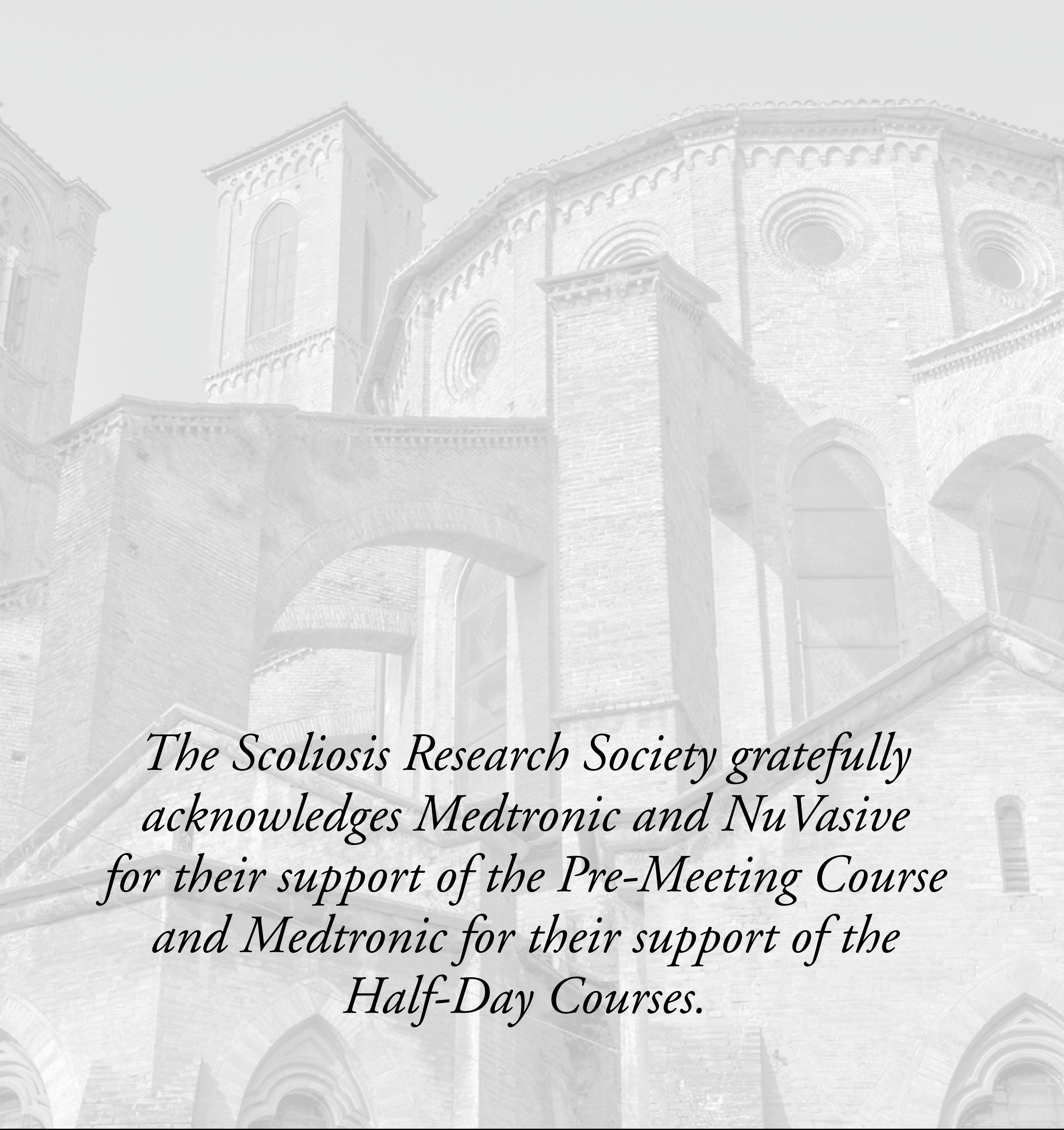
13:20-13:29 **Discussion**

Adjourn

13:30

Notes

Pre-Meeting Course & Half-Day Course Handouts



The Scoliosis Research Society gratefully acknowledges Medtronic and NuVasive for their support of the Pre-Meeting Course and Medtronic for their support of the Half-Day Courses.

Physician Well Being for the Benefit of the Patient: How Can We be Better for Everyone Else?

Scoliosis Research Society • Pre-Meeting Course

Wednesday, October 10, 2017
9:00 – 13:00
Bologna Polo Congressuale
Bologna, Italy

Course Chair
Suken A. Shah, MD
Co-Chairs:
John R. Dimar II, MD
Michael D. Daubs, MD
Burt Yaszay, MD

2017-2018 Education Committee
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Gabriel KP Liu, FRCS(Orth), MSC
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Yan Wang, MD
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The 2018 Pre-Meeting Course is supported by grants from Medtronic and NuVasive.

Annual Meeting Course: Physician Well Being for the Benefit of the Patient: How Can We Be Better for Everyone Else?

Chair: Suken A. Shah, MD
Co-Chairs: Michael D. Daubs, MD; John R. Dimar, MD; Burt Yaszay, MD

Session 1: Physician Preservation

Moderators: Kenneth MC Cheung, MD & Peter O. Newton, MD

9:00 – 9:04	**Introduction** *Todd J. Albert, MD; Suken A Shah, MD*
9:04-9:12	**Professional Burnout: Scope of the Problem and Avoidance** *Todd J. Albert, MD*
9:12-9:18	**Substance Abuse & Bad Behavior…Coping Mechanisms?** *David Hanscom, MD*
9:18-9:24	**Time Management, Getting Enough Rest and Avoiding Sleep Deprivation** *John M. Flynn, MD*
9:24-9:36	**Discussion**
9:36-9:42	**Overuse Syndromes and New Technology to Prevent Them** *Baron S. Lonner, MD*
9:42-9:48	**Reduction of Radiation Exposure to Surgeon and Patient** *John R. Dimar, II, MD*
9:48-9:54	**Other Environmental Hazards of the O/R** *Christopher I. Shaffrey, MD*
9:54-10:00	**Developing Emotional Discipline in Dealing with Complications Reduces Personal Stress and Clarifies Responsibility** *David S. Marks, FRCS, FRCS(Orth)*
10:00-10:12	**Discussion**
10:12-10:18	**The Benefits of Mindfulness/Meditation and Yoga** *David Skaggs, MD*
10:18-10:26	**Getting Fit after 40** *Abhay Nene, MD*
10:26-10:34	**Peak Performance – Lessons Learned from Science and Sociology** *Michael G. Vitale, MD*
10:34-10:44	**Discussion**
10:44-11:02	**Break**

Session 2: Physician Growth

Moderators: Suken A. Shah, MD & Michael D. Daubs, MD

11:02-11:22	**Coaching / Mentoring – The Surgeon as a Professional Athlete** ***Mentor Panel*** *–Behrooz A. Akbarnia, MD; Laurel C. Blakemore, MD; Alvin H. Crawford, MD; Ferran Pellisé, MD; Vernon Tolo, MD* ***Mentee Panel*** *– Lindsay Andras, MD; Robert Cho, MD; Charles Crawford, MD; Han Jo Kim, MD; Kota Watanabe, MD*
11:22-11:28	***Surgeon Leadership is Essential to the Future of Spine Surgery*** *David W. Polly, Jr., MD*
11:28-11:34	**Lifelong Learning and How to Stay Current** *Lawrence G. Lenke, MD*
11:34-11:40	**Building High Functioning, Resilient Teams** *Rajiv K. Sethi, MD*
11:40-11:50	**Discussion**
11:50-11:56	**Getting Through the Mid-Career Blues** *Michael D. Daubs, MD*
11:56 - 12:02	**Working in a Toxic Environment: Have that Courageous Conversation** *Paul Rubery, MD*

12:02-12:08	**The Benefits of Global Outreach and Philanthropy** *Gregory M. Mundis, Jr., MD*
12:08-12:18	**Discussion**
12:18-12:24	**Managing Family Relationships and Work-Life Balance** *Serena S Hu, MD*
12:24-12:30	**Work-Life Balance: Perspective from Europe to America** *Benny T. Dahl, MD, PhD, DMSci*
12:30-12:36	**The Path: Teachings from Asian Philosophy** *Kenneth MC Cheung, MD, FRCS*
12:36-12:43	**Discussion**
12:43-12:58	**Panel: Hobbies and Passions: How to Really Relax After Work** *Alvin Crawford, FRACS; James Sanders, MD; Frank J. Schwab, MD; Michael Vitale, MD; Burt Yaszay, MD*
12:58-13:00	**Closing Remarks/Final Thoughts** *Suken A. Shah, MD*

Hidden Epidemic in Medicine: Physician Impairment and Burnout

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This is a topic I have been quite interested in, in the last couple of years. I wrote a piece in KevinMD published on September 4, 2017 on this topic.

Burnout has been defined by Dr. Herbert Freudenberger in 1974 as a state of emotional, mental, and physical exhaustion caused by excessive and prolonged stress. The burnout has three elements: Emotional exhaustion, depersonalization-a detached cynical view of patients and colleagues, and a perceived lack of personal accomplishments. Many people who have the syndrome are going through the motions rather than being present, suffer from sleeplessness and undiagnosable physical pain and most importantly not treating loved ones with love and personal touch they deserve.

This is not new. Healthcare professionals have been exposed to difficult experiences throughout time. Walt Whitman and Louisa May Alcott were nurses in the Civil War who experienced severe trauma related to what they saw in wartime.

Historically in medicine, doctors were expected to dedicate themselves to patient welfare above all other considerations; they were committed to the public good and they were impervious to financial temptation or other self-interests. As a result: they enjoyed public respect and trust, autonomy and discretion at their work, and they were delighted with their choice of profession.

But the questions arises as to whether our profession is out of balance. With altruistic intent, our healthcare professionals may place professional responsibilities above personal responsibilities. Also, our role models range from academic superstars with impressive research credentials and international claim to committed clinician-teachers who are at the hospital seven days a week. Their heroes lead lives that are desperately out of balance. So, the paradigm of healthcare has changed and what happened?

We have less autonomy work, we have a focus on cost and productivity, patients are sicker, we have decreased patient trust and we have added stress in academic centers due to decreased research funding and resident work hour limitations. The mounting burnout epidemic is due to:

1. Asymmetrical rewards.
2. Loss of autonomy.
3. Cognitive scarcity defined as the need to continuously make consequential decisions that create stress for physicians without time buffers.

Professional signs of this include decreased quality of care, decrease of patient satisfaction and decreased productivity as well as increased physician turnover. Personal signs include broken relationships, alcohol and substance use and abuse, depression and suicide.

There are many articles related to physician suicide at burnout. Disturbing numbers around this problem include 400 physician suicides a year, two times the rate of the general population, two to four times completion rate for suicide, and suicide being the second leading cause of death among residents.

Fifty four percent of doctors say they are burned out, 98% of doctors are moderately or severely stressed and 59% of doctors would not recommend a career in medicine to their children.

Much work has been done on the prevalence of work-life balance and physician burnout, much has been done at the Mayo Clinic, showing an increase in burnout worsening between 2012 and 2015 from 32.5% to 54.4% and significant problems with work-life balance and satisfaction.

While trainees entering medical school have less burnout and better mental health, all of this reversed by the second year of medical school. An interesting paper by Sargent et al. and JBJS looked at the risks factors for residents for burnout including a high level of sleep deprivation, high level of work-life balance conflict, interrupting work with personal concerns, high level of anger, loneliness or anxiety, stressing from relationships at work and anxiousness about their own capacity.

Ultimately, all markers of burnout decreased among faculty except for chairman and program directors. If the question is when do our rates normalize, 10 years into our careers. Clinical Orthopaedics and Related Research published a paper in 2009 looking at orthopaedic leadership. Orthopaedic faculty leaders had higher rates of emotional exhaustion and there were 38% of orthopaedic department chairs who scored highest in the range of emotional exhaustion and residency program directors with the highest rates of exhaustion at 52%.

How can we treat this? There were two main categories of treatment: Physician-directed treatment and organizational-directed treatment:

Physician-directed treatment includes mindfulness techniques, cognitive behavioral techniques, and personal coping mechanism.

Organizationally-directed interventions include:

1. Reduction in workload.
2. Improved teamwork.
3. Enhancement of job control.
4. Increased participation in decision-making.

The most important thing we can do is destigmatize the problem and create a safe and caring culture. For trainees, we have to foster relationships with colleagues and family and create resiliency programs. This includes mindfulness exercise and relationship building.

Another thing to be considered is resiliency which is defined as a dynamic process in which individuals exhibit positive behavioral adaptation in times of significant adversity, stress and trauma or tragedy. It involves the capacity to bounce back after disruption and resist future negative events or outcomes. It can be learned.

The problem with physician-directed care is:

1. It requires individuals to acknowledge there is a problem.

2. It requires the individual to get (and make time) for help.

Orthopaedic surgeons have amongst the lowest scores for likeliness to seek help as well as the highest risk of work-life balance problems. It has been well shown that the cost of burnout is quite important. Physicians with symptoms of burnout are more likely to report having a major medical error in the past three months and nationally it is felt that we are at a tipping point. The National Academy of Medicine has recognized it and in a first for the U.S. academic medical centers, Stanford Medicine hired a chief wellness officer.

The cost of turnover has been estimated to be in recruitment, training and lost revenue and estimate by Stanford at 15 to 55 million dollars over two years.

What strategies can be used to combat this:
1. Acknowledge and assess the problem.
2. Harness the power of leadership.
3. Develop and implement targeted work unit interventions.
4. Cultivate community at work.
5. Use rewards and incentives wisely.
6. Align values in strength and culture.
7. Promote flexibility and work-life integration.
8. Provide resources to promote resilience and self-care.
9. Facilitate and fund organizational science.

In conclusion, the consequences of self-care versus no self-care for patients and for physicians include:

If we participate in self-care and interpersonal professional care, we have better physical health, mental clarity, social attunement/attachment satisfaction and well-being and if we choose not to we will have increased fatigue, weakened immune system, interpersonal and relational distress and burnout, depression, substance abuse and potential exit from the profession.

In summary, it is quite obvious the rewards and improvement from focusing on physician well-being and the attempts to decrease burnout.

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The Ring of Fire

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Overview

Learning to live with anxiety is a lot different than conquering it. Avoiding it just increases it – The White Bears example.

We spend most of our time going back and forth between "doing and achieving" (blue) and "self-protection" (red) trying to avoid feeling anxious and vulnerable. Eventually you will wear out and you will descend into the ring. You then spend your life developing and maintaining a façade (identity) to present to the world while trying to cope with progressive anxiety. If you are reading this piece and don't think you have anxiety, think again. There are an infinite number of ways to disguise and disconnect from it. You can't survive without anxiety. But disconnecting from this innate emotion has significant mental and physical health implications.

Compassion-Focused Therapy

A few years ago, I was attending a conference on compassion in Louisville, KY. I was introduced to the concept of Compassion Focused Therapy (CFT) popularized by Paul Gilbert. The speaker was Dr. Chris Irons who's a London psychologist. He pointed out that there are three core categories of emotions that allow us to function as humans:

- **Threat and self-protection**
- **Doing and achieving**
- **Contentment and feeling safe**

He presented a slide that showed how people go back and forth between these three states. It made a lot of sense. I was excited about the conceptual model and showed it to my daughter who was about 21 at the time and also wise beyond her years. She looked at it for a while and said, "These should be in circles." After some thought, I saw her point. Here is what it looks like:

Here are some of the reasons that I agree with her.

I was raised in a difficult family situation filled with a lot of anger and dysfunctional behaviors. As I was the oldest of four children, I spent an inordinate amount of my childhood trying to create some calm, but to no avail. Finally, at age 15, I quietly shut the door on that part of my life and "moved on" – except I didn't. What I now know what happened is that I disassociated. I completely suppressed the craziness of my childhood and created a life and persona that I wanted and pursued my dreams. Sounds pretty reasonable – right?

My new life

I became athletic, social, smart, and developed leadership skills. I took extra college credits in addition to working 10 to 20 hours a week. I was having a great time experiencing this new life. I also internally developed an identity of being stable as a rock and "cool". Nothing phased me or stopped me. I never got angry and thought it was a waste of time. I was somewhat legendary with regards to how much stress I could take for how long. When I entered medical school I developed another identity of "being compassionate, wise and a good listener."

It worked great until it didn't. Things started to become unraveled in 1990 when I began experiencing panic attacks out of the blue and I didn't even know what anxiety was. It marked the beginning of a 13-year burnout and descent into hell. By 1997 I had a full-blown Obsessive Compulsive Disorder (OCD), which is characterized by intense and unrelenting intrusive thoughts. I had the internal version of OCD with no outward behaviors. I had an endless string of intense negative intrusive thoughts that I would counter with positive thoughts. OCD is the ultimate anxiety disorder. I didn't become a major spine surgeon by having anxiety. I achieved it by suppressing it. My modes of suppression included positive thinking, determination, not complaining, and moving through any obstacle that might be holding me back. All these sound great on paper – even now as I am writing this post.

Avoiding the ring of fire

None of us enjoy the feeling of being anxious and vulnerable so we avoid it. We suppress it, avoid stressful situations, control ourselves and others around us and mask it with anger. The ring of fire is not the place that we want to live. I also did what most of us do is that I worked hard to stay in the blue by creating a life that was enjoyable, busy, interesting and stimulating. Additionally, I became so enmeshed in this process that my identity became the blue zone. For many years I was successful or at least it felt like I was. The energy of my youth kept me hovering above the red to the point that I didn't even know what the word anxiety meant.

"Bring it on"

I admitted a patient with an anxiety disorder during my first year of orthopedic residency. I was perplexed and I had to look up anxiety in my textbook of medicine. I was moving so fast that I was fearless – except I didn't have a clue that my speed was because I was running so scared. I remember sitting in my office late one evening in 1990 thinking about my day. I had a patient who I had just surgically drained for a huge deep wound infection, another patient, who weighed over 300 pounds, had just gotten in an altercation with the hospital security guards, I didn't get a paycheck that month because of high office overhead, and I had a malpractice lawsuit notice sitting on my desk. My thought was, "This is a bad day but bring it on." I thought I could deal with almost anything. Two weeks later I had my first panic attack driving across a bridge over Lake Washington at 10 o'clock at night.

It takes a lot of energy staying out of the ring of fire and my hovercraft ran out of fuel. I went into a 13-year tailspin that I survived out of luck or fate depending on how you want to view it. By 2002, I didn't have a shred of hope after trying every possible means to pull myself out of it. I did not realize that by spending so much effort trying to both treat and avoid anxiety that I was actually fueling it. I think most of us spend a lot of our time between the blue and the red trying to stay out of the red. It eventually wears you out and it does not work. We spend our lives developing a façade to present to the world and ourselves that does not include having anxiety. "You have anxiety?" The problem is that anxiety is the essence of survival and is the core neurological response to the environment in every living creature – especially humans. How did we become the top of the food chain? Then you become connected to this identity instead of connecting to who you really are.

The Center

The bigger issue is that you aren't connected to the core of who you are, which is the green circle in the center. How can you get there when you are moving at 1000 miles per hour? If you can't connect with you how can you really see others as they they are and meet his or her needs? I thought I was compassionate and a remarkable listener. In retrospect I was neither. I was attached to the labels.

The obstacle stopping you getting to the center is that you have to pass through the ring of fire. It's critical that you learn to live with anxiety and use it to thrive, not just survive. Your anxiety isn't going to disappear, otherwise you'd simply die. The paradox is that the more you fight it or try to fix it the more powerful it will become. Also, as you age anxiety will increase simply with repetition. For my generation the age that I think it becomes troublesome is in the mid to late 30's. My problems began at age 37. This generation is in trouble in that the incidence of chronic pain has risen over 800% in seven years in adolescents between ages 12 to 18. I am witnessing this trend in my office and seeing many patients in their 20's with widespread chronic pain and crippling anxiety. They are often buckling quickly when entering the workforce with its attendant demands.

I now live much of my life in the center and quickly am aware when I am in the red. I am not happy about the way I found my way to the center. I don't think that it's necessary to endure the extreme suffering I experienced to find it. I was in chronic pain for 15 years with the last seven of them being intolerable. The essence of how I ended up in the center is that I was completely stripped clean. Every link to the identity that I had created for me was broken and there was nothing left. I lived in the red for many years, which was intolerable. I had lost the capacity to even enter the blue zone. During the worst part of my ordeal I was working on trying to survive the next 10 minutes.

You do have to go through the ring of fire to get to the center but it is a learned skill and eventually what you initially perceived as a ring of fire just becomes part of your life and becomes somewhat of a non-issue. You don't have to go down in flames to enter the green zone.

Procrastination

One insight that helped me understand this model was my tendency to procrastinate. To get back to the blue, which is also a critical part of the human experience does require going back through the ring. Every new experience from meeting a new friend to taking on a big project has some level of anxiety associated with it. I realized that my tendency to put things off was associated with fear of failure or of rejection. The longer I procrastinated on a given project the deeper the feelings. This is the topic of another paper, but you can't keep passing through this barrier with just willpower. The block is too strong and encompassing. You may have already accomplished a lot or not. But continually charging through this ring by sheer force of energy will also eventually wear you down.

Living in center

I live most of my life in the center and am aware every time I pass through the ring of fire in either direction and it is steadily becoming less difficult. I'm also sobered when I get stuck in the red ring. One day of being in this spot sucks out the equivalent of a week's energy. What's sobering is that I lived so much of my life in this state without any awareness of its existence.

It doesn't require effort to be in the green center and stay there. I'm not in a constant mental frenzy. I'm aware when I'm not there and use the tools that I learned to return to the center. I have almost an endless amount of emotional energy and am limited just by the hours of the day and getting physically tired. One metaphor that has stuck with me was one that I learned from reading a small book, *365 Tao*. It presents some basic tenets of Taoism in a concise format. I often become overwhelmed with everything that needs to be done and I do take on too much. One thought for the day described a stork who patiently stands on one leg waiting for a fish to swim by. It simply reaches down

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and grabs its next meal. You can only accomplish what is in your arena and within your range of skills.

I wasn't aware of the existence of a center. I suspect that this is the case for many people – especially while suffering from chronic mental or physical pain. It's there, if you know to look for it and learn how to pass back and forth through the ring of fire.

BTW, Johnny Cash's depiction of the ring of fire is incredibly accurate. The antidote to anxiety is control. Falling in love creates a loss of control – and also liberates you. It is a great experience until we try to reel ourselves and the other person back in. What if you could live your whole life with that degree of freedom?

Time Management, Getting Enough Rest and Avoiding Sleep Deprivation

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Professor of Orthopaedic Surgery, The University of Pennsylvania
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Time management: spine surgeons are good at making more work and more money; most are bad at making more time. Learn to manage your time so you have more for the Priorities in Life.

- Tactics
  - Put in the big rocks 1st
  - No-fly zone
  - 90 day calendar management
  - Using small bits of time well
  - The right task at the right time
  - Attention control and Deep Work
  - Next action step mentality
  - Essentialism
  - Margin
  - Life-Work Integration
- Sleep: you are not your best sleep-deprived. Sleep-starvation may have worked in Residency, but is a recipe for poor performance throughout your career. Sleep-deprivation is part of the impaired-surgeon complex
  - Prioritize sleep like you are an Olympic athlete in training
  - Get the timing right
  - Get conditions right

<u>Related reading from Flynn Life-Work Integration bibliography</u>

1. <u>When</u>—Daniel Pink. Valuable for those trying to improve their productivity and make the most of time available. Explains, with science, the normal daily human energy rhythms and how to maximize performance. Some say the Nappucino concept worth the price of the book. Like most of these books, you can read the summary at the end of each chapter and get 90% of the info.
2. <u>Getting Things Done</u>--David Allen. Stress free high performance. Not just a book, but a system to be productive. Some elements that are a bit outdated in our digital world (paper files, etc), but there are modern digital companion systems (like Wunderlist) that modernize the classic concepts
3. <u>Essentialism: The Disciplined Pursuit of Less--</u>Greg McKeown. Caution: this is NOT the book to read as you start practice. It's for later, when you are stretched too thin, have said "yes" too often, and don't feel like you are doing anything as well as you can. I have sent this book to several mid-career friends around the world and they tell me it's changed their life.
4. <u>Margin: Restoring Emotional, Physical, Financial, and Time Reserves to Overloaded Lives</u>--Richard Swenson. Another great book for mid-career. Margin is the space that once existed between ourselves and our limits. Today we use margin just to get by. Caveat: some may be turned off by Christian tone of the book
5. <u>Deep Work: Rules for Focused Success in a Distracted</u>

World.--Cal Newport. A CompSci Prof, Newport first sets the scene with the increasingly distracted world we live in, then offers very practical steps to thrive

6. The Making of a Corporate Athlete-- Jim Loehr Tony Schwartz HBR Jan 2001. A classic. Change title in your mind to "Making of the Surgeon-Athlete". Using skills mastered by high performance athletes can help surgeons function at their highest level—their ideal performance state. Oscillation and mobilizing energy on demand are key concepts
7. 7 Habits of Highly Effective People-- Steven Covey. The gold standard for over 25 years. If your goal is to grow as person, to make yourself more useful to others, this is the first book to read (and re-read).
8. Total Leadership—Stewart Friedman. Wharton Business School Professor describes 30yrs of teaching and research on his "Work/Life Integration Project". Introduces concept of 4-way wins (work, home, community and self) and the key insight that it's not a zero sum game, it's about overlapping domains. It's a little "business-schooly" but the message is profound. Easy to speed-read and still get all the value. If you want to think about how your own work-life integration is going, try the 4 circle exercise at www.fourcircles.com

Overuse Syndromes and New Technology to Prevent Them

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Musculoskeletal overuse disorders (MOD) definitions and Epidemiology:

- **Overuse injuries**, otherwise known as cumulative trauma disorders, are described as tissue damage of tendons, muscles, nerves and supporting structures of the body that results from repetitive demand over the course of time. The term refers to a vast array of diagnoses, including occupational, recreational, and habitual activities.
- Recognized as related to occupations beginning in the early 18th century
- 1970's-epidemiological studies began to be conducted
- Thousands of related studies currently
- Little data on physicians and preventative strategies
- Occupational Safety and Health Administration (OSHA) under the United States Department of Labor has enacted regulations for manufacturing and construction sectors but has done little to date in the hospital setting.
- OSHA reporting of injuries has been limited to hospital workers, no reporting of physician well-being
- 600,000 MOD injuries per year in US hospitals (physicians not considered separately), representing 34% of lost days from work, $20 billion workers compensation payments, $100 billion indirect costs, personal toll (2014)
- OSHA has recommended that work-place guidelines be developed to address MOD's and improved ergonomics in the hospital (2014)
- **Ergonomics**: an applied science concerned with designing and arranging things people use so that the people and things interact most efficiently and safely — called also biotechnology, human engineering, human factors. (Merriam-Webster dictionary)
- Substantial body of research that provides a strong level of evidence supporting association of MOD's with work-related physical factors.
- Risks associated with frequency, duration, and intensity of the exposure
- Most risky activities: heavy lifting, whole body vibration, overhead work, neck in chronic flexion, forceful repetitive tasks
  - Spine deformity surgeons uniquely at risk due to prolonged surgeries, forceful repetitive shoulder abduction, forearm pronation and supination and use of shoulder, elbow joints and musculotendinous units in exposing the spine and placing pedicle screws with neck in flexed positions
  - Effect on career longevity, quality of life, earning potential

Current Related Literature:

Prevalence of Work-related Musculoskeletal Disorders Among Surgeons and Interventionalists : A Systematic Review and Meta-analysis (JAMA Surg, 2018) Sherise Epstein, MPH[1,2]; Emily H. Sparer, ScD[1]; Bao N. Tran, MD[2]; et al

- 21 articles of interventionalists and surgeons
- 5,828 physicians, mean age 46 yrs, 78.5% male, 12.8 yrs in practice, 14.4 hours in procedures per week

- 12% leave of absence, work restriction, or early retirement
- Degen. cervical 17%
- Rotator cuff 18%
- Carpal tunnel syndrome 9%
- Degenerative lumbar 19%
- CONCLUSION: Research needed to develop and validate an evidence-based applied ergonomics program

Prevalence of Work Related Musculoskeletal Disorders Among Physicians, Surgeons and Dentists: A Comparative Study (Annals of Medical and Health Sciences Research, 2014) Rambabu T, Suneetha K
- Musculoskeletal pain assessed in 100 practitioners in each of 3 groups: dentists, surgeons, and non-interventional physicians
- Dentists 61%
- Surgeons 37%
- Physicians 20%

Musculoskeletal Disorders Among Spine Surgeons *Results of a Survey of the Scoliosis Research Society Membership* Joshua D. Auerbach, MD, Zachary D. Weidner, MD, Andrew H. Milby, MD, Mohammad Diab, MD, and Baron S. Lonner, MD (Spine 2011)
- Survey of the SRS membership [561 respondents (62%)]
- Mean age 54 yrs
- Mean 147 cases, 62 deformity

TABLE 2. Most Common Self-Reported Diagnoses

PAIN LOCATION	DIAGNOSIS	PREVALENCE IN RESPONDENTS, N (%)	POPULATION PREVALENCE IN PUBLICHED SERIES
Neck	Pain/strain/sprain/spasm/HA	214 (38.2)	20%–51% [20,22,23,30–32]
	Degenerative disc disease	51 (9.1)	N/A
Neck (with radiculopathy)	Cervical disc herniation	155 (27.6)	0.1%–0.4% [27–29]
	Cervical spinal stenosis	32 (5.7)	N/A
Shoulder	Rotator cuff pathology	134 (23.9)	4.5%–6.8% [25,30]
Elbow	Lateral epicondylitis	99 (17.7)	1.1%–2.0% [31]
	Cubital tunnel syndrome	13 (2.3)	N/A
Wrist	Carpal tunnel syndrome	48 (8.6)	1.2%–19.0% [23,37–39]
	Bilateral symptoms	16 (2.9)	N/A
Finger	CMC/basal thumb arthritis	49 (8.7)	N/A
	DIP/PIP arthritis	28 (5.0)	N/A
Low Back	Degenerative disc disease	76 (13.6)	N/A
	Spondylosis/arthritis	27 (4.8)	N/A
Low Back (with radiculopathy)	Lumbar disc herniation	172 (30.7)	1.0%–5.0% [40–43]
	Lumbar spinal stenosis	36 (6.4)	N/A
Lower Extremity	Varicose veins/edema	112 (20.0)	6.8%–15.0% [37,38]

TABLE 3. Treatment Received for Most Common Self-Reported Diagnoses

Diagnosis	Immobilization, Brace, Rest, or Traction (%)*	Physical Therapy and/or Exercise (%)*	NSAIDS, Analgesics, Muscle Relaxants (%)*	Oral Steroids (%)*	Injection (%)*	Surgery (%)*	Time Off from Work (%)*
Cervical disc herniation	26.2	20.5	33.6	8.2	2.8	10.7	18.9
Rotator cuff pathology	10.8	27.0	37.8		6.8	14.9	20.8
Lateral epicondylitis	23.9	21.7	22.8		37.0	5.4	8.7
Carpal tunnel syndrome	25.0	2.1	14.6			39.6	35.4
CMC/basal thumb arthritis	20.3	1.4	23.0		9.5	6.8	9.5

What has been the personal experience of the SRS Presidential Line of the past two decades?
- Use power for screw placement, bone scalpel
- Avoid overhead bins when traveling so as not to lift overhead
- Use fellows to assist
- Navigation and O-arm to allow more junior surgeons to do the work
- Lifting patients onto the OR table is a problem
- Not always overuse, can be genetic predisposition
- Need less weighty tools and batteries
- Injuries include rotator cuff, lateral epicondylitis, low back degeneration requiring multiple operations, fractured phalanx during rod bending with open fracture sustained of thumb, bilateral shoulder replacements, bilateral carpal tunnel surgery and counting…

How do we prevent MODs for our self-preservation on behalf of our patients and future generations of surgeons? (* areas we can intervene)

Canadian Centre for Occupational Health and Safety

Job Design

Mechanization*
Job Rotation
Job Enlargement/Enrichment
Team work*

Workplace Design*

Eg. Standing versus sitting

Tools and Equipment Design*

Well maintained tools such as sharp Cobbs, high speed burrs and drills

Work practices*

Training

Current and Future Solutions
- Power tools
- Avoid abduction of shoulder
- Appropriate length tools
- Use of assistants
- Robotics
- Video-assisted techniques, 90- degree vision goggles to minimize neck flexion
- Let's remember our operating room teams
  - Lighter, pared down trays, fewer trays
  - Maintain general health
  - Keep weight down
  - Improved shoe-wear

Implemented Ergonomics Programs
- Duke University School of Medicine
  - Program educates surgeons on adjusting the height/position of the patient and the operating table, alternating postures by sitting when feasible depending on the type of case, and selecting the most ergonomic equipment to use

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Radiation Safety & Exposure

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Louisville, Kentucky, USA

Deformities Require Frequent 36" Films
<u>During Treatment:</u> Common Measurements

1. Central Sacral Vertical Line
2. Lateral Translation
3. Cobb Angles
4. Pelvic Obliquity
5. Shoulder Balance

So, How Much Radiation Do You Expose Your Patients to During Routine Radiographs?

A. Definitions

1. **<u>Rad (Radiation Absorbed Dose</u>**: The Amount of Radiant Energy Absorbed in a Certain Amount of Tissue
2. **<u>Gray (Gy</u>**): A Unit of Absorbed Radiation Equal to the Dose of One Joule of Energy Absorbed Per Kilogram of Matter, or 100 Rad
3. **<u>Milligray (mGy):</u>** A unit of Absorbed Radiation Equal to 0.001 Gray, or 0.1 Rad
4. **<u>Sievert (Sv) (see-vert</u>**): The Unit for Measuring Ionizing Radiation Effective Dose, Which Accounts for Relative Sensitivities of Different Tissue and Organs Exposed to Radiation (1 Joule/Kg)
5. **<u>Millisievert (mSv) (mill-i-see-vert):</u>** One Thousandth of a Sievert, the Unit for Measuring the ***Effective Dose***

1mGy = 1 mSv

<u>Remember:</u> The Milligray & Millisievert are Measures of Radiation *Dose & Exposure*

B. Effective Dose:

1. **<u>E – Effective Dose (1990, ICRP – Int Commission on Radiological Protection):</u>** ***Unit is Sievert Sv (mSv)*** To compare biological effects of different radiographic procedures and to measure potential harm that a certain

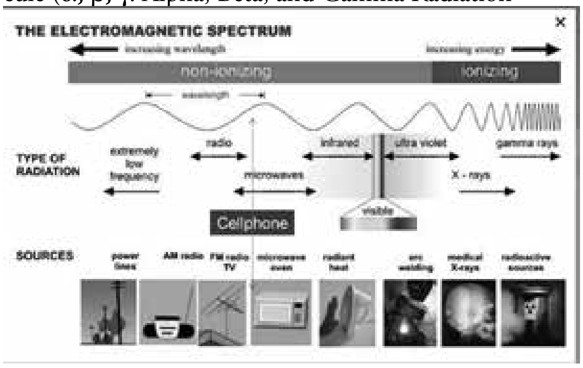
Pre-Meeting Course

amount of energy absorbed will produce, taking into account differences in organ sensitivity and type of ionizing radiation (IR)

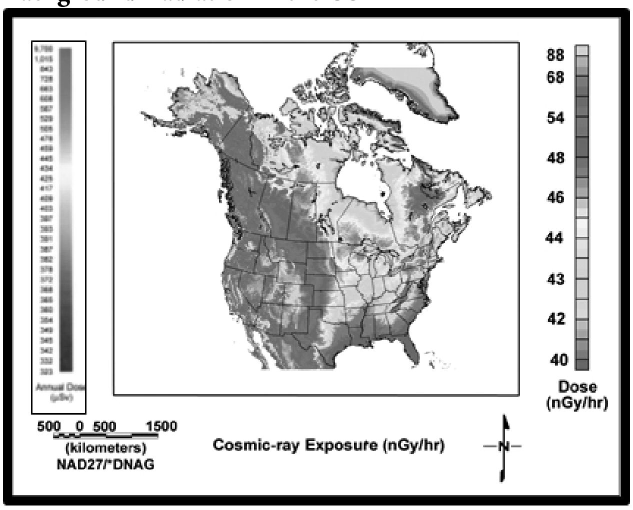
2. **Effect of Different Doses:**
   Early: Burns, Necrosis, Nausea/Vomiting, Cardiac
   Late: Induce Cancer, Heredity

C. Types of Radiation
Nonionizing

1. Radiowaves
2. Microwaves
3. Infrared light
4. Visible light **Ionizing**
   Electromagnetic Radiation from the Spectrum Strong Enough to Remove an Electron from an Atom or Molecule (α, β, γ: Alpha, Beta, and Gamma Radiation

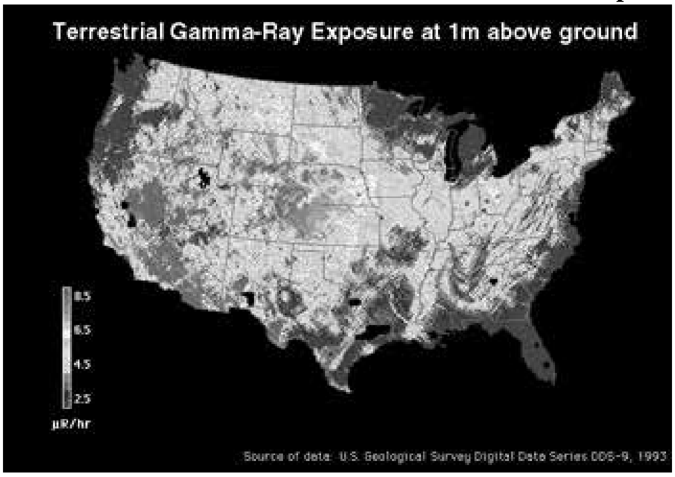


D. Background Radiation in the US

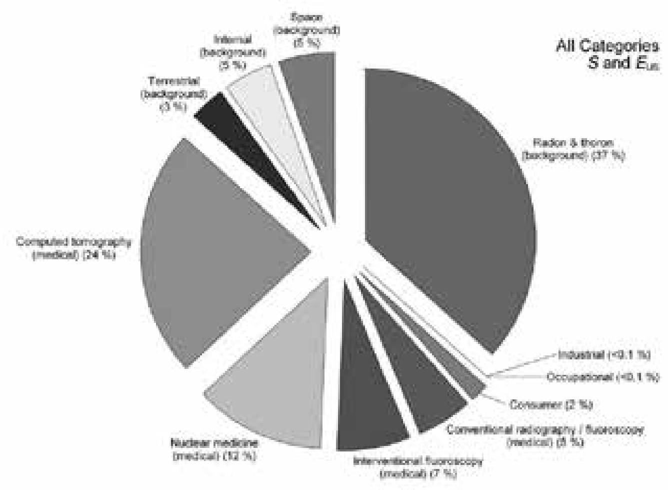


Altitude's Effect:
Denver: 2 X Sea Level Dose
Mexico City: 3X
La Paz Bolivia: 5X

E. Radiation from Terrestrial Sources: Radon for Example



F. Total Background Radiation: About l.2 mSv/Year



Breakdown:

1. "Medical": 48% (3 mSv) & ↑Elderly Primarily CT >50%
2. "Natural" – 50% (~3 mSv)
3. Nuclear Power Plants and Heavy Industry- 2%

G. What Dose of Radiation Can You Expect From During Your Daily Activities?

Background Radiation Source	Daily mSv
Living Within 50 Miles of a Nuclear Plant	.0001
Airplane	.005/hr
Living in Gulf/Atlantic Coast State	.16
Smoking 1 PPD	.36
Consuming Food	.4
Breathing Radon	2.28

H. Test: Most Physicians Have a POOR Understanding of Radiation Dosage. Please Answer the Questions Below, Answers at the End of the Outline

Pre-Meeting Course

A Bone Scan Exposes the Patient to How Much Equivalent Radiation?

A. 1 Chest XR ← Most Said This Incorrectly
B. 10 Chest XRs
C. 80 Chest XR
D. 200 Chest XRs
E. 1000 Chest XRs

What is the Mortality Risk of a Bone Scan?

A. 1 /5000
B. 1/10,000
C. 1/40,000
D. 1/100,000
E. 1/1,000,000 ← Most Said This Incorrectly
F. 1/100,000,000

******Answers at end of Outline!***

I. Doses in mSv for Various Diagnostic Tests

Study	*mSv*		*Study*	*mSv*
DEXA	**.001**		**CT Chest**	**7**
Hand/Foot	**.005**		**CT Ab/Pelvis**	**10**
CXR	**.02**		**Vertebroplasty**	**16**
6 Hr. Flight	**.03**		**Cardiac Intervention**	**30**
C-Spine	**.2**		**Non-Cardiac Embolization**	**55**
Pelvis	**.7**		**Stress Test**	**11-41**
T-Spine	**1**		**PET**	**14**
L-Spine	**1.5**			
Head CT	**2**			
Barium Enema	**7**			
Bone Scan	**6**			

Additional Sources During Spine Surgery:

1. **Instant Plain Radiographs:** *1.5mSv Per Shot*
2. **Fluoroscopy:** *Up to 12.5 mSv Per Year to Surgeon*
3. **Intra-operative CT:** *Up to 15 mSv with 3 Spins to Patient*

J. Comparison of Dosages of Traditional Radiographs to Intra-operative CT (ICT) Scanning in mSvs. **

1. *Lumbar XR: 1.5*
2. **ICT Low Dose Mode, Small Patient: 1.59**
3. **ICT Cranial: 2.38**
4. *Background: 3.0*
5. *Nuclear Power Plant Worker: 5.0 Max. Dose/Yr.*
6. **ICT Standard Mode, Large Patient: 5.66**
7. **ICT HD Mode, Large Patient, Abdomen: 7.79**
8. *Abdomen CT: 10.0*
9. *Coronary CT: 20.0*

****Remember:** ***This is for Just 1 CT Scan Over 5-6 Levels either for Image Guidance or to Confirm Instrumentation Placement, Often Multiple Scans are Done***

K. Studies Indicate Increased Cancer in Patients & Physicians with Increase Medical Radiation Exposure

1. Danish Studies Show Increased Breast & Uterine Cancer Risk
2. Several Recent Studies in Female Orthopedists Show Increased Prevalence of Breast Cancer

Chou LB, Cox CA, et.al., Prevalence of Cancer in Female Orthopedic Surgeons, J Bone Joint Surg Am, 2010; 92: 240-44

Chou LB, Chandran S, et.al., Increased Breast Cancer Prevalence Among Female Orthopedic Surgeons, Journal of Women's Health, Vol 21, No 6, 20_

L. National Radiation Exposure Risk Awareness is Still Poor for Physicains: Recent Surveys (US & Latin America) of Orthopedic Residency Programs Concerning Radiation Safety Compliance Showed Increased Awareness of Lead Shielding Techniques Decreasing Negative Health Effects

1. 517 Surveys
2. 52.4% Reported the Use of Lead Gown & Shield
3. 33.8% Reported NO Personal Protection Equipment!
4. Only 21% Use of Lead Glasses
5. Poor Compliance Associated with Lack of Availability
6. Concluded That Greater Efforts (Mandatory) Need to Be Implemented Since the Number One Reason for Not Using a Lead Gown

Bowman JR, Razi Afshin, et.al., Topics in Training: What Leads to Lead, Results of a Nationwide Survey Exploring Attitudes And Practices in Orthopaedic Surgery, J Bone Joint Surg AM, 2018; 100e16(1-7)

Falavigna A, Ramos, MD, et.al., Knowledge and Attitude Regarding Radiation Exposure Among Spine Surgeons in Latin America, World Neurosurgery, 112; e823-e829, April 2018

M. Recommendations:

1. Physicians Are Just Lackadaisical when it Comes to Radiation Safety Frequently Ignoring the Recommended Use of Lead!
2. Maximum Allowable Yearly Radiation Exposure Set by International Commission on Radiologic Protection < 20 mSv

N. Conclusions:

1. Background Radiation is Significant Already
2. Medical Radiation Reaches Similar Doses to Those Seen in *A-Bomb Exposure*
3. Many Patients Receive Doses That Exceed Nuclear Power Plant Workers Annual Limit of *5 mSvs*
4. Limit Yearly Maximum Exposure to *20 mSvs*
5. Physicians are Unaware of the Doses That Common Tests Deliver
6. Nuclear Medicine Tests Deliver Significant Does
7. Intra-operative Radiographs May Deliver Significant Doses to Physicians & Patients
8. XR Exposure Should be Actively Minimized
9. Long Term Effects are Not Know But Probably Bad
10. Lead Usage Should be Encouraged by Residencies, Medical Staffs and the Hospital Systems

******Answer to Questions: 200 Chest XR & 1/5000 ↑ Risk of Cancer***

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The Benefits of Meditation, Mindfulness and Yoga

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Objective:

Goleman and Davidson, Altered Traits: Science Reveals How Meditation Changes Your Mind, Brain and Body.

- Training even as short as three days produces a short-term decrease in inflammatory cytokines, the molecules responsible for inflammation. The more you practice, the lower the level becomes. This seems to become a trait effect with extensive practice.
- The enzyme telomerase, which slows cellular aging, increases after three months of intensive practice.
- Meditation slows the usual shrinkage of our brain as we age: at age fifty, longtime meditators' brains are "younger" by 7.5 years compared to brains of nonmeditators of the same age.

Goyal M, Singh S, Sibinga EMS, et al. Meditation Programs for Psychological Stress and Well-beingA Systematic Review and Meta-analysis. *JAMA Intern Med.* 2014;174(3):357–368.

- 47 trials, 3515 patients
- moderate evidence of improved anxiety, depression, and pain
- no evidence that meditation programs were better than any active treatment (ie, drugs, exercise, and other behavioral therapies).
- low or no evidence of any effect on positive mood, attention, substance use, eating habits, sleep, and weight

Subjective:

The Buddha

"success in meditation comes to those who work the hardest"

Hulnick, Loyalty to Your Soul

Spiritual evolution (growth) is a process, not an event.

Goleman and Davidson, Altered Traits: Science Reveals How Meditation Changes Your Mind, Brain and Body.

"The most compelling impacts of meditation are not better health or sharper business performance but, rather, a further reach toward our better nature."

"The further reaches of the deep path cultivate enduring qualities like selflessness, equanimity, a loving presence, and impartial compassion—highly positive altered traits. these deep changes are external signs of strikingly different brain function."

"The mark of progress along this path is whether our reactions in daily life signal a shift toward healthy states. The goal is to establish the healthy states as predominant, lasting traits."

"There are two paths, the deep and the wide. The deep can be total commitment. Years of committed practice. Changes in brain chemistry, traits and behavior. The wide can be mindfulness-based stress reduction, watered-down, handy for the largest number of people, widest benefit – i.e. Meditation Apps.

"The mix of meditation and monetizing has a sorry track record as a recipe for hucksterism, disappointment, even scandal."

Eknath Easwaran, Conquest of Mind

"Today we hear "meditation" used to describe a number of things, some of which have nothing to do with meditation. These techniques may be relaxing, they may be inspiring, they may be good for your physical health, but as far as accomplishing enduring, beneficial changes in the mind, they have no more effect than writing on water."

"So when you are tempted to stay in bed at the expense of meditation, remember these words: Give up a small pleasure for a lasting joy." Meditation will enhance everything in your life. It will follow you to work and make you calmer, more energetic, more creative, and more secure."

"The way to protect yourself against any ill-will … is the same: do not let your mind dwell on any unpleasant memory or negative thought."

Jon Kabat-Zinn, Full Catastrophe Living

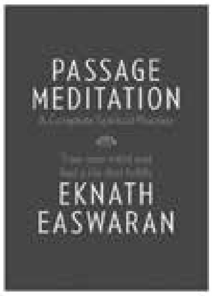
Mindfulness: "The awareness that arises from paying attention, on purpose, in the present moment, and non-judgmentally."

Further Resources

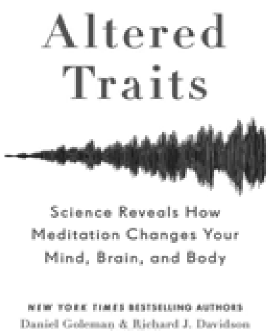
Start Here

https://www.bmcm.org/learn/getting-startedoverview/

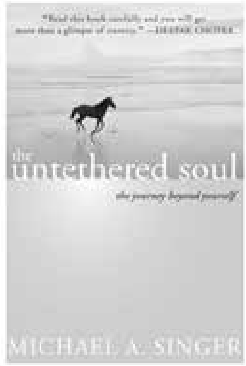
Or Here



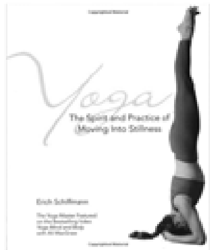
Physiologic and Mental changes resulting from meditation summarized by a mainstream academic scientist and author



Approach this book with the "willing suspension of disbelief". Powerful, challenging, life changing if you are open to it.



Wonderful blend of the mental and physical aspects of yoga. Without a still mind, yoga is just calisthenics.



but, beware of Craziness ……. from the lunch line at Children's Hospital Los Angeles

The neuroscience of mindfulness meditation

Yi-Yuan Tang[1,2], Britta K. Hölzel[3,4]* and Michael I. Posner[2]*

NATURE REVIEWS | NEUROSCIENCE VOLUME 16 | APRIL 2015 |

As is relatively common in a new field of research, studies suffer from low methodo- logical quality and present with speculative post-hoc inter-pretations. Knowledge of the mechanisms that underlie the effects of meditation is therefore still in its infancy. However, there is emerging evidence that mindfulness meditation might cause neuroplastic changes in the struc- ture and function of brain regions involved in regulation of attention, emotion and self-awareness.

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Table 1 | Structural changes in the brain associated with mindfulness meditation

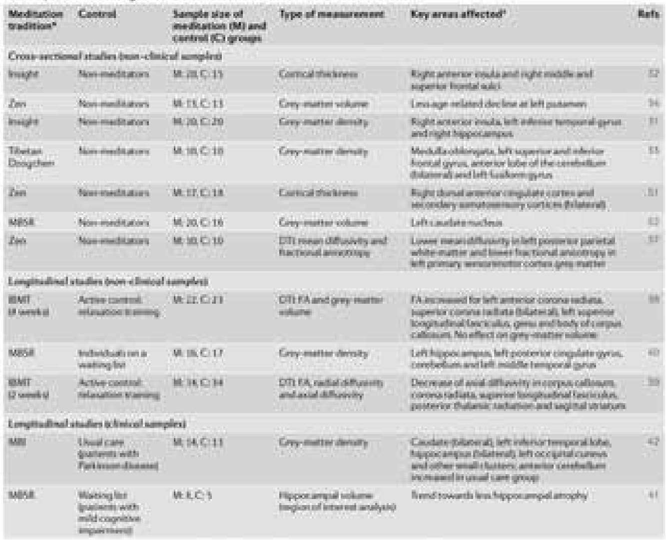
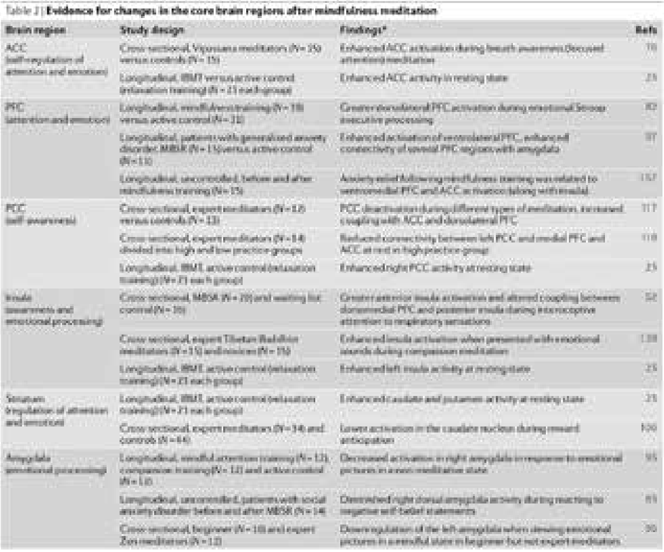


Table 2 | Evidence for changes in the core brain regions after mindfulness meditation



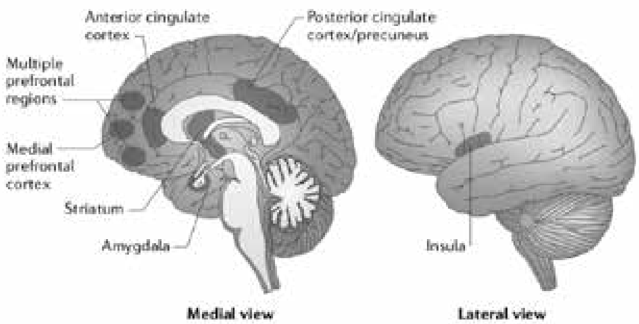


Figure 1 | **Brain regions involved in the components of mindfulness meditation.** Schematic view of some of the brain regions involved in attention control (the anterior cingulate cortex and the striatum), emotion regulation (multiple prefrontal regions, limbic regions and the striatum) and self-awareness (the insula, medial prefrontal cortex and posterior cingulate cortex and precuneus).

Getting fit after 40 – A Surgeons Guide

Abhay Nene
Spine Clinic, P D Hinduja National Hospital
Mumbai, India

Surgeons are medical sportsmen. Just like Formula One drivers, Golfers and Chess players - a high level of physical and mental fitness is mandatory for high performance at our jobs. Though fitness doesn't get listed amongst our core competencies, it is a clear necessity for a physically demanding profession like ours.

After spending our best years in training to become good surgeons – most of us realize the need for fitness in our 40s, to keep our mind and body in good stead for the second half of our lives.

Is it then easy to just decide and start getting fit one day? Not really!

Getting fit after 40 demands a structured, systematic approach that involves initially simple modifications in daily activities and diet , graduating to low impact endurance training and optimization of body weight, and then moving to muscle building activities and sports,

Some basic medical work up so as to not take the cardio vascular system for granted – is clearly needed, and work out regimens may need to be modified based on potential risk factors.

Making time for this new fitness plan, having the mental reliance to overcome the standard obstacles that will impede progress and finding tricks to stay motivated over long periods, become the key factors to a successful effort to become fit at mid-life.

The rewards one gets are tangible - there's a palpable bounce in day to day jobs including surgeries and outpatient clinics …. the endorphin high takes all lethargy away, , improved self-confidence, sound sleep, a sense of well-being, and the person in the mirror now turns up as a sharper and radiant chap.

These become a driving factor to do more, as the need for exercise becomes an addiction!

Most of all, the mental toughness one stands to build as a consequence of this effort, can make challenging surgical problems including dealing with surgical complications - a simpler, well-rehearsed job!

Let's step out of our comfort zones and demystify this fitness mantra. Invest in our body …it's the only place we have to live in!

Peak Performance: Lessons Learned from Science and Sociology

Michael Vitale, MD, MPH
Children's Hospital of NY Presbyterian
New York, New York, USA

How Can We *PERFORM* Better?
- Doctor and Surgeon
- Colleague and Mentor
- Spouse, Parent, Friend

Definitions
- Ability
- Knowledge
- Skill
- Performance

Examples from
- Chess
- Sports
- Musicians

Intellectually Gifted Vs Motivationally Gifted

Grit and 10,000 hours

Tiger Mom / Immigrant Mentality
- Sense that you can work harder/ do it better
- Fear of Failure
- Impulse Control

Mischel's Marshmallow Experiment of 1970

Deliberate Practice
- Deep training – Chunking
- Get Outside Comfort Zone
- Self Criticize and Measure

Using stress to your advantage
"Selection at the Gate": British fertility clinics
"difficult cases enable greater learning from prior experience because they promote experimentation, communication among various actors, and the codification of new knowledge"

Meta cognition - the ability to self-observe
Top performers are always more critical and more specific in their criticism of themselves

Small Gains Accrue Over time, ….If We Learn from Mistakes

From Skill to Performance
Ability, Skill, Knowledge get you "in the room" – "prerequisite to play"
Your ability to *Perform* Differentiates you in a competitive Field

How to Bring Your Best Self to Game Day: Sleep and Performance
- AM vs PM start as a determinant of transfusion for AIS patients
- Get Your Colonoscopy in the Morning!
When: *From Nap Detractor to Nap Devotee….*

Managing Pressure by "Pre Creating" the Performance
- Top performers make a habit of *pre-creating* pressure situations in vivid detail, so that when the time comes, they're ready and have less performance anxiety, fear, and choke potential

Virtuoso violinist Nathan Milstein :
"If you practice with your fingers, no amount is enough. If you practice with your head, two hours is plenty.'"

How Preshot Routines Can Improve Your Performance -Patrick Cohn

Game Sense /Playing Unconscious
"What distinguishes a great bridge player or a great surgeon or a great pilot from the rest of us mortals is how much they have on automatic. When the bulk of what an expert does is on automatic, people say she has "great intuitions."

Flow: The Psychology of Optimal Experience *Mihaly Csikszentmihalyi*

"Very few people get to experience the pressure of great moments"
Billie Jean King

Managing Stress: Oscillate to Recovery

"Operating Badly, Well"
The greatest and toughest art in golf is "playing badly well." All the greats have been masters at it. ---JACK NICKLAUS

"Teaming"
- Make People Feel Safe
- Don't Hoard Information
- Find Win-Win

The Marshmallow Challenge

Build Safe Connections
Share Vulnerability
Establish Purpose

Mid Career: Importance of Essentialism
We define ourselves as much by what we choose not to do

The Importance of Deep Work
Protect time for deep work
Embrace boredom
Disconnect
"Drain the Shallows"

Why Surgeon Leadership is Still Needed

David W. Polly Jr., MD
Department of Orthopaedic Surgery
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Minneapolis, Minnesota, USA

Process of Care
- Patient presents with complaint or finding
- History
- Physical
- Imaging

Assessment of Problem
Is there an anatomic basis for the complaint?
- Deformity
- Deformity progression
- Neurologic compression
- Bone failure

Assessment of What Would it Take to Fix the Problem
- Deformity what would it take to fix the problem
- Is decompression feasible and can it be done alone
- If fracture can it be fixed
- If bone insufficiency what treatment

Surgical Invasiveness Score
- Mirza scoring system
- Neuman scoring system

Assessment of Can the Patient Tolerate the Fix?
- Frailty concept
- Cardiovascular
- Renal
- Metabolic
- Osteoporosis

Can the Patient Benefit from the Fix?
- Life expectancy
- Patient expectations
- Surgeon expectations
- Intensity of resources required to fix the problem – are they available?

Orchestrating the Surgery
- Optimizing the anesthesia process
- Positioning the patient
- Prep and drape
- Exposure
- Level confirmation
- Instrumentation
- Decompression
- Deformity correction
- Fusion

- Cell saver
- Neuromonitoring
- Monitoring blood loss and labs
- Intraoperative imaging

- Post-op hand off
- Meeting with family
- Dictation
- EMR work

Orchestrating the Recovery
- Post-op level of care: ICU, IMC, floor
- Drains
- Pain meds
- Duration of hospital stay
- Medical optimization
- Use of bracing
- PT OT limitations
- Discharge planning/placement
- Follow up evaluation

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Life Long Learning and How to Stay Current

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Surgeon-in-Chief
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LIFE LONG LEARNING

- Necessary
- Multiple Different Means
- Individualized
- Marked Difference in Private Practice (Solo) vs Group Practice
- Difference between Academia and Private Practice
- Many Resources Available Now via the Internet!

WHAT HAS WORKED FOR ME?

- Full-Time Academic Practice X 27 Yrs
- Associated with Spinal Surgery Fellows X 27 Yrs
- Very Active in Clinical Research for almost 30 Yrs
- Fortunate to have Over 500 Surgeon-Visitors to Observe both Clinical and Research Work to Interact with and Learn from

WEEKLY SPINE DIVISION PRE/POSTOP SURGICAL CONFERENCE

- Started July 1991 (Beginning of Spine Fellowship)
- Keith Bridwell/Chris Baldus
- Larry Lenke/Kathy Blanke
- Monday 6am-7am Weekly Conference
- Every Preop/Postop Case I have ever done, and Every Spine Case Done at Wash U./Columbia has been Presented at this Conference!
- Great for "Peer-Review" for Preop and Postop considerations
- 27 Consecutive Years of this Weekly Conference, still continues…
- Also allows to stay current in other areas i.e. Cervical Spine Surgery (K. Daniel Riew, MD)

AUGUST 6, 2018

AUGUST 6, 2018

AUGUST 6, 2018

WEEKLY SPINAL DEFORMITY PRE/POSTOP SURGICAL CONFERENCE

- Started July 1991 @ Shriners Hospital –St.Louis
- Attendees: LGL, Perry Shoenecker, MD, Ortho Residents, Spine Fellows, Nursing Staff, Visiting Surgeons
- Continued Weekly until 2015 with Departure to Columbia/NYC

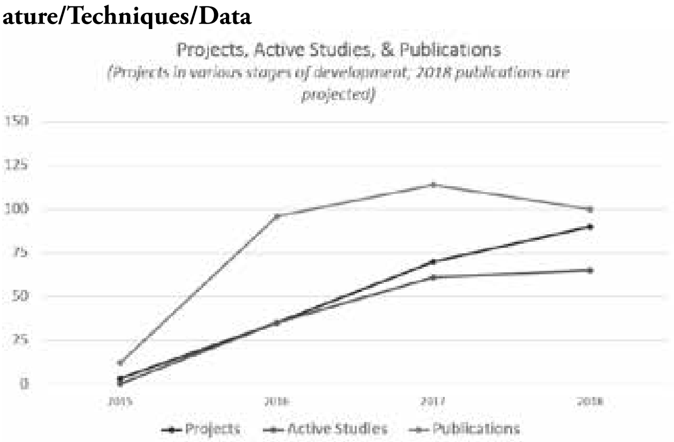
WEEKLY SPINAL DEFORMITY CASE CONFERENCE

- Weekly 1-2 Hour Conference
- Pre & Postop Cases Shown and Discussed with In-depth Discussion of pertinent Literature, Techniques, Tips & Tricks
- Plenty of Q & A with Informal Environment
- Attendees: Residents, Fellows, Other Attendings, Visiting Surgeons, PA's, Clinical Research Team

MONTHLY CONFERENCE SCHEDULE

- Weekly Monday 0600 Case Conference (EVERY CASE PRESENTED)
- Weekly Spinal Deformity Case Conference
- Weekly Teaching/Educational Conf.
- Monthly Spine Division Research Mtg
- Monthly Spine M & M (Ortho/Neuro)
- Monthly Spine Attending Mtg
- Monthly Journal Club
- Monthly Spine Integration Mtg (Ortho/Neuro/Physiatry/NYP Admin)

Robust Research Program an Essential Component to a World Class Pgm & also Helpful to Staying Current on Literature/Techniques/Data



CLINICAL RESEARCH

Publications

- In 2017, Our group was named on 132 published papers in peer-reviewed journals, with a near 70% acceptance rate

Faculty Member	H-index	Published Papers, Career	Published Papers, 2017
Lenke	108	642	33
Riew	54	458	59
Lehman	36	263	23
Weidenbaum	20	43	3
Kim	13	51	12
			Total=132

Conferences

- Our work was presented 150+ times at numerous professional meetings worldwide in 2017
- This included 28 acceptances at SRS, 5 at IMAST, 14 at LSRS, and 31 at NASS

SURGEON VISITORS 2015-17: Communication Enhances Global Perspective on Spinal Deformity Care!

Argentina - 3	Iran - 1	Qatar - 1
Australia - 2	Italy - 8	Saudi Arabia -1
Brazil - 5	Japan - 13	Spain - 3
China - 56	Korea - 8	Switzerland - 1
Dominican Rep - 1	Kuwait - 1	Thailand - 4
Egypt - 6	Mexico - 1	Taiwan - 2
France - 3	Nepal - 1	Turkey - 1
Germany - 81	New Zealand - 2	USA - 27
Hungary - 1	Nigeria - 1	Venezuela - 1
India - 3	Pakistan - 2	**Total 171**

2018 SRS TRAVELLING FELLOWS

MEETINGS: IMAST

- Attended Every IMAST since 1998
- "Groomed" by R. Betz for IMAST Chair 1999-2003
- IMAST Chair 2004-2009
- I am Definitely Biased in favor of IMAST being my 2nd most favorite mtg. every year, after the SRS AM!

MEETINGS: SRS

- Attended Every SRS AM since 1991 (Honolulu, HI)
- Won Hibbs Award (Great way to start Spine Fellowship Year!)
- SRS Presidential Line 2009-2012
- I am Definitely Biased as the SRS AM as My Favorite Spine Mtg of the Year!

MEETINGS: OTHERS

Take your Pick!

- Virtually a Spine Surgery Conf. Nearly Every Fri/Sat. of the Year Now!
- Society Mtgs: AAOS, Jt. Section (AANS), NASS, LSRS, CSRS, SMISS, AOSpine
- Non-Society Deformity Mtgs: Peds Spine: On the Cutting Edge: Shufflebarger/Newton; ISDS: Lenke/Shaffrey/Schwab
- Industry-Sponsored Mtgs: Many to Choose Really NO EXCUSE not to stay Current in Knowledge/Literature/Techniques

JOURNALS: PICK & CHOOSE!

-Spine Deformity: SRS
-Spine
-The Spine Journal
-JNS Spine
-European Spine Journal
-Global Spine Journal (AO Spine)
-Journal of Spine Surgery
-Clinical Spine Surgery
-Scoliosis

WEBINARS: PICK & CHOOSE!
- VuMedi
- Broadwater
- Society-Sponsored
- Industry-Sponsored
- Hospital/Univ. Sponsored
- Can View at One's Discretion as Enduring Material

SURGICAL TECHNIQUE VIDEOS: PICK & CHOOSE!
- YouTube
- VuMedi
- SRS and other Spine Societies
- Industry Sponsored
- Can find any Spinal Surgery Technique Video to review Prior to OR!
- Can View at One's Discretion as Enduring Material

TEXTBOOKS/ON-LINE CONTENT
- TTSS: Bridwell/Dewald
- Pediatric Spine: Weinstein
- SRS Core Curriculum (On SRS Website)
- Tricks of the Trade: Vaccaro/Albert
- Spinal Deformity: Mummaneni
- GOOGLE!
- Can View at One's Discretion as Enduring Material

STUDY GROUPS……..
- HSG: Harms Study Group
- ISSG: International Spine Study Group
- ESSG: European Spine Study Group
- AO Knowledge Forum: Deformity
- SRS M & M: Every SRS Member has Access to that Database to use for Clinical Research!

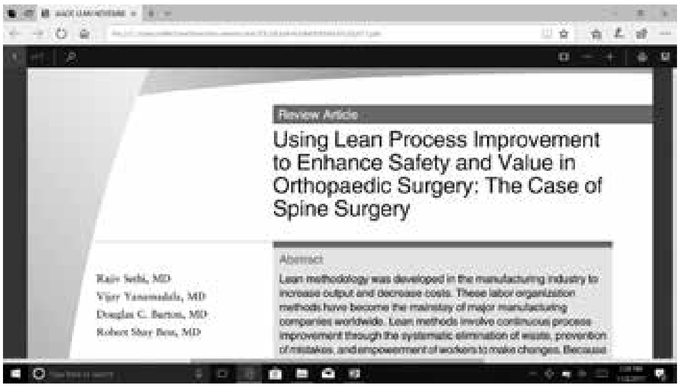
SURGICAL DATABASE
- Very Easy to Construct (REDCAP): Free!
- Much more Difficult to Keep Current/Log in Cases/Details
- Tied into PRO's that Should also be Captured for All Surgical (?Non-Surgical) Patients
- Encourage EVERY Surgeon to Do this….
- Will Eventually be Mandated for Recertification (Ortho/Neuro)

CONCLUSIONS
- Life Long Learning is an Essential Component to Clincal Competency and Excellence
- Many Forms now Available….Really No Excuse not to Stay Current and Practice 2018 Spinal Deformity Surgery
- Actually, Not Worried about Surgeons at this Meeting!
- Much More Worried about Spinal Deformity Surgeons Not at this mtg or part f The SRS…..!

THANK YOU!

Building High Functioning Resilient Teams

Rajiv K. Sethi MD
Chair of the Virginia Mason Neuroscience Institute
Clinical Professor of Health Services Research
Virginia Mason Medical Center
University of Washington
Seattle, Washington, USA



Boosting medical diagnostics by pooling independent judgments

Ralf H. J. M. Kurvers, Stefan M. Herzog, Ralph Hertwig, Jens Krause, Patricia A. Carney, Andy Bogart, Giuseppe Argenziano, Iris Zalaudek, and Max Wolf

Edited by Lee D. Ross, Stanford University, Stanford, CA, and approved June 7, 2016 (received for review February 2, 2016)

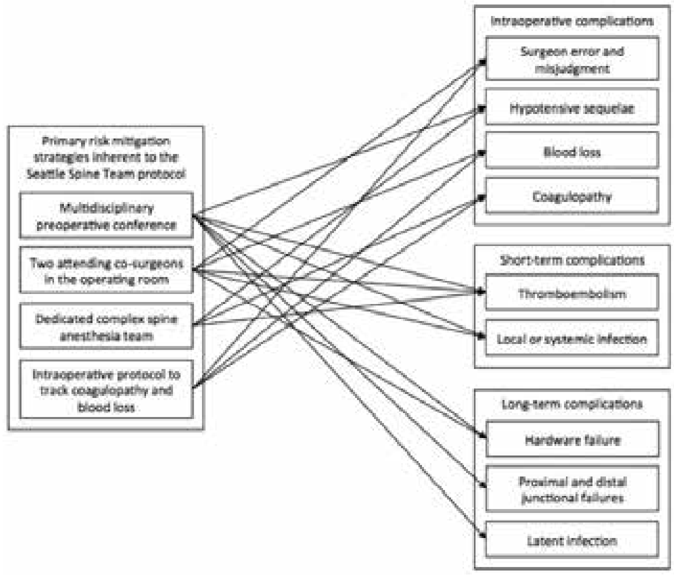
"Aggregating the independent judgments of doctors outperforms the best doctor in a group"

Curr Rev Musculoskelet Med
DOI 10.1007/s12178-016-9351-x

COMPLICATIONS IN SPINE SURGERY (E KLINEBERG, SECTION EDITOR)

Complication avoidance with pre-operative screening: insights from the Seattle spine team

Quinlan D. Buchlak[1] · Vijay Yanamadala[1] · Jean-Christophe Leveque[1] · Rajiv Sethi[1,2]



This diagram reveals the effect of standardization of multiple series of complications seen in spinal deformity surgery.

Spine Deformity

Clinical Series

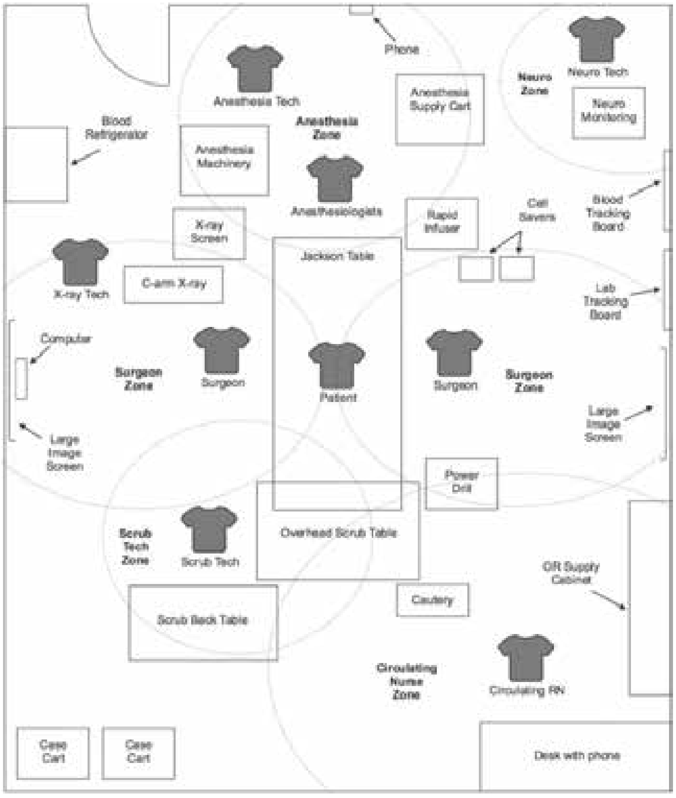
The Seattle Spine Team Approach to Adult Deformity Surgery: A Systems-Based Approach to Perioperative Care and Subsequent Reduction in Perioperative Complication Rates

Rajiv K. Sethi, MD, Ryan P. Pong, MD, Jean-Christophe Leveque, MD, Thomas C. Dean, MD, Stephen J. Olivar, MD, Stephen M. Rupp, MD

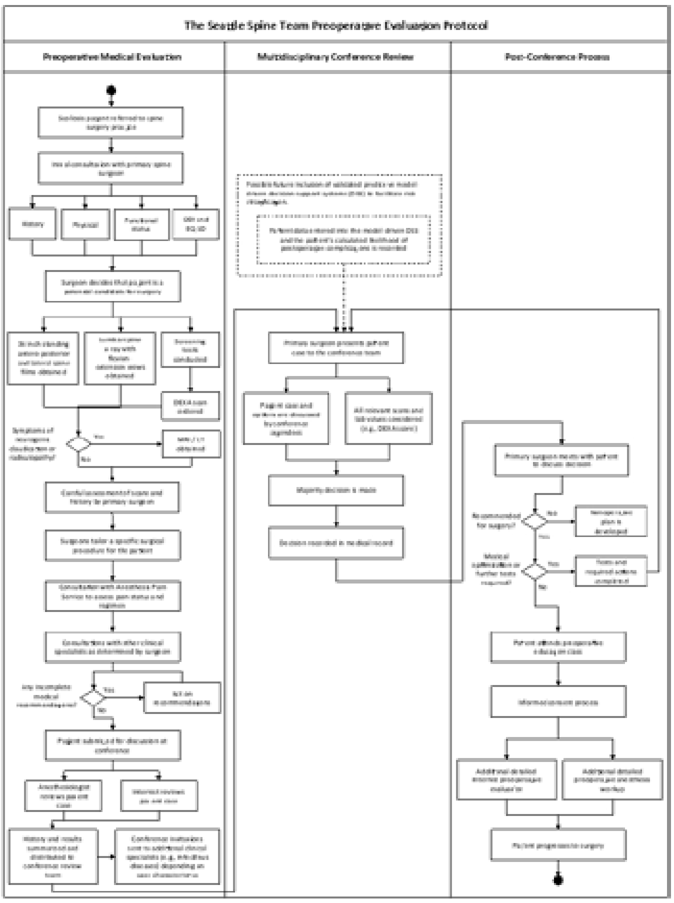
Time	Suction Canister	Cell Saver EBL	Field Irrigation	Total EBL	Hct	pH / BE	PT / INR	Platelet Count	Fibrinogen / D-dimer
9:00	N/A	N/A	N/A	N/A	33	7.38 / -2.9	13.7 / 1.1	108	798 / 2.74
10:03	550	100	0	650	30	7.35 / -4.5	14.2 / 1.1	100	647 / 2.65
11:00	650	550	0	1200	29	7.38 / -3.6	15.3 / 1.2	95	497 / 1.94
12:00	800	1250	0	2050	31	7.34 / -4.2	16.4 / 1.3	90	411 / 2.52
13:04	1300	1700	0	3000	21	7.31 / -4.8	18.1 / 1.5	110	335 / 1.93
14:01	1500	2000	0	3500	31	7.30 / -4.5	17.3 / 1.4	125	280 / 1.95
15:05	1600	2200	0	3800	29	7.33 / -4.1	17.0 / 1.4	103	290 / 7.49

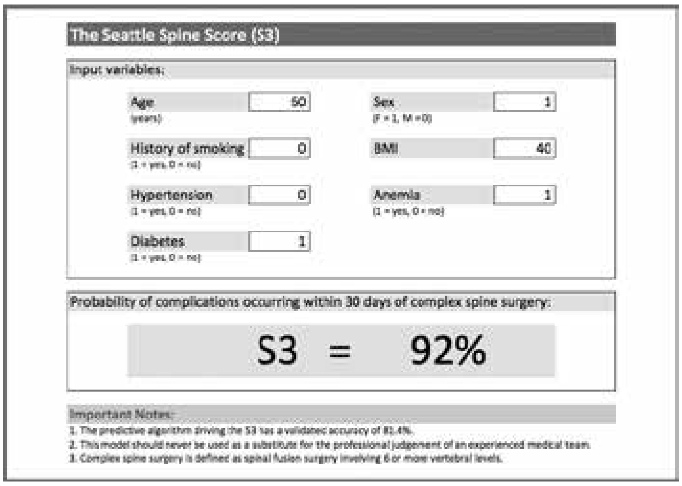
Standardization of all complex spine cases using principles of the Toyota Production System. This is an example of "visual control" as a standard method of communication around coagulopathy and blood loss.

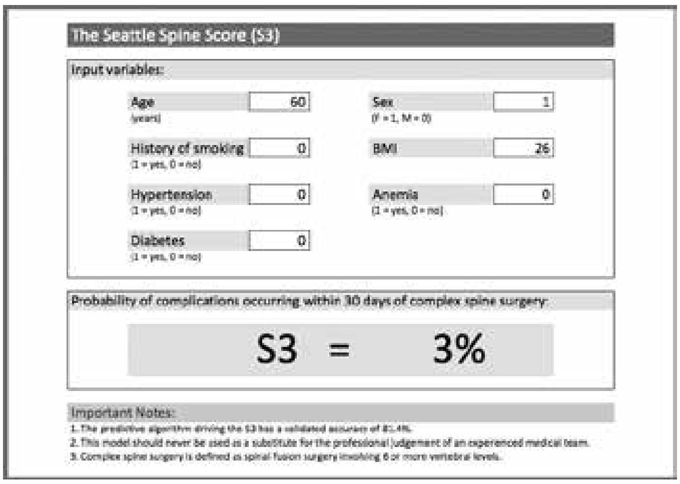
Pre-Meeting Course



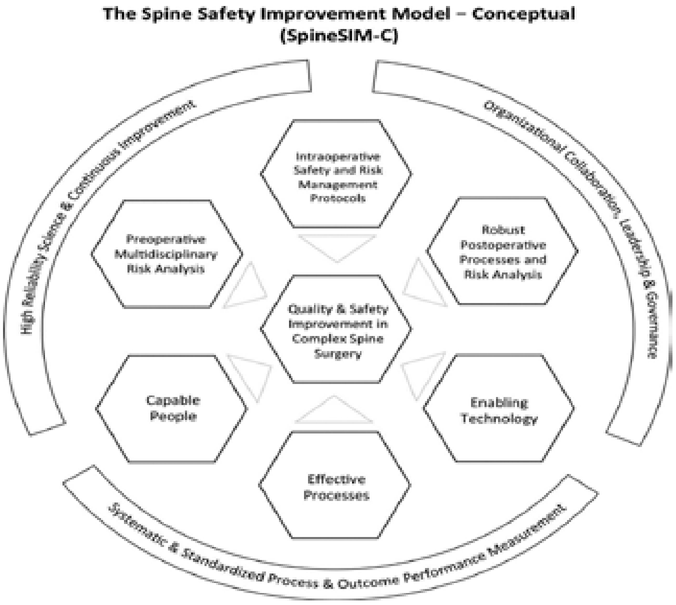
This is an example of enhanced "flow" optimizing position of team members of the complex spine operating room using principles of the Toyota production system.

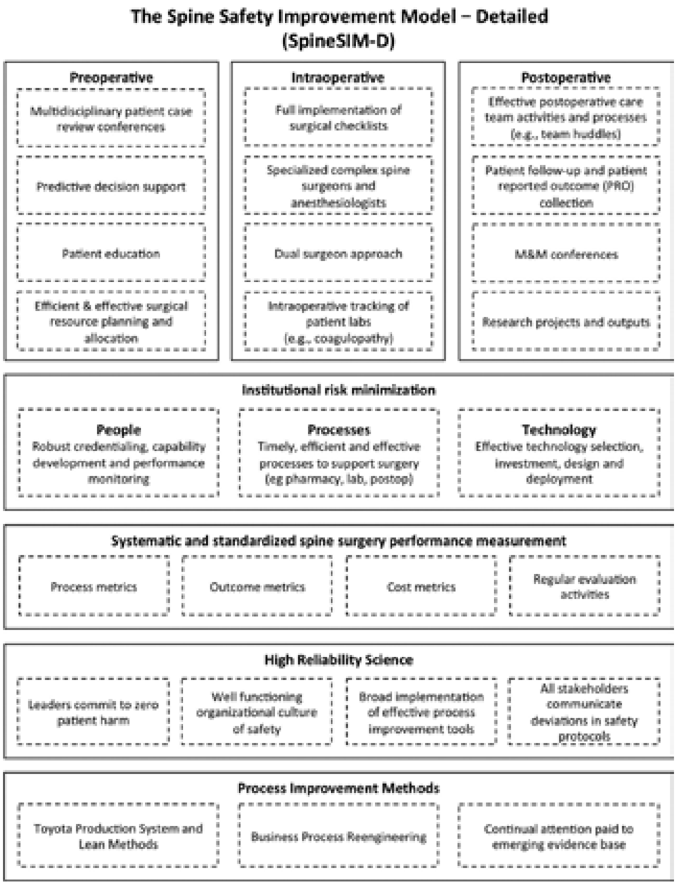






Pre-Meeting Course





Getting Through the Mid-Career Blues

Michael D Daubs, MD
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Department of Orthopaedics
UNLV School of Medicine
Las Vegas, Nevada, USA

Background:
Medical training is long and requires a level of perseverance unlike may professions. The acceptance of delayed satisfaction is inherent in the decision to enter medicine. The multiple steps of training: undergraduate, medical school, residency, and fellowship are each entered with new hope for growth professionally and personally. Some of the hope for increased personal and professional satisfaction is dimmed by the reality of the stress of surgical training. However, there is always hope projected into the next professional phase. “ It will be great when I am in practice !” The young spine surgeon starts practice and indeed it’s another step with both hope and challenge. In five years she has made it through complicated cases, dealt with complications, and is feeling competent professionally. Another three years go by and the competence continues to improve and a hint of professional monotony seeps in and by 10 years it can morph into boredom and dissatisfaction. The ambitious, striving spinal surgeon has no next steps to look forward to. This period can lead professional and personal re-evaluation. “ This is it? This is what I strived for all those years? What now?”

Problem:
- Multifactorial
- Feeling stagnant
- Hopeless
- Lack of new goals
- Nothing new on the horizon
- Loss of self-esteem without striving, struggle
- 40+ something, first glimpse of mortality, first gray hairs, loss of hair (men)

Solutions?
- new car?
- new significant other, spouse?
- new hospital?
- new group?
- new profession?
- new hobby?
- new job?
- **Anything, something to look forward to ! A new horizon!**

Process:
1. Take a deep breath
2. Slow down
3. Don’t dive deeper into work or play
4. Don’t turn to alcohol and drugs
5. Get off the Hedonic treadmill
6. Don’t rush into change
7. Take time for self-evaluation
8. Talk to your spouse, friends, mentors, partners
9. See a therapist, counselor
10. **Take a deep breath! You’re not alone.**

Real Solutions:
- Unique and individual
- Commitment to self-assessment
- Commitment to self-discovery
- Commitment to change
- **Don't be afraid to make changes, small or large.**
- **Be true to yourself and you will find the answer.**

Suggestions:

Professional:
- Consider new roles, at hospital, in group, in organizations
- Expand your surgical skills
- Get an MBA, MPH
- Visit other surgeons, mini-fellowships
- Write a scientific paper for publication
- Take a sabbatical
- Change careers

Personal:
- Include your spouse, significant other in the discussions
- Don't go through it alone
- Consider a therapist
- New hobby
- Classes at University
- Consider returning to interests you put off during training
- Read all the classics
- Art: painting, sculpting, acting, etc

Take home points:
- **We all go through this**
- **It's okay to question your career**
- **You're not alone**
- **Share your thoughts, reach out, don't hide**
- **The answers are unique to each of us, recognizing the issue is the the first step**
- **Dig deep, do some honest self reflection**
- **This too will pass**

Working in a Toxic Environment: Having that Courageous Conversation

Paul T. Rubery MD
Marjorie Strong Wehle Professor and Chair
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Rochester, New York, USA

I. **Goals**:
  1) Surgeon's role as **team leader**
  2) Definition of **toxic workplace**
  3) **Strategies** to employ in difficult conversations
  4) **Details** requiring attention.

II. Leadership Skill: **Emotional Intelligence**
  a. Must <u>Develop 4 capabilities</u> based upon <u>competencies</u>
    i. Self-awareness
      1. Emotional insight
      2. Self-confidence
    ii. Self-management
      1. Self-control
      2. Adaptability
    iii. Social awareness
      1. Empathy
    iv. Social skill
      1. Communication
      2. Conflict management
      3. Teambuilding

III. **Toxic** Workplace
  a. Hostile workplace
    i. Legal term
    ii. Harassment of a protected class
  b. Toxic workplace
    i. Behavior that negatively impacts the work environment or employee morale, which is not based on or directed toward a protected class
  c. Leaders have responsibility to manage the work environment

IV. Difficult **conversations**
  a. Conversations are face to face discussion
  b. Preparation may take longer than conversation
  c. Keys to success
    i. Pause- await opportune moment
    ii. Private and <u>scheduled</u>
    iii. Get the facts straight
    iv. Understand policy and institutional procedures ahead of time
  d. Caveats for USA leaders:
    i. Everything you say or email is admissible in court
    ii. Nothing said in administrative role is "off the record"
    iii. "How would this look as a headline?" test

V. **Practical advice** for difficult conversations
  a. Written agenda
    i. Keeps it moving
    ii. Cover it all
  b. Document discussion and response
  c. Consider a role-appropriate third part presence

Pre-Meeting Course

   d. Follow-up note
      i. Thanks for meeting
      ii. We discussed XXX
      iii. We agreed YYY
      iv. Save in file

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The Benefits of Global Outreach and Philanthropy

Gregory M Mundis Jr., MD
Scripps Clinic Medical Group
San Diego, California, USA

5 Benefits of Philanthropy

1. Give without expecting anything in return
   a. It FEELS great-
      i. It is pure
      ii. Making someone better creates positive energy which feeds your own soul
   b. It results in reciprocal giving
      i. The effect of your gift can be far reaching
      ii. Your impact does not stop with your gift
2. You will build a much broader social network
   a. Benefits are obvious during future travel
   b. You are able to engage your network at local and international society meetings
   c. Openly discussing
3. Learn how to overcome obstacles
   a. Part of philanthropy is contributing financially, however the more important component is the time and energy spent in making your investment bear the most fruit possible
   b. Overcoming obstacles requires you to take chances and to step out of your comfort zone
   c. The result is learning, growing and hopefully celebrating how the obstacles were overcome
4. Education that no classroom can teach
   a. Because philanthropy requires you to engage parts of yourself that don’t get much exercise, the growth that can occur over short periods of time is tremendous
   b. There are few instances in life where on the job training will have a positive direct impact on your employment, managing style, and your ability to lead
5. Thinking outside the box- engaging your creative inner self.
   a. Philanthropy requires you to engage parts of your brain that are not used to getting exercise
   b. Problem solving skills are strengthened

5 Benefits of Global Outreach

1. Build Relationships that would otherwise not occur
   a. Learning to build trusting relationships
   b. Learning to build teams across cultures, specialties and service lines
2. Sharing of knowledge
   a. Teaching in the outreach setting is particularly gratifying
   b. The audience is keenly interested in your expertise
   c. Teaching occurs in the setting of rapid adoption
   d. Being taught new techniques by local surgeons
3. Using your talent in the most altruistic way
   a. Global outreach is the most pure delivery of health care
   b. It is free of financial, commercial or personal bias

4. Stretching your comfort zone
   a. Problem solving to deliver medical care
   b. Using foundational knowledge in the setting of adversity
5. Getting to know yourself all over again
   a. Rediscovering why you chose a career in medicine
   b. Allowing yourself to make medical decisions alongside patients without bias or alternative motivation
   c. Restoring the calling on our profession, to act selflessly for the betterment of our fellow man.

Managing Family Relationships and Work-life Balance

Serena S. Hu, MD
Professor and Vice Chair
Chief, Spine Service
Department of Orthopedic Surgery
And, by courtesy,
Professor of Neurosurgery
Stanford University
Redwood City, California, USA

Overview
- Importance of work-life balance
- Family relationships
- How to achieve balance

Work

Relationships

Health

Balance
- Professional
- Social
- Spiritual
- Financial
- Family
- Physical
- Mental
- Other

Why is it important?
- Quality of life
- Avoiding burnout
- May be associated with success

Characteristics of highly successful orthopedic surgeons (J. Can Chir. Vol 56(3) Jun 2013. Klein, Hussain, Sprague, Mehlman, Dogbey, Bhandari)
- Chairs of ortho departments and subspecialty dept
- Editors of peer review ortho journals
- Presidents of AAOS, AOA, subspecialty societies
- Q'aire developed with ortho focus group, US and Can
  - Motivation
  - Work-life balance
  - Job satisfaction
- 2009 "Great American Physician Survey"
  - 750 MDs, 60% response
- 47 Q's, online, 10 min
- 388 surgeons
- 152 completed 39.2%
- 11 started but did not complete
- Answers submitted were included
- 99% male

- Mean age 55 y (36-77)
  - Trauma (29.9%) Sports (14.3%)
  - Adult knee (20.1%) Pedi (17.5%)
  - Adult hip (18.2%) Pedi spine (12.3%)
  - Total joint (18.2%) Ortho onc (11.7%)
  - Arthroscopy (17.5%) Adult spine (11%)
  - Shoulder (17.5%) Foot/ankle (10.4%)
  - Hand (15.6%)
- Motivation for leadership positions: desire for new challenges
- 94.5% willing to serve another term
- 94.9% happy with subspecialty
- 4.5% would discourage their kid from ortho
- 41.7% "hours too long"
- 40.7% "stress too high"
- Happiness as orthopedic surgeon associated with:
- Sports medicine (p = 0.039)
- Leadership for personal development (p = 0.026)

Quality of Life during orthopedic training and practice (Sargent, Sotile, Sotile, Rubash, Barrack, JBJS 2009)
- 384 ortho residents
- 262 full time ortho faculty
- Questionnaires (Maslach Burnout Inventory, Gen Health Q'aire-12, Revised Dyadic Adjustment Scale)
- Psychological distress:
  - 16% residents
  - 19% faculty
- Faculty: greater levels of stress, greater satisfaction with work and work/life balance
- Factors such as making time for hobbies, limiting EtOH use, correlated with decr dysfunction

Personal choices/examples

Work-Life Balance: Perspective from Europe to America

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Work-Life Balance definition (OECD):
- Percentage of employees working very long hours (more than 50 hours a week)
- The employment rate for women with children
- The time spent on "leisure and personal care" (including sleeping.)

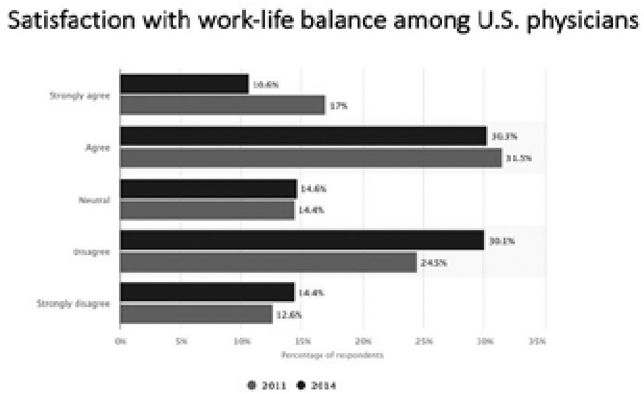
Physicians work time
- Patient contact
- Administrative duties
- Charting
- Teaching
- Meeting
- Research

Life time
- Sleep
- Nutrition
- Exercise
- Spiritual pursuits
- Social interaction

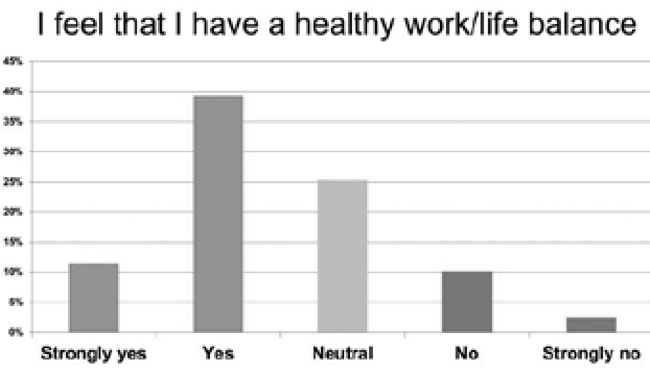
Grey-zone and dilemma
- Work time can easily creep into life time with mobile technology
- Is a career in medicine compatible with work-life balance?

Work-Life Balance - the Danish way

- Flexibility at work
- Working from home
- Minimum 5 week's paid holiday for all wage earners
- Maternity leave
- Childcare facilities



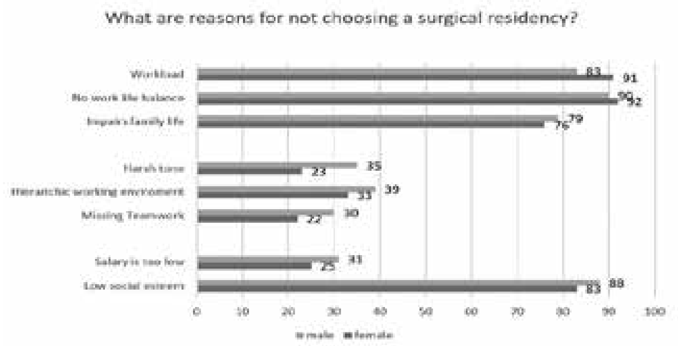
Work-Life Balance at Texas Children's Hospital



If no; please describe what prevents you from achieving a healthy work-life balance and what the department could do to help:

- Burned out
- Clinical load
- Academic obligations mostly done off hours
- Not enough dedicated non-clinical time to achieve balance
- Epic, charting, and e-mail after hours
- System inefficiencies
- Less control over schedules
- RVU pressures

Work-Life Balance for future European surgeons



Conclusion

A comparison of work-life balance between European and US surgeons cannot be done without taking various societal, political and health-economic aspects into consideration. Although there are few studies focusing on spine surgery, there is evidence that work-life balance will be an increasingly relevant variable in the future recruitment of surgeons.

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Hobbies and Passions: How to Really Relax After Work

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1. **Relationship of Leisure Activity to Burnout:**
    a. In studies evaluating physicians showing reliance, three consistent major domains have been identified:
        i. **Attitudes and perspectives** - valuing the physician role, maintaining interest, developing self-awareness, and accepting personal limitations.
        ii. **Balance and prioritization** - setting limits, taking effective approaches to continuing professional development, and honoring the self, practice management style, which includes sound business management, having good staff, and using effective practice arrangement - ***having some control over schedule and hours worked was the strongest predictor of work–life balance and burnout.***
        iii. **supportive relations** - personal relationships, effective professional relationships, and good communication

Resilience Strategies and Their Frequency According to Discipline as Reported in 200 Semistructured Interviews With German Physicians, 2010–2011

	Theme	Whole sample (n = 200)	General practitioners (n = 51)	Psychiatrists (n = 38)	Surgeons (n = 45)	Other disciplines (n = 66)
Job-related sources of gratification						
1	Gratification from doctor–patient relationship	134 (67)	38 (75)	28 (74)	19 (42)	49 (74)
2	Gratification from medical efficacy	118 (59)	16 (31)	17 (45)	39 (87)	44 (67)
Resilience strategies 1: Practices and routines						
3	Leisure-time activity	158 (79)	42 (82)	33 (88)	31 (69)	52 (79)
4	Quest for and cultivation of contact with colleagues	110 (55)	26 (51)	26 (69)	27 (60)	31 (47)
5	Cultivation of relations with family and friends	102 (51)	25 (49)	25 (66)	27 (60)	25 (38)
6	Proactive engagement with the limits of one's own skills, complications that crop up and treatment errors when communicating with colleagues and disciplinarians	88 (44)	20 (39)	16 (42)	16 (36)	36 (55)
7	Proactive engagement with the limits of one's own skills, complications that crop up and treatment errors when communicating with patients	80 (40)	19 (37)	6 (16)	20 (44)	37 (56)
8	Personal reflection and goal setting	80 (40)	23 (45)	13 (34)	21 (47)	23 (35)
9	Self-demarcation with patients	80 (40)	28 (54)	16 (42)	14 (31)	22 (33)
10	Talking about job-related stress with private relations	76 (38)	17 (33)	12 (32)	9 (20)	38 (58)
11	Self-organization with bureaucracy and regular chores	72 (36)	21 (41)	16 (42)	14 (31)	21 (32)
12	Self-demarcation with colleagues and disciplinarians	68 (34)	8 (16)	22 (58)	19 (42)	19 (29)
13	Cultivation of one's own professionalism	64 (32)	19 (38)	18 (47)	12 (27)	15 (23)
14	Limitation of working hours	62 (31)	13 (25)	14 (37)	14 (31)	21 (32)
15	Error management	54 (27)	13 (25)	5 (13)	10 (22)	26 (39)
16	Ritualized time-out periods	52 (26)	18 (35)	9 (24)	7 (16)	18 (27)
17	Institutionalized exchange forums (i.e., quality circles or Balint groups)	40 (20)	20 (40)	9 (24)	2 (4)	9 (14)
18	Supervision, coaching, psychotherapy	30 (15)	9 (18)	9 (24)	6 (13)	6 (9)
19	Long-time, nonprofessional fields of interest	28 (14)	14 (27)	3 (8)	3 (7)	8 (12)
20	Self-discipline in connection with diagnosis and information	24 (12)	5 (10)	4 (11)	3 (7)	12 (18)
21	Prioritization of basic needs	24 (12)	4 (8)	2 (5)	10 (22)	8 (12)
22	Spirituality	18 (9)	5 (10)	8 (21)	3 (7)	2 (3)
Resilience strategies 2: Useful attitudes						
23	Acceptance and realism	112 (56)	28 (55)	25 (66)	20 (44)	39 (59)
24	Self-awareness and reflexivity	106 (53)	44 (86)	12 (32)	22 (49)	28 (42)
25	Active engagement with the downside(s) of the medical profession	94 (47)	32 (63)	21 (55)	17 (37)	24 (36)
26	Accepting personal boundaries	88 (44)	34 (67)	21 (55)	9 (20)	24 (36)
27	Recognizing when change is necessary	66 (33)	13 (25)	21 (55)	13 (29)	19 (29)
28	Creating inner distance by taking an observer perspective	48 (24)	8 (16)	9 (24)	18 (40)	13 (20)
29	Appreciating the good things	48 (24)	18 (35)	11 (29)	10 (22)	9 (14)
30	Interest in the person behind the symptom	36 (18)	10 (19)	6 (15)	9 (20)	11 (17)

From : If Every Fifth Physician Is Affected by Burnout, What About the Other Four? Resilience Strategies of Experienced Physicians. Julika Zwack, PhD, and Jochen Schweitzer, PhD Academic Medicine, Vol. 88, No. 3 / March 2013

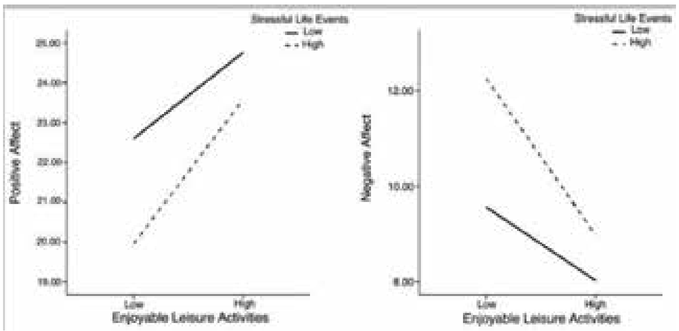
The major areas where physicians across specialties can keep their enthusiasm high comes in two areas – work related and resilience practices.

    a. Work Related:
        i. Gratification from the doctor–patient relationship.
        ii. Gratification from medical efficacy (the thrill of the work itself – diagnosis or treatment)
    b. Resilience practices:
        i. Leisure-time activity to reduce stress.
            1. Sporting activity was mostly an immediate way of reducing tension and facilitated a change of mental focus
            2. Participants engaged in cultural matters (music, literature, art) to extend horizons and put professional concerns into perspective. Cultural activities were also a rich source of aesthetic pleasure and harmony
            3. For some respondents, compensatory activity transcended the limits of a mere hobby. These individuals reported that long-time nonprofessional fields of interest provided a "second leg to stand on" (gynecologist, 53) and frequently called for the investment of substantial time resources.
            4. Through the experiences of success that they enabled, compensatory activities contributed much to participants' feelings of inner freedom. Respondents did not simply pursue hobbies when they had time to do so. Rather, they made sure to find the time they needed to pursue the hobbies that were important to them.

2. **Even Leisure has its academics:**
    a. Taxonomy
        i. Casual Leisure
        ii. Serious Leisure
            1. Amateurs - engage in pursuits that have a professional counterpart, such as playing an instrument or astronomy
            2. Hobbyists
                a. Collecting
                b. making and tinkering (like embroidery and car restoration)
                c. activity participation (like fishing and singing)
                d. sports and games,
                e. liberal-arts hobbies (like languages, cuisine, literature)
            3. Volunteers - commit to organizations where they work as guides, counsellors, gardeners and so on
        iii. Even among elite athletes, strategic down time improves performance. Sperlich G, Stoggl TL. The training intensity distribution among well-trained and elite endurance athletes Front Physiol. 2015; 6: 295. 2015 Oct 27. Periods of high intensity interposed with rest provide optimum performance.
3. **Leisure is associated with much more than work related benefits:**
    Individuals who engaged in more frequent enjoyable leisure activities had better psychological and physical functioning. They reported greater PA, life satisfaction, life engagement, social support as well as lower depression and NA; they had lower blood pressure, cortisol AUC, BMI, WC, and better

perceived physical function, even after adjusting for the standard demographic variables. Pressman, S. D., Matthews, K. A., Cohen, S., Martire, L. M., Scheier, M., Baum, A., & Schulz, R. (2009). Association of Enjoyable Leisure Activities With Psychological and Physical Well-Being. Psychosomatic *Medicine, 71(7), 725–732. http://doi.org/10.1097/PSY.0b013e3181ad7978*

It also buffers against the highs and lows of life*:*



Pre-Meeting Course

Achieving Excellence in the Management of Severe Pediatric Spinal Deformity

Room: Hall 19

Course Chairs:
Patrick J. Cahill, MD and Burt Yaszay, MD

Faculty:
Kenneth MC Cheung, MD, FRCS; Brice Ilharreborde, MD, PhD; Noriaki Kawakami, MD, DMSc; Lawrence G. Lenke, MD; Gregory M. Mundis Jr., MD; Peter O. Newton, MD; Jean Ouellet, MD, FRSC; Joshua M. Pahys, MD; Stefan Parent, MD, PhD; Amer F. Samdani, MD; James O. Sanders, MD; Harry L. Shufflebarger, MD; Paul D. Sponseller, MD; Muharrem Yazici, MD

Achieving Excellence in the Management of Severe Pediatric Spinal Deformity

Chairs: Patrick J. Cahill, MD and Burt Yaszay, MD

Part I: Understanding the Development of Severe Scoliosis

Moderators: Patrick J. Cahill, MD and Burt Yaszay, MD

15:00-15:10 **Quantification of Growth in the Early Years**
James O. Sanders, MD

15:10-15:20 **Understanding and Quantifying Peri-pubertal Growth**
James O. Sanders, MD

15:20-15:28 **Looking at Growth in 3D**
Stefan Parent, MD, PhD

15:28-15:38 **Discussion**

Part II: Prevention of Severe Scoliosis

Moderators: Patrick J. Cahill, MD and Burt Yaszay, MD

15:39-15:47 **Early Intervention – Casting/Bracing**
Noriaki Kawakami, MD, DMSc

15:47-15:55 **Distraction Based**
Kenneth MC Cheung, MD, FRCS

15:55-16:03 **Growth Guidance**
Jean Ouellet, MD, FRSC

16:03-16:11 **Tether**
Patrick J. Cahill, MD

16:11-16:21 **Discussion**

Part III: Treatment of Severe Scoliosis: Avoiding the VCR

Moderators: Amer F. Samdani, MD and Suken A Shah, MD

16:22-16:32 **Anterior Surgery**
Peter O. Newton, MD

16:32-16:42 **Skeletal Traction/Internal Distraction**
Joshua M. Pahys, MD

16:42-16:52 **Posterior Releases (including asymmetric resection/post. discectomy)**
Harry L. Shufflebarger, MD

16:52-17:02 **Discussion**

Part IV: Treatment of Severe Scoliosis: Performing the VCR

Moderators: Amer F. Samdani, MD and Suken A Shah, MD

17:03-17:13 **Surgical Technique**
Lawrence G. Lenke, MD

17:13-17:21 **Preop Construct Planning**
Brice Ilharreborde, MD, PhD

17:21-17:29 **Preop Optimization**
Gregory M. Mundis, Jr., MD

17:29-17:39 **Discussion**

Part V: Case Based Discussions

Moderators: Patrick J. Cahill, MD and Burt Yaszay, MD
Panelists: *Lawrence G. Lenke, MD; Amer F Samdani, MD; Paul D. Sponseller, MD; Muharrem Yazici, MD*

17:40-17:45 **Case 1 – Cervical-Thoracic Congenital Scoliosis**

17:45-17:50 **Case 2 – Neuromonitoring Loss – Apical Pedicle Screw Insertion**

17:50-17:55 **Case 3 – Severe Scoliosis → Anterior Release**

17:55-18:00 **Case 4 – Delayed Onset of Neurologic Deficit**

Understanding and Quantifying Childhood and Peri-pubertal Growth:

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Dept. of Orthopedics
University of Rochester
Rochester, New York, USA

Humans grow differently than other animals:
1. Human's large brains require a large maternal pelvic canal
2. Humans have a prolonged period of relatively slow growth before reaching sexual maturity.
3. The adolescent growth spurt is unique among animals

Early Growth (Infancy to age 3):
1. Children are within a relatively narrow range of size and weight at birth. They must be of sufficient size to pass through the mother's birth canal without mishap to either the child or the mother.
2. The periods after birth is associated with very rapid growth but decelerating growth until about age 3.
3. Their skulls continue to grow rapidly to accommodate the growing brain.
4. Infants are susceptible to growth stunting from malnutrition or illness
   a. If they recover sufficiently, they will undergo catch-up growth
   b. They will tend to resume their prior percentile of height
   c. Prolonged illness can prevent full catch-up growth
5. Skeletal maturity is not a good determinant of growth at this stage.

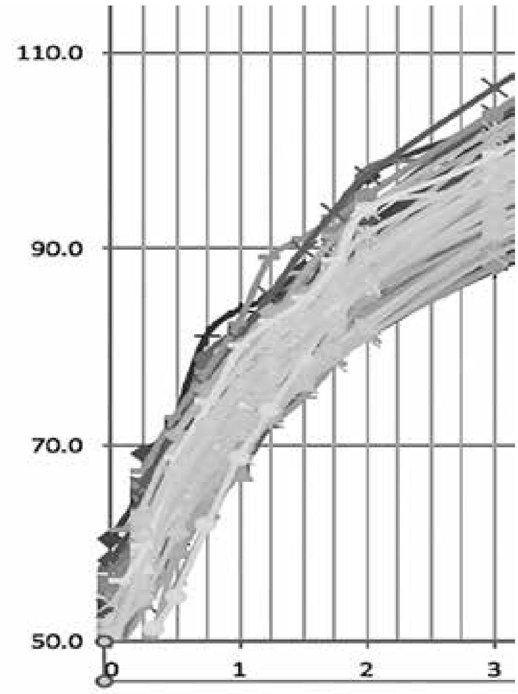


Figure 1 Height vs age in children ages 1-3

Childhood Growth (age 3 – preadolescence):
1. This phase continues until the adolescent growth spurt.
2. Children of taller parents tend to be taller during this stage.
3. By age 3, children hit a steady state of growth characterized by following a specific percentile of growth – termed canalization.
4. Growth is nearly linear during this phase.
5. Skull growth slows significantly.
6. Skeletal maturity is linked, but not tightly, to the amount of growth remaining.
7. Boys continue in this phase for two years longer than girls which accounts for the difference in final stature between boys and girls.
8. Like infants, children are susceptible to growth stunting from malnutrition or illness.
   a. If they recover sufficiently, they will undergo catch-up growth
   b. They will tend to resume their prior percentile of height
   c. Prolonged illness can prevent full catch-up growth
9. There are some smaller spurts during this phase, but they are generally not significant in the overall pattern of growth or its prediction.

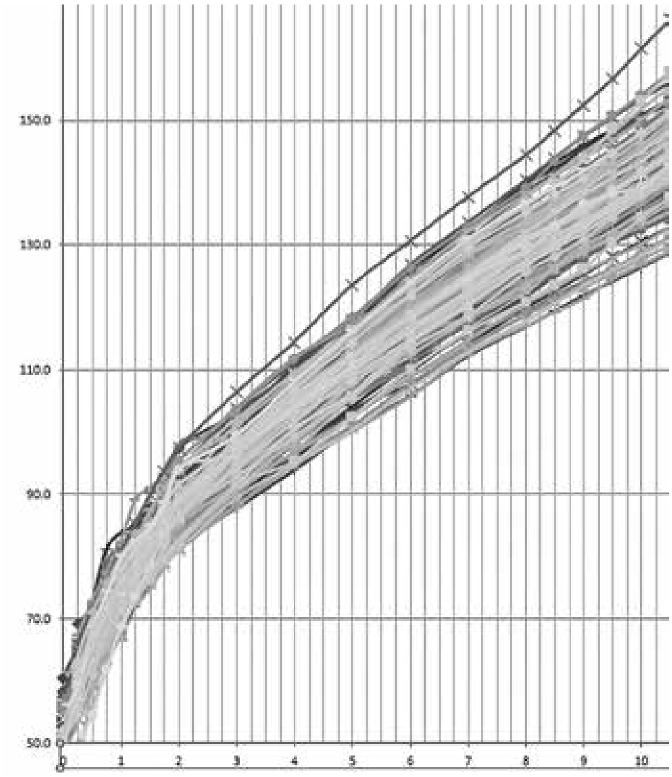


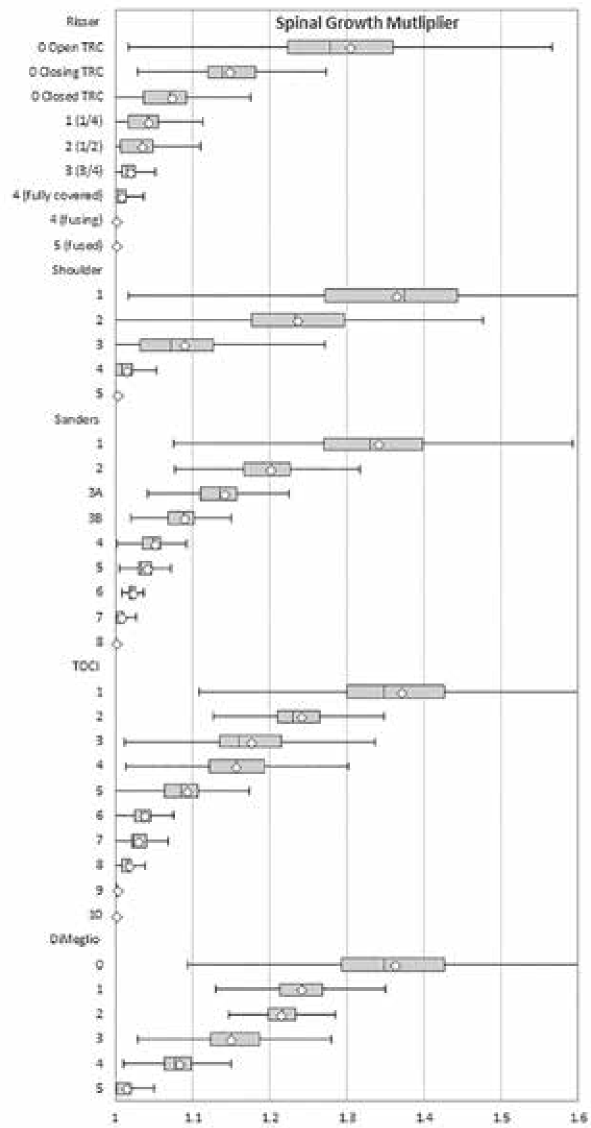
Figure 2 Height gain in children up to age 10 showing relatively linear growth ages 3-10

Adolescent Growth (~2yrs before peak height velocity to growth completion)
1. The growth spurt is initiated by pulsatile release of GHRH
2. For both sexes, this stimulates estrogen production which directly stimulates longitudinal physeal growth.
3. In girls, this is expressed by early breast development and in both sexes by rapid growth seen in the hands and feet.
4. Children will gain their final 15% of height during this last phase.
5. Their rate of overall height growth reaches its maximum rate at 90% of final height and is known as the peak height velocity (PHV).

6. From the PHV, growth begins to slow until it is negligible at 4yrs after the PHV.
7. The pattern of growth when normalized for final adult height is identical for boys and girls during this phase.
8. Skeletal maturity becomes highly reflective of the amount of growth remaining during this phase.
9. The skull has negligible growth during adolescence.
10. The extremities undergo their growth spurt ahead of the overall height peak and have completed 91.3% of their adult length.
11. The extremities grow until 2.5 years after the PHV.
12. The spine is at 85% of its final height at the PHV.
13. Menarche occurs after the PHV, averaging 1year but having a significant standard deviations.

Predication of Future Growth:

1. Several models of growth have developed. The most useful have been either linear models such as the White and Menelaus for the extremities and the DiMeglio and Winter values for the spine, or multiplier models popularized by Paley, et al.
2. Linear growth models:
   a. Winter estimated spinal growth at 0.7mm/segment/year
   b. DiMeglio's identified rates of 1.2cm/year T1-S1 between ages 5-10 and 1.8cm/year between ages 10 and skeletal maturity.
   c. While reasonably accurate per year, linear models do not determine growth completion and final length.
   d. The models have limited information on the adolescent growth spurt.
3. Multiplier model:
   a. Multipliers were initially described by Bailey in her evaluation of children's growth. It was not frequently referenced or used.
   b. The method was further elucidated by Paley et al who extended it to use with height, upper extremity, foot, and hand growth estimations.
   c. In the multiplier, a child's future growth to maturity is determined by the growth they have currently attainted. If a child has completed 75% of their final growth, then multiplying their current length by 1/75% or 1.33 will give their final length.
   d. E.g.:
      i. Assume a child's spine is 20cm in length
      ii. You identify a multiplier of 1.33,
      iii. Final spinal length will be 20x1.33=26.7cm
   e. The multiplier identifies the ultimate length but does not inform about the growth rate per year.
   f. Multipliers, originally described by Paley based upon chronological age, can be based on any maturity measure.
   g. The method can be applied to any dimension for which multipliers are identified
4. Creating accurate models of future growth, both rate and total growth remaining
   a. Creating this data is a challenge because it requires a longitudinal study of spine, height, or extremity lengths.
   b. This type of longitudinal study does not explicitly exist for spinal dimensions.
   c. We have extrapolated data from radiographic-anthropometric correlations in a study focusing on the anthropometrics but also obtained skeletal radiographs (Bolton-Brush).
   d. With this type of data, we can identify both growth rates and final lengths.
5. From the growth curves of the Bolton-Brush collection, we identified multipliers of height, spine, and extremities.
6. Because these are tightly correlated with skeletal maturity, we have also identified the multipliers relative to skeletal maturity.
7. The spinal growth mutlipliers relative to PHV (PGA90%), and skeletal maturity of the pelvis, hand, elbow, and shoulder are shown below.



Figures 3 and 4: Timing relative to PHV for various maturity measures and their multipliers

Maturity Determination:

1. In childhood, sex, percentile of height, and chronological age appear to be the main determinants of ultimate growth. Skeletal maturity is not tightly related to growth but may be a harbinger for when growth will accelerate with the adolescent growth spurt.
2. During adolescence, skeletal maturity becomes closely correlated with growth remaining and becomes a reliable guide. Other markers such as secondary sexual characteristics (Tanner stages) or growth markers (type X collagen breakdown markers) are either not reasonable for most orthopaedic practices (Tanner stages) or require further study (type X collagen).

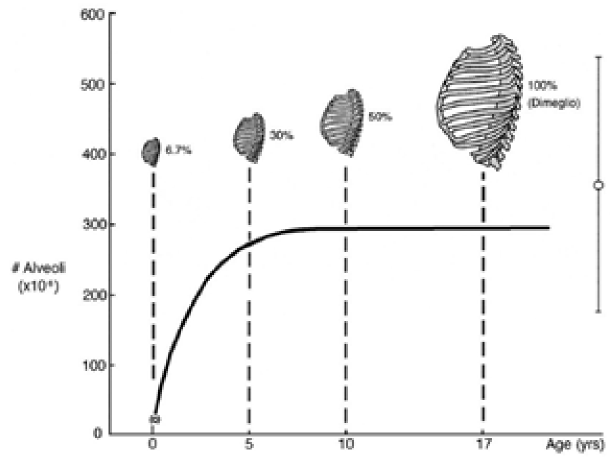
Sagittal alignment changes:

Children all start with a general kyphosis at birth with development of cervical lordosis when they gain head control. Lumbar lordosis begins to develop with sitting and further develops with standing such that the eyes remain able to look agead. While several recent studies have evaluated sagittal alignment changes with growth, they are limited in scope. In general, there is an increase in thoracic kyphosis, lumbar lordosis, and pelvic incidence with growth.

Chest and lung volume changes:

Despite its importance for early onset scoliosis and overall spinal deformity assessment and treatment, there is very little information available on thoracic and lung volume growth over time. There appears to be a differential growth between the upper and lower thoracic spine.

A large amount of volume increase occurs during the adolescent growth spurt which appears very important for ultimate pulmonary function.



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Most of the information in this handout is prepublication. Helpful published references include:

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Looking at Growth in 3D

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Introduction and Background

Normal vertebral growth is the result of a complex interaction between more130 functioning growth plates that work together to allow for 3D growth of the spine, as well as for the development of the thoracic cage and the lungs [1,2]. It is a complex process involving succession of acceleration and deceleration phases. Knowledge of normal growth parameters is mandatory to understand the pathologic modifications induced on a growing spine by an early onset spinal deformity [1,2]. Spinal growth abnormalities result in a significant reduction of thoracic and lung volume [1,2,3,4], which may lead to thoracic insufficiency syndrome [5]. Left untreated, this condition may eventually lead to *cor pulmonale* and death [1,2].

Idiopathic scoliosis is the most common form of scoliosis and affects 2-4% of children and adolescents. As adolescent idiopathic scoliosis (AIS) is a deformity affecting youth (>10 y.o.), juvenile idiopathic scoliosis (JIS) is a subset of scoliosis characterized by early onset at an age below 10 years. The risk of progression of scoliosis is related to both the magnitude of the spinal curvature and to the remaining growth of the child. As a result, JIS patients are at greater risk for developing severe deformities.

The treatment of early onset scoliosis is critical to enhance quality of life, to prevent complications and to permit normal thoracic and lung development. The choice of corrective treatment depends on the severity of the curve. Non-operative treatment by casting and/or braces can be used for patients with progressive JIS greater than 25°. When the curve exceeds 40-50°, surgical treatment is often indicated. For several years, the traditional surgical treatment has been spinal fusion, a definitive procedure in which vertebrae are fused together by arthrodesis. Unfortunately, this treatment was at the expense of any remaining spine growth within the fused regions and, when performed before the end of growth, spinal fusion resulted in a shortened trunk with impaired thoracic development and subsequent pulmonary hypoplasia. More recently, "growth friendly" treatments have been developed that not only prevent further scoliosis progression, but are critical to permit normal spine, thoracic and lung development. These techniques include expandable rods that stabilize the scoliosis, yet allow for continued growth. A thorough knowledge of 3D thoracospinal growth is essential to the understanding of the best timing for these interventions, for determining the extend of required induced growth modulation and operative strategies, as well as for assessing the success of these interventions.

What do we know about normal spine growth?

The vertebrae form from the primitive neural axis during embryological spine formation. The mesoderm will form into paired somites around the notochord (which itself will develop into the nucleus pulposus). The somites will give rise to the sclerotomes

Half-Day Course

with the ventral portion becoming the vertebra and the dorsal portion becoming the neural arch. These will in turn give rise to several ossification centers and also provide ossification centers for the ribs. As the spine grows, ossification occurs, and these ossification centers will eventually fuse. The spine grows more rapidly than the neural elements explaining the position of the cord at birth compared to early gestation. At birth, the cord is usually in its mature position and ends around L1-L2.

Longitudinal bone growth occurs through endochondral ossification and intramembranous bone growth occurs in flat bones such as the skull. Long bones respond to different stresses and stimuli. The Hueter-Volkman law states that bone growth is retarded by increased mechanical compression and is accelerated by reduced loading. Wolf's law states that bone will adapt to loads it experiences (more load increases bone density). Longitudinal bone growth results from endochondral ossification i.e. synthesis of cartilaginous structure with secondary ossification. The physis (growth plate) is the location of this activity and is subject to hormonal variations and loads. Longitudinal bone growth usually stops at the end of adolescence with closure of the physis. Early during formation a fetal hyaline model develops for long bones. Cartilage then starts calcifying giving rise to primary ossification center forms in diaphysis and secondary ossification centers form in epiphysis. Towards the end of growth, ossification of the physis occurs and and bone growth stops

The vertebra does not have a formal growth plate but rather a growing cartilage. This growing cartilage is located at the junction between disk and vertebral body. The ring apophysis will appear during growth and progressively ossify until it unites with the body at the end of growth.

Some studies have attempted to partially fulfill the goal of understanding normal vertebral growth, but it has never been achieved in a detailed, precise and reliable way [6-10]. Using one dimensional coronal plane radiographs, Dimeglio et al. has published sparse data on expected total spine height change during growth but no data at the individual vertebral level or thorax. According to their data, the growth of the thoracic spine is 1.3 cm/year between birth and 5 years of age, 0.7 cm/year between the ages of 5 and 10 years and 1.1 cm/year throughout puberty [1,2]. This one-dimensional data has long been the gold standard for the measurement of spine growth. As current 3D reference spinal dimensions and growth curves for the pediatric spine did not exist, current prescriptions for growth-friendly scoliosis surgeries are made with limited knowledge of the normative growth of the immature spine.

Recently, clinicians have had access to an innovative biplanar imaging technology that utilizes two orthogonal beams of X-rays directed towards a particle detector (Charpak 1992; Nobel prize), intersecting to create two simultaneous linked orthogonal images of an object (in this case, the full length of the spine of a patient), one postero-anterior (PA) and one lateral (LAT). This technique significantly decreases radiation exposure: 8 to 10 times that of conventional X-rays and 800-1000 times that of CT-scan. The digital images can then be imported in a software to create an accurate full-length 3D reconstruction of the spine. This technology allows for low radiation acquisition of cross-sectional and longitudinal data for this comprehensive 3D reference data set of spine growth in normal spines.

In an effort to characterize spine growth in all three dimensions, our research group has developed and validated custom software for precisely measuring the spine throughout multiple dimensions. This includes sagittal spine length (SSL) and 3D true spine length (3D-TSL). A recent multicenter effort has provided the data for longitudinal spine growth to provide reference values for 3D spine dimensions in healthy children and to measure 3D True Spinal Length (3D TSL) and Vertebral body heights as a function of age. This data was then used to estimate centile curves for 3D TSL as a function of age and to calculate growth rate (changes in 3D TSL per month) in the selected age categories.

Methods

This was a multicenter retrospective and prospective observational study. Over 345 subjects using the 3D-TSL method with biplanar 3D imaging to evaluate normal spine dimensions in healthy individuals. Precise reference values were derived for spinal dimensions in healthy children and spinal dimension charts showed that the 3D-TSL changed relatively constantly across the age groups closely resembling World Health Organization total body height charts.

i. Participants – We have studied healthy children aged 3 to 11 y.o. who have undergone high-quality radiologic examinations of the full spine with biplanar 3D imaging. Eligible participants were identified (both retrospectively and prospectively) from radiology databases in the participating centers between biplanar 3D imaging setup date and July 2017. Spine examinations performed in various contexts such as, but not limited to asthma, back pain, ruling out spinal deformity, appendicitis or trauma were retrieved. Patients with a single examination (cross-sectional length/height measurements) and with at least 3 visits (longitudinal growth rate) were included. Exclusion criteria include: presence of spinal deformity>10° or spinal dysplasia, thoracic kyphosis>50°, previous spine surgery, known disease affecting growth or regular use of steroids.

3D indices selected for clinical relevance and reliability on the basis of a surgeons' survey, were computed for further analysis: 3D True Spine Length (sum of the 3-D distances between centers of each vertebral endplate, from the superior endplate of T1, to the superior endplate S1), T1-L5 linear length (linear distance between the 3D coordinates of the centers of the superior endplate of T1, and the superior endplate S1), kyphosis (angle between the superior endplate of T1 and the inferior endplate of T12, on sagittal view), lordosis (angle between the superior endplate of L1 and the superior endplate of S1, on sagittal view). In addition, vertebral body height at each thoracic and lumbar level were computed as well as vertebral unit height, as defined by the 3D length between the inferior vertebral plate of the inferior vertebra and the superior vertebral plate of the superior vertebra, including the intervertebral disk, from the anterior, posterior and midline coordinates of the vertebra. Case report forms were completed for each subject with data retrieved from medical records: date of birth, sex, date of radiologic examination, diagnosis, and if available, weight and height at time of examination, and maturity parameters (menarche status and bone age). In accordance to previously reported inflexion points on the changes in spinal lengths curves, cut-points were chosen in order to report growth estimation for the following age subgroups: 3-5.9, 6-7.9, 8-10.9. Growth rate were calculated from as the ratio of the difference in the indices values (e.g. 3D-TSL) to the time elapsed between the visits, in mm/month.

Centiles were estimated from computed indices as a function of age. The Box-Cox-power-exponential (BCPE) method, with curve smoothing by cubic splines, was selected as the approach for constructing the child growth reference centile curves as implemented in the GAMLSS software (available from *R* library) [11] Deviance, Q-tests and worm plots were examined for goodness of fit and model appropriateness.

Results

Figure 1 illustrates mean vertebral body heights (mid-vertebra) computed for thoracic and lumbar vertebral levels. Colors identify the selected age groups. Figure 2 presents the centile curves (5th, 10th, 25th, 50th, 75th, 90th, 95th) as a function of age for the 3D True Spine Length (T1-S1). On longitudinal data, mean growth rates were: 3-5.9 yo: 1.16mm ±0.55mm; 6-7.9 yo: 1.15mm ±0.44mm; 8-10.9 yo: 1.29mm ±0.86mm.

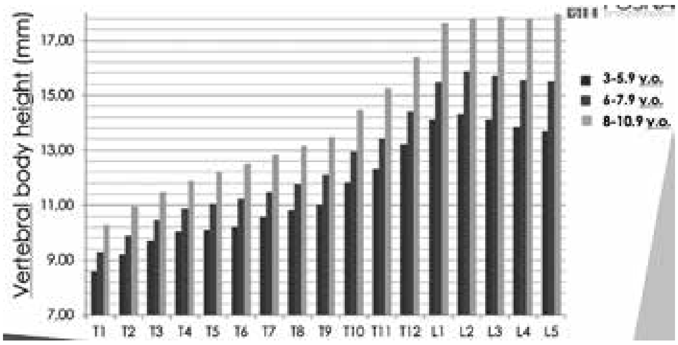

Figure 1. Mean vertebral body heights (mm).

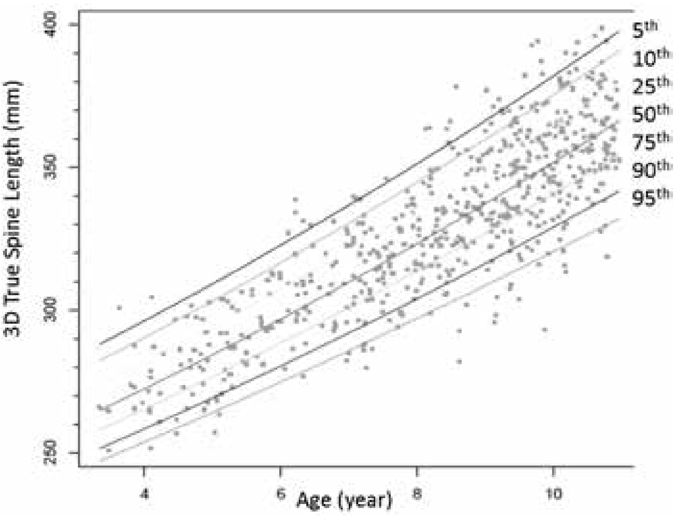

Figure 2. Centile curves for 3D True Spine Length (mm) as a function of age.

Conclusions

Recent data provides valid and reliable reference values for 3D spinal dimensions and growth parameters in healthy children. The obtained detailed and accurate reference values will help physicians better assess their patients' growth potential. It could also be used to predict expected spinal and rib cage dimensions at maturity or changes in pathologic conditions as well as to assess the impact of growth friendly interventions.

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Early Intervention - Casting /Bracing

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Background

- Cast/brace treatment may prevent growth of thoracic cage and respiratory function
  Noble-Jamieson CM et al. 1986, Priftis KN et al. 2003, Sevastikoglou JA et al. 1976

→Gaining popularity of Growth-friendly operations
→Higher rate of periop. complications, esp. for the very immature pts.
→Return of the Cast to "buy more time"
Mehta MH. 2005, Sanders JO et al. 2009

Reports of Serial Cast Treatment

- Mehta MH (2005): Growth as a corrective force in the early treatment of progressive infantile scoliosis. J Bone Joint Surg Br 2005;87(9):1237-1247.
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- Iorio J, et al (2017). Serial Casting for Infantile Idiopathic Scoliosis: Radiographic Outcomes and Factors Associated With Response to Treatment. J Pediatr Orthop 2017;37(5):311-316.

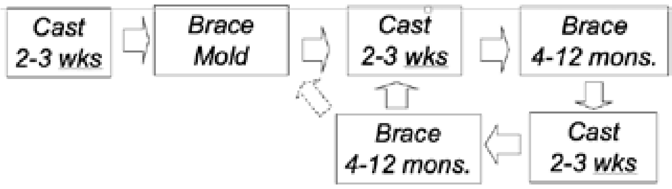
All cast placement are performed under genital anesthesia.

Anesthetic Toxicity in Children

FDA Drug Safety Communication: FDA review results in new warnings about using general anesthetics and sedation drugs in young children and pregnant women. 12-14-2016

The Timing and Duration of Casting

- Mehta MH (2005) Intervals of Jacket-change
  - ≤2 yrs 8-10 weeks
  - >2 yrs. 12-16 weeks
- Sanders JO (2009) Cast changes based on age:
  - ≤2 yrs 2 months
  - 3yrs 3 months
  - ≥4yrs 4 months
- Kawakami N. (2015) Alternatively repetitive cast/brace (ARCB) treatment



The effect of Serial cast placement

- Sanders JO et al. J Pediatr Orthop 2009;29:581–587
  - Serial cast correction for IS
  ⇒Full correction in infants with idiopathic curves ≤ 60°if started ≤ 20 months of age.
  - Older pts. with larger curves or non-IS
  ⇒Curve improvement with improvement in chest and body shape.
- Iorio J, et al. J Pediatr Orthop 2017;37(5):311-316.
  - 2.38 increase in the chance of Improvement for each unit increase of BMI.
  - Amount of correction at initial casting not confirm treatment success.
  - age ≦1.8 years at 1 s t casting to correct RVAD <20 degrees.

Factors Related with Response to Treatment

- Age at the 1st cast placement
- Diagnosis
- Phenotype
- BMI
- Curve magnitude
- RVAD (precast and postcast)

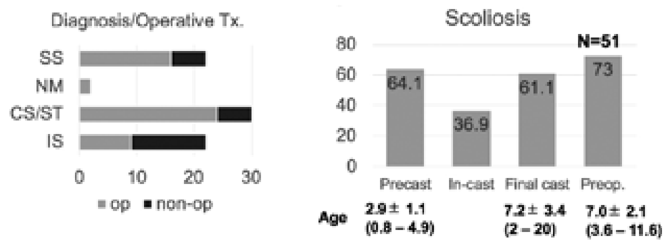
Mehta (2005), Sanders (2009), Iorio (2017)

Scoliosis Magnitude in Each Report

	Age at initial casting	Scoliosis at precasting	Scoliosis in a cast	Number of casting/FU years	Scoliosis after final cast	Scoliosis at final FU
Sanders (2009)	2.2 (7-64 months)	51 (25-100)				
Flecher (2012)	4.4 ± 2.1 years	**68.8** ± 12.3	39.1 ± 16.4	3.0 ± 1.8 /1.4 ± 1.1 years	60.9 ± 18.4	76.3 ± 24.0
Waldron (2013)	3.8 ± 2.3 years	**74** ± 18 (40-118)	48 ± 14 (25-75)	4.7 ± 2.2 /16.9 ± 9.1 months	51.0±12 (35-70)	53 ± 28 (GR 7 pts)
Demirkiran (2015): CS	39.5 ± 23 months	**70.7**±14.4 (44-88)	54.4 ± 14.7 (22-72)	6.2 (3-10)		55.1 ± 17.2 (16-78)
Hassanzadeh (2017)	18.8 ± 9.5 months	**52.7**		6.9 (2-16)		
Iorio (2017) IIS	2.1 (0.7-5.4) years	**48 (24-72)**		6.9 (2-16)		Group 1: 21 (0-61) Group 2 : 56 (33-82)

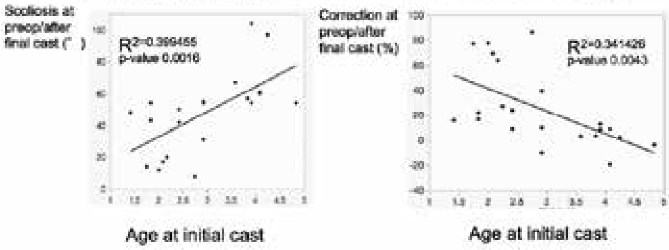
Radiographic Outcome of Presenter's Series

- N=76 (Age at initial casting≦4, Scoliosis≦50°, Min. FU 2 yrs.)



Early Cast Placement Leads Better Correction in IIS

	CS/ST	IS	NM	SS	p value
Age at initial cast	2.7 ± 1.1	2.9 ± 1.0	4.0 ± 0.3	3.2 ± 1.0	0.1911
Scoliosis at initial cast	67 ± 14	62 ± 16	61 ± 5	64 ± 13	0.3793
Scoliosis at Preop/after final cast	65 ± 23	47 ± 25	76 ± 8	72 ± 27	0.0082



Conclusions

- Serial cast placement is a useful treatment option in terms of prevention of progression of scoliosis and delayed tactic before surgery although its effectiveness varies between patient to patient and also in each diagnosis.
- Casting does not require any form of anesthesia in my series and we can apply a corrective cast more frequently with combination of brace wearing.
- The earlier the cast application, the better outcome of scoliosis correction, particularly in Infantile idiopathic scoliosis.

Prevention of Severe Scoliosis - Distraction Based

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Single/Dual Traditional Growing Rod (TGR)

The principle of distraction-based techniques is to place implants into the spine without fusion, and to lengthen the spine surgically at regular intervals. This serves two effects, one to maintain spinal growth and second to correct any residual deformity. Such systems are generally referred to as growing rods, and globally is probably one of the most popular methods for the treatment of early onset scoliosis. The principle of such systems is that anchors are placed only in the upper and lower end vertebrae, usually in the form of a set of 4 pedicle screws or a claw-hook construct. They are then connected via rods placed in the sub-fascial plane, without the need to expose the spine and therefore reducing the risk of spontaneous fusion. Studies have shown that such strategies are able to maintain spinal growth, which is measured by T1 to S1 length on the posteroanterior radiograph. In addition, the coronal deformity is well-controlled, and lung function improves by longitudinal lengthening. Implants are converted to final fusion at the end of skeletal maturity. (ref 1-6)

Dual growing rods is the preferred configuration by many surgeons as, compared to a single rod, they are able to provide better correction, increased stability, and a greater proportion of expect spinal growth. Akbarnia et al. (2) published the largest clinical series of dual growing rods consisting of 23 patients who had undergone an average of 6.6 lengthenings per patient with a minimum of 2-year follow-up. Mean coronal Cobb angle improved from 82° (range, 50°-130°) to 38° (range, 13°-56°) after initial surgery and was 36° (range, 4°-53°) at final follow-up. There was a mean increase of T1-S1 length of 1.21cm per year. However, complications occurred in 11 patients (48%) with a total of 13 complications.

However, invariable with non-fusion systems that require repeated surgical procedures to lengthen the spine, numerous complications have been reported. These include implant failure, increasing difficulties to distract with time, wound complications and infections. In an analysis of 140 patients who underwent single or dual growing rod(7), 58% of patients had at least one complication. However, the authors found that the risk of complications decreased by 13% for each year of increased patient age at the initiation of treatment. They concluded that complications could be reduced by delaying rod implantation if possible, using dual rods, limiting the number of lengthening procedures and placing the rods under the deep fascia. Wound complications are more common with more frequent lengthening intervals, and implant-related complications tend to be associated with longer intervals. One of the major short-comings of repeated distractions is the so called "law of diminishing returns" (8). This is the phenomenon whereby with successive distractions, the length gain is progressively reduced. This is thought to be related to intersegmental fusion.

Magnetically controlled growing rods (MCGR)

Recently magnetically controlled growing rods (MCGR) have been developed to allow outpatient distraction after surgical implantation (9). The indications, technique and principle of surgical implantation are the same as traditional growing rods. The difference is in the rod design, which houses an internal "motor" that can be activated by use of a large external magnet (actuator). Thus repeated percutaneous lengthening can be performed without the need for general anesthesia. Studies have showed that MCGR is effective in controlling curve progression, increasing T1-S1 lengths, and improving pulmonary function (9-16).

As repeated general anesthesia is not needed, it is possible to carry out more frequent distractions of lesser amount, to more closely mimic physiological spinal growth. In a finite element study, shorter intervals of distraction led to reduced stresses on the rods and may reduce chances of rod breakage for the same spinal height gain (17). There is currently no consensus on the optimal distraction frequency and length (18). Proponents of frequent distraction (one monthly) would claim that it more closely mimic physiological growth, while those of less frequent distractions (4-6 months) would feel that there is no difference in length gain, while frequently distractions is impractical as patients often come very long way away to have this performed in specialized centers.

In our experience, MCGR is best used for early onset scoliosis patients without significant kyphosis. Our technique involves two incisions at the foundation sites, with a preference for pedicle screws provided the tracks can be found, and sub-fascial tunneling of dual MCGRs, using one standard and one off-set rods. We do not maximally distract the curves intra-operatively, and fusion of both foundation sites is performed. We allow fusion to consolidate before performing the first distraction. Our distraction protocol is usually 2mm every month, although it may vary depending on growth velocity and the ability of the rod to distract.

Despite the early results showing promising outcomes, studies have shown that MCGR is also associated with complications. In one study it was found that 38.8% of patients experienced at least one complication (19). Although the infection rate was lower than TGR (3.7% vs. 11.1%), MCGR usage is associated with all common implant-related complications including rod breakage and foundation failure. Although MCGR reduced the number of planned lengthening procedures, another multicenter study with minimal follow up showed an unplanned reoperation rate of 46.7% after the initial procedure (20). Causes of unplanned reoperation were failure of rod distractions, proximal foundation failure, rod breakage and infection, and more frequent distractions (between 1 week and 2 months) was associated with a higher reoperation rate.

MCGR experiences similar complications to TGR, but it can reduce the number of surgical procedures compared with TGR (21). Currently the longest follow up is about 10 years, and cases are limited to know whether at the end of growth what should be done. My own experience and due to the known metallosis related to the implant are to either remove the implant or remove it and perform a posterior spinal fusion. More experience will be needed before any recommendations can be given.

End of distraction-based surgical techniques

Flynn et al. reported on 99 early-onset scoliosis patients who had been managed with growing rods and either had undergone final fusion or reached the end of spinal growth. They found that final fusion was most commonly triggered by a complication (such as implant failure or infection) or by the assessment that there was minimal remaining growth potential. Final fusion was extended distally for coronal balance, or proximally for proximal junctional kyphosis or implant migration. In most cases, final fusion involves a difficult spinal exposure, although there was no additional blood loss or higher neurologic risk compared with a typical posterior spinal fusion. More recently, a retrospective comparative analysis of graduated early-onset scoliosis patients found that graduation by fusion depended on major curve deformity magnitude or progression, sagittal malalignment or implant complications; whilst observation with retention of previous implants depended on curve stabilization, Cobb angle of <50°, and coronal misalignment of <20mm. There is currently not enough long-term evidence to recommend when to choose observation for these patients at the end of growth (22, 23).

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Growth Guidance Modern Luque Trolley

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Eduardo Luque described the first self-growing rod construct in 1977 [1] followed by Moe in 1984.[2] Using segmental sublaminar wires and U or L shaped rods to treat young patients (<11 years) that had severe scoliosis that did not respond to bracing. The Luqué Trolley was described as a rigid internal brace that would allowed the spine to grow along the rods. The spine was instrumented but not fused. Luqué published his early results showing that the technique had good corrective power decreasing average Cobb from 72° to 22° while still allowing on average 2.5 cm growth over 2 years. [1] Subsequent long-term results showed poor maintenance of spinal growth (range, 32%-49% of expected growth) [3,4], high spontaneous fusion (range, 4%-100%) [3] and a high implant failure rate of 32% [5]. In 1999, Pratt et al published a five year follow up retrospective study looking at 26 patients with a diagnosis of EOS treated with Luqué trolleys where 18 had anterior apical epiphysiodesis in addition to the the posterior segmental growth guidance technique. They concluded that Luqué Trolley did prevent curve progression (From 48° to 25° to a final Cobb of 43°). They also showed that Luque Trolley allowed for 50% of expected growth if the epiphysiodesis was not done. The addition of the anterior epiphysiodesis improve curve control decreasing the average preop Cobb from 65° to 26° to a final Cobb of 32° however the apical hemiepiphysiodes had not surprisingly worst growth potential with an average of 32% of expected growth. [5] Complications remained high mainly secondary to implant failures. The authors concluded that there was a need for improved instrumentation and for new surgical measures to allow better spinal growth and curve control. Patients who did poorly with the classic Luque trolley were those with large rigid curves preoperatively and/or patients who had large residual postoperative curves.

In 2011, Ouellet & al, published a small series of 5 patients with EOS treated with a Modern version of the Luqué trolley that had been followed for 4.5 yrs. They described a new surgical technique that instrumented the apex of the deformity via minimal invasive muscle sparing exposure coupled with solid proximal and distal anchors.[6] The small case series demonstrated that self-lengthening growth guidance systems could be indeed successful to reduce overall surgical procedure, to prevent progression of spinal deformity in EOS while maintaining spinal growth. With a mean follow-up of 4.5 years, the scoliotic deformity on average was decreased from 61° (range, 38-94°) to a mean of 21°(range, 10-33°) with gradual increase back to 35° at the last follow up. During the same interval, the spine grew on average 67% (range, 26-91%) of expected growth.[6] We recently reviewed an additional 15 patients with self-growing constructs and found similar results with an average Cobb reduction of 47% with an average 4 year follow up. Patient spines grew on average 63% of the calculated growth and was found to be inversely proportional to the residual post-operative Cobb angle. (Pearson's R score of -0.546; $p=0.035$) Residual Cobb angle less than 25° had close to normal expected spinal growth. (Table 1)

Self-growing rod constructs can vary significantly depending on type and rigidity of curve. In general, we recommend that a greater number of gliding anchors are used above and below the apex for large deformities. However if there are too many anchors used, greater is the risk of spontaneous fusion. For such large and rigid deformities, then classic dual growing rods requiring active distraction may be more appropriate.[7,8] One can use off label modern spinal implants to achieve gliding construct as the case we illustrated. (Fig.1) or use specific implants that have been developed to allow for gliding anchors. Via special access program Trolley Gliding screws are available in Canada. Both systems have been tested in animals showing the system grows with little to no local inflammatory response. [9,10]

Granted that both the guided growth construct and the Modern Luque Trolley are guided growth techniques, they are technically as well as conceptually different. The guided growth system is based on a two rod construct with apical fusions while having the ends vertebra growth away from the apex. In contrast, classic Modern Luque Trolley relies on solid proximal and distal anchors with intercalated apical gliding anchors translating the apex back to midline with a FOUR rod construct. (**Fig. 3**) Longterm clinical follow up remains spares on either constructs, however guided growth surgery remains an attractive option for a specific patients with early onset scoliosis. Skeletally immature patients (younger than 10 yr old with open triradiate cartilage) unable to tolerate repetitive anesthesia, with collapsing progressive flexible scoliosis are ideal candidate for Modern Luque Trolleys.

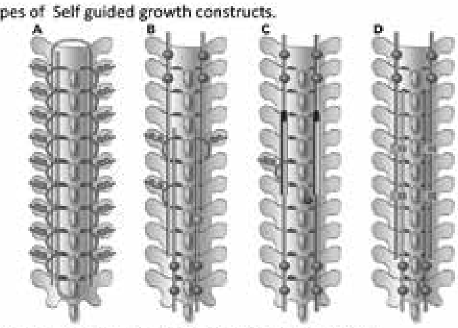
Surgical Procedure

The patient, under general anesthetic on a radiolucent table with appropriate bolsters, are to be prep and draped in a sterile fashion exposing the entire spine. Using intra operative fluoroscopy, location of the fixed proximal & distal anchor points are to be marked on the skin. (**Fig. 3a,b**) The pedicles of the apical vertebra, as well as all planned location of gliding anchors need to identified by fluoroscopy to minimize surgical exposure. Using a midline incision, a classic subperiosteal dissection was performed to insert bilateral pedicle screws into T3&T4 and L4&L5. (**Fig. 3c,d**) These segments were decorticated and a formal inter laminar and intra articular fusion was undertaken. Great care was taken to ensure that each screws was perfectly placed and that the pedicle screw diameter filled to the lumen of the pedicle to optimize fixation. (**Fig. 3d**) Once the proximal and distal fixed anchors were place, we turned our attention to capturing the apical vertebra. For the gliding anchors, pre-operative planning and execution is crucial. Incisions must be planned to ensure that no incision lye directly over any spinal implant.

Location and density of gliding anchors are dictated by the type of deformity and the severity of the deformity. Considering this deformity was very flexible, we choose to only capture the apical vertebra at T12. The incision was made directly over the spinous process of T12, thus avoiding the risk that an implant be located bellow the incision. The skin was incised, fascia was open midline then an oblique transmuscular dissection was taken down toward the transvers process on the convexity leaving a good cuff of muscle and fascia above the planned implant, still ensuring that there is still a layer of the paravertebral muscles covering the lamina to avoid spontaneous fusions. (**Fig. 3e**) The dissection to insert a gliding anchor must be undertake in a extra periosteal / transmuscular fashion. Specific to this case, we used a **"Post"** technique that allowed us to cantilever the apical vertebra across midline, maximizing correction. This was possible by placing a pedicle screw on the convexity of the apical vertebra. This post is a standard non articulated pedicle screw that is NOT connected to the rod but acts as a fulcrum for the rod to reduce the deformity. As the convex rods is attached to the proximal anchor points and is translated to align with the distal anchor points, the "**Post"** translate the apex and corrects the deformity. In addition, we captured the apical vertebra in its concavity with a sub laminar wire to achieve maximal apical translation and control. The sub laminar wire was inserted by performing two small laminotomy in T11 and L1 avoiding taking down the inter laminar ligament. As one dissect along the convex lamina one must leave a thin layer of muscle on top of the periosteum or performing an extensive dissection avoiding to expose bone. The concept of self-growing rods was achieved by using the prosthetic rib construct rods in an off label fashion. One intentionally does not place the locking clip allowing for expansion of the male female parts as the spine grows. The added benefits of using such implant is that it is extremely robust, as well confers some anti rotational force as the I beam nature of the overlaid segments of the unlocked prosthetic rib construct does not allow for rotation. The rods were inserted in a transmuscular fashion from the proximal anchor dissection towards the Post and the sublaminar wire to all the way down to the distal anchors dissection. This requires some practice and patience as passing the rods through the muscle is not easy. One must take advantage of the kyphotic sagittal shape of the rod to facilitate capturing the apex. Then rotating the rod in the appropriate sagittal orientation, then the coronal deformity is corrected as the distal end of the rod is cantilevered and connected to the distal anchors. The post causes the apex to translate medially. After the convex rod was inserted, the concave rod was inserted and the apical sublaminar wire was tensioned, additional correction is achieved. Wounds were thoroughly irrigated and meticulous facial closure above the implants was done taking care not to injure the soft tissue envelop covering the implants.

Figures

Fig 1: Types of Self guided growth constructs.



a) Classic Luque Trolley with U shape rods and sublaminar wires
b) Modern Luque Trolley with mix of oversized gliding screws and sublaminar Wires
c) Modern Luque Trolley with VEPTR as expandable implant with out the locking clip and a Apical Post allowing to translate apex back to midline
d) Modern Luque Trolley with new Gliding implants at the apex of the curve.

Fig 2.

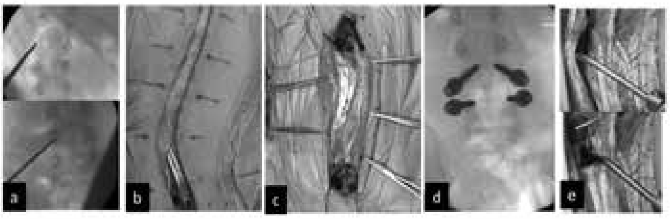
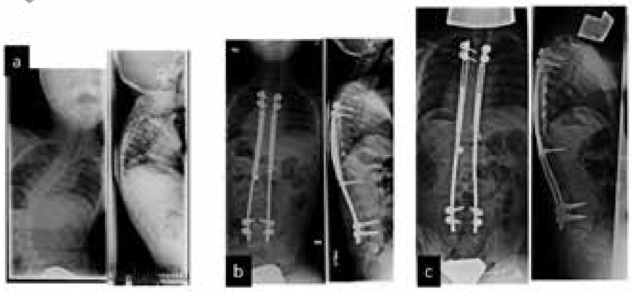
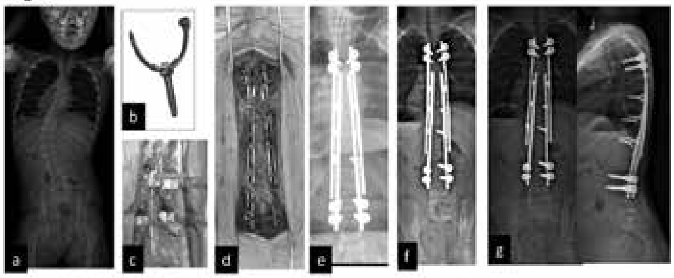


Fig 3.



a) Preoperative AP / Lat x-ray at the age of 5 yr old with congenital myopathy.
b) Immediate post operative x-ray illustrate the power of the Post cantilever reduction technique (Apex is translated to mid line with one sublaminar wire and a Regular Pedicle screw acting as a buttress as rod being cantilevered across midline)
c) Post operative x-ray at the age of 11 with no lengthening nor any revision surgery. Curve remains controlled and the spine has grown 5 cm across the instrumented spine illustrate by the space now seen in the female VEPTR chamber.

Fig 4.



a) 5 yr old girl with Pradder Willy, failed conservative treatment, progressing 50 degrees.
b) New gliding implant: Trolley gliding Vehicle. It is a pedicle screw with a PEEK cable tie and a Ultra-high-molecular-weight polyethylene liner that captures the rods.
c) Transmuscular insertion of the Trolley gliding anchors.
d) Intraoperative picture of the final construct with the proximal and distal fixed anchors at T3/4 and L3/4 and gliding anchors at T7,10,12
e) Intraoperative x-ray showing the three gliding anchors capturing the apex of the deformity.
f) Post operative x-rays two year after surgery
g) Post Op 3.5 yr after surgery, no revision nor lengthening surgery. The spine has grown 3.5 cm across the 10 instrumented vertebra representing 100% of expected growth based on Demiglio calculation (3.5 yr X 10 vertebral X 1 mm = 35mm)

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Half-Day Course

Prevention of Severe Scoliosis: Tether

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1. Historical Justification
    a. Growth Modulation in the axial skeleton
    b. Previous use of VBS
2. Tethering
    a. 100% avoidance of fusion
    b. peri-op
        i. avg. duration: 271 min. total OR time
        ii. median EBL: 100cc
    c. recovery: <48h hospitalization
3. Surgical Decision Making
    a. Indications
        i. Age/maturity – must have growth remaining to modulate growth
            1. Upper end: Sanders digital stage
                a. Most important indicator of maturity in surgical decision making
                b. Candidates must be stage 4 or less
            2. Upper end: Menarche status
            3. Lower end: chronologic
                a. VBS: 7+
                b. Tether: 10+
        ii. Diagnosis
            1. Idiopathic: infantile, juvenile, adolescent
            2. Borderline: Syndromic- Marfan, etc.
        iii. Radiographic parameters
            1. Cobb angle
                a. Thoracic curve: 35- ???
                b. Lumbar curve: ???
            2. Curve flexibility. Relative contra-indication: residual curve is greater than 20˚ on bending film
    b. contraindications
        i. Age/maturity: any patient without potential for further growth
        ii. Diagnosis
            1. Congenital
            2. Neuromuscular: any condition with high probability of progression to the point of requiring fusion
                a. Duchenne's muscular dystrophy
                b. SCI
    c. Planning
        i. Level selection –
            1. cobb angle levels
            2. unangled disc between curves – leave uninstrumented
        ii. approach: thoracoscopic
4. Surgical Technique
    a. Positioning
        i. Lateral decubitus
        ii. Position bolsters to allow curve to sag
        iii. Ensure direct lateral positioning
        iv. Ensure visualization with C-arm
        v. Ensure C-arm has room to slide cephalad yet remain in field
        vi. Under lateral flouro guidance but before draping – mark out a line on the skin down the mid portion of the vertebral bodies directly lateral to the bodies
        vii. Under flouro guidance but before draping – mark out the position of the cephalad and caudad vertebra to be instrumented
    b. Approach
        i. Thoracoscopic
            1. Scope portal position
                a. Need two-three 5mm instrument portals–
                    i. one 25% and one 75% of the distance from the inferior vertabra to the superior
                    ii. in line with anterior axillary line
            2. Working/implant portals
                a. If 5 levels or less to be instrumented then one incision 2 cm long straddling the line drawn lateral to the bodies in line with langers lines. Utilize several intercostal windows to access the chest so that implants are inserted directly laterally or slightly anterior
            3. Visualization
                a. Use low CO2 insufflation to keep lung down
                b. Single lung ventilation with double lumen tube for intubation
                c. In larger patients fan retraction of the lung may work
                d. May need to suspend respirations when staple being inserted
    c. Tether insertion
        i. Place screws through centering staple on lateral vertebral body
            1. Cauterize segmentals first
            2. Place staples over body under biplanar scope views
        ii. Screw length- must be very accurate
        iii. Rope insertion
            1. Secure with set screw at either apex or most proximal level
            2. Tension level-by-level. Judge tension by the angulation of the disc
            3. Lever set screw towers to facilitate segmental correction
            4. No tension between distal most two levels
            5. Cut rope with cautery
5. Post-op Management
    a. Pulmonary
        i. d/c chest tube when output <200cc/24h
        ii. incentive spirometer, pulmonary toilet, etc.
    b. Activity
        i. Oob POD #1
        ii. No sports, gym, etc. until 6 weeks post-op
        iii. Consider brace immobilization for 6 weeks if child

is rambunctious or otherwise unable to comply with activity modification

6. Pearls and Pitfalls
    a. Segmental vessels
        i. Best strategy is to avoid perforation – if concerned that it may be in the path of a desired staple,
            1. use cautery to incise pleura and then push out of way with peanut
            2. cautherize with bipolar
        ii. Control of bleeding segmental vessel
            1. Apply pressure with peanut/cherry/sponge stick
            2. Thrombin/gelfoam, floseal™ then apply pressure
            3. Bipolar cautery
    b. Maintaining thoracoscopic visualization
        i. Entire tether procedure can be done through portals with a bladder seal
        ii. Vaseline gauze applied to incision to allow CO2 pressure to be maintained
        iii. Place thoracoscopic peanut through portal and under the spine to hold the lung back
    c. Post-op management
        i. Chest tube
        ii. No sports, gym, etc x 6 weeks
    d. Complications
        i. Pneumothorax. Tx: chest tube
        ii. Tether overcorrestion:
            1. release tension via set screw loosening
            2. consider dividing tether
        iii. Curve progression. Tx: fusion
        iv. Infection: haven't had any infections. Infections in anterior scoliosis surgery are fortunately rare
        v. Neurologic: have not had neurologic injury with these techniques

Descriptive Surgical Technique

Equipments/Instrumentation

- Bipolar cautary, monopolar cautery
- Thoracoscope
- Anterior tether implant (none currently FDA approved): centering staples, monoaxial hydroxyapatite coated screw, braided PET tether
- Fluoroscopy

Anesthesia and positioning

- General anesthesia and intubation with a double lumen endotracheal tube for thoracic curves
- Lateral decubitus position with convex side of the scoliosis in the up position
- Soft pads under all pressure points
- C-arm under table for PA and lateral imaging

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Anterior Surgery for Scoliosis

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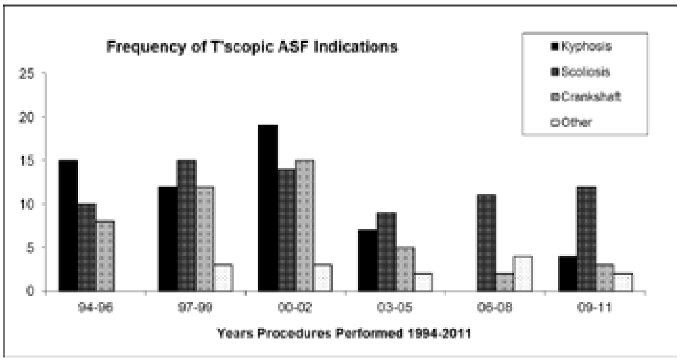
Anterior Release – Traditional Indications in Scoliosis
- Large Deformity: >70 degrees
- Rigid Deformity: Bending >50 degrees
- Crankshaft Risk: Risser 0, Triradiate open

Pedicle Screws Changed the Indications
- More powerful correction
- Posterior column osteotomies
- Recent literature showing questionable benefit of anterior release



Pedicle screws compared to Hook or Hybrid Constructs
- Greater coronal correction
- Greater transverse plane correction
- Reduced thoracic kyphosis

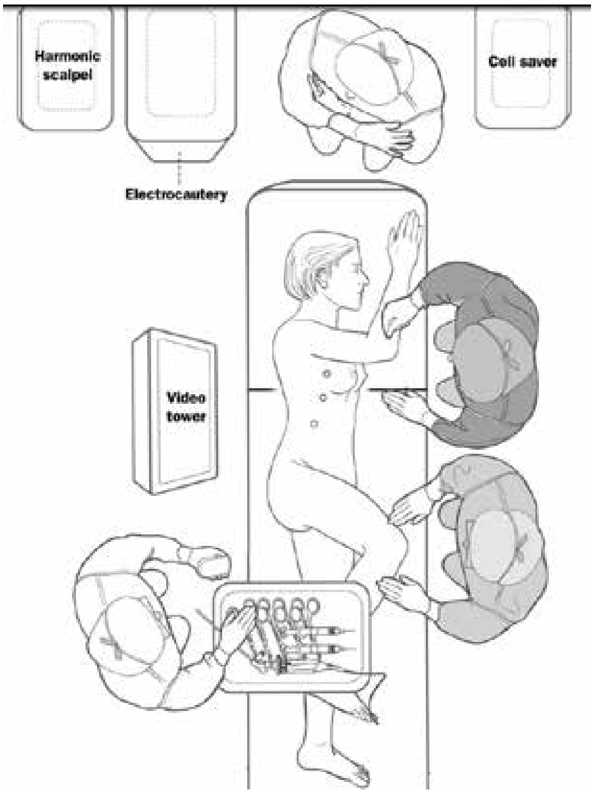
Why a loss of kyphosis?
- Scoliosis associated with "extra" relative anterior column length
- Greater derotation puts the extra length back in front
- Thus less kyphosis

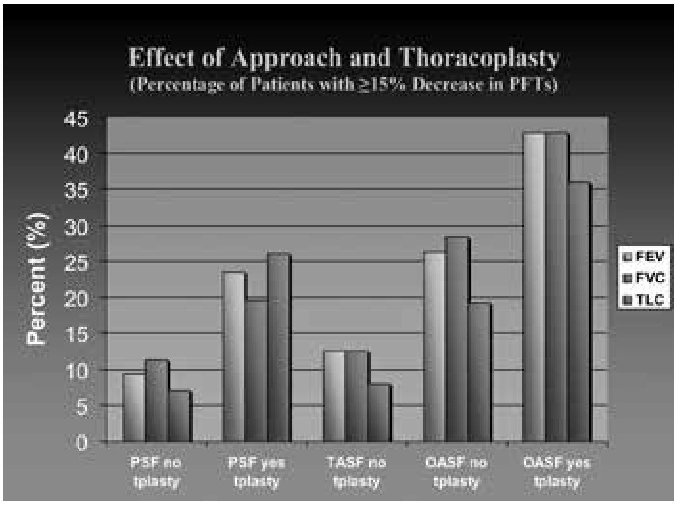
3D Assessment of Thoracic Kyphosis in AIS
- Less than measured on lateral xray
- True lateral segmental analysis
- Loss of Kyphosis correlated with Greater Cobb angle

Correction of Axial and Sagittal Together is Hard
- Greater derotation demands greater kyphosis creation
- Anterior disc excision makes both easier, "makes room" for derotation

Fight the Loss of Kyphosis – Goal ~30 degrees
- Posterior column lengthening, good for mild to moderate degrees of rotation and lordosis
- Anterior column lengthening, best when the combined deformities are "larger"

Surgical Approach
- Open vs Thoracoscopic
- Pulmonary function effects modest
- Learning curve





Why Bother?

- Correction is important to the patients
- The rib hump matters – maximize derotation
- Sagittal alignment matters – maximizing thoracic kyphosis maximizes lumbar and cervical lordosis

Other Anterior Indications

- Anterior Instrumentation/Fusion
  - Thoracolumbar, AIS and Neuromuscular
  - EOS, short anterior rather than posterior
- Anterior Growth Modulation

Summary

- Powerful posterior instrumentation (along with posterior osteotomies for increasing posterior column length) will handle most cases of AIS
- Anterior release procedures remain valuable for the more severe cases – as they did traditionally
- Anterior release indications should be based on the curve pattern, magnitude of all 3 planes of deformity, desired degree of 3 plane correction and the associated morbidity of the anterior procedure

Preoperative and Intraoperative Traction for Severe Spinal Deformity

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I. Background of early traction devices
   a. Halo-femoral
   b. Halo-tibial
   c. Halo-pelvic
   d. Halo-gravity

II. Halo Gravity Traction (HGT)
   a. Deformity correction
      i. Majority of studies report 20-35% curve correction prior to definitive surgery
      ii. Nemani: coronal>sagittal Cobb (34% vs. 22%, p=0.01) correction with preop HGT likely due to more rigid kyphotic deformities (congenital or infectious etiology) in the study group
   b. Duration of preoperative traction
      i. Reports in literature range from 2 to 23 weeks
      ii. Watanabe: 18% correction at 1 week and 23% correction at 3 weeks of HGT with no improvement after 3 weeks
      iii. Park: 66% of maximal coronal curve correction achieved at 2 weeks, 88% by 3 weeks, and 96% by 4 weeks
      iv. Nemani: deformity correction plateaued at 63 days
   c. Goal HGT weight
      i. Goal HGT weight approximately 33%-50% of patient total body weight (TBW)
         1. HGT of 75% of TBW has been described at some institutions
         2. Alternative method of HGT goal weight: "when the patient is suspended"
      ii. Applied via free weights or spring mechanism
      iii. Weights generally added at five pounds/day increments to achieve goal weight in 1-2 weeks
   d. Nutritional optimization
      i. Nemani: "Traction Camp" to optimize nutrition
      ii. Philadelphia Shriners (Pahys):
         1. Average weight gain of 5.7% of TBW (range -2.1kg to 8.7kg) with nasogastric tube feeding during HGT
         2. 11.4% increase in Prealbumin after HGT
   e. Pulmonary optimization
      i. Bugonovic: 9% improvement in PFT prior to fusion with HGT; 19/22 patients had improvement in PFT after HGT
      ii. Philadelphia Shriners: 20% improvement in PFT prior to fusion with HGT
   f. Avoidance of a VCR
      i. Sponseller: Decreased number of three column osteotomies for traction vs. no traction group in multicenter retrospective review. No difference between either group in curve correction, OR time, blood loss, or complications
      ii. Nemani: 10/29 HGT patients underwent VCR;

9/10 were for angular kyphosis secondary to tuberculosis or congenital deformity
iii. Philadelphia Shriners: 6/20 patients with coronal/sagittal Cobb averaging 110° "required" a VCR
g. Complications
i. Historically, cranial nerve palsies (VI and XII), nystagmus, and even paralysis reported. Concern that traction weight applied/increased too rapidly. Post traction fractures reported in 28/37 patients in halo-femoral traction. Neck pain or headaches typically resolve with decrease of HGT weight.
ii. Pin site complications: typically treated with oral antibiotics and/or pin removal/exchange; Rare reports of cranial osteomyelitis and extradural abscess exist
iii. Nemani: No neurologic complications; 11 pin tract infections: 5 treated with pin exchange, 6 treated with oral antibiotics
iv. Bogunovic: 27% overall complication rate; nystagmus (n=3), pin site infection (n=3), upper extremity numbness (n=1), unilateral miotic pupil (n=1)

III. Intraoperative External Traction
a. Adolescent idiopathic scoliosis
i. Jhaveri: 50% TBW through femoral pins and 25% skull traction with Gardner-Wells tongs. Significant improvement in apical vertebral rotation with intraop traction
ii. Lewis: 36 AIS patients with intraop skull femoral traction
1. 18/36 patients with intraop motor evoked potential (MEP) changes; improved at a mean 5.5 minutes (range 1-29 minutes) after reduction or removal of traction
2. Risk factors for MEP changes: location of major curve in thoracic spine, increased Cobb angle (86° vs. 70°), and rigidity of major curve
3. Curves >80° treated with intraop traction had a 75% risk of MEP changes
4. No permanent deficit reported
5. "Presence of any MEP recordings irrespective of amplitude at closure was associated with normal neurologic function"
iii. Da Cunha: Intraop skull femoral traction in 45 AIS patients vs. 28 without traction undergoing posterior spinal fusion
1. Lower EBL and operative time in traction group
2. Lower transfusion rates in traction group
3. No difference in complication rates
4. Significant cost reduction in traction vs. no traction group
b. Neuromuscular Scoliosis
i. Keeler: Cerebral Palsy patients treated with halo femoral traction and posterior fusion vs. anterior release and posterior spinal fusion
1. No differences in final Cobb angle
2. Shorter operative time, lower EBL, less perioperative and postoperative pulmonary complications in traction group compared to anterior release group
ii. Jhaveri: improved apical vertebral rotation in intraop traction group for NM scoliosis
iii. Jackson: Intraop traction and posterior spinal fusion provided similar curve correction with decreased operative times and blood loss compared to anterior release and posterior spinal fusion for cerebral palsy patients with scoliosis >100°.

IV. Intraoperative Internal Distraction
a. Temporary Internal Distraction
i. Buchowski: Ten patients with mean preop Cobb angle of 104° treated with anterior and/or posterior releases with temporary internal distraction
1. 6/10 underwent a second "lengthening" of temporary distraction prior to definitive fusion
2. Mean time between initial procedure and final fusion; 2.4 weeks
3. 53% average curve correction with releases and internal distraction alone
4. Mean 80% final curve correction after definitive fusion; authors advocate that temporary distraction may obviate need for anterior release
5. No neurologic deficits or infections reported
ii. Hu: Temporary internal distraction between two stage surgery (3.5 month average) demonstrated improvements in curve magnitude and pulmonary function
iii. Cheung: Described temporary magnetically controlled growing rod (MCGR) implantation with daily distractions for 2.5 months prior to definitive fusion in 12-year-old female with severe kyphoscoliosis and concurrent syringomyelia and Chiari Type I malformation.

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Posterior Releases

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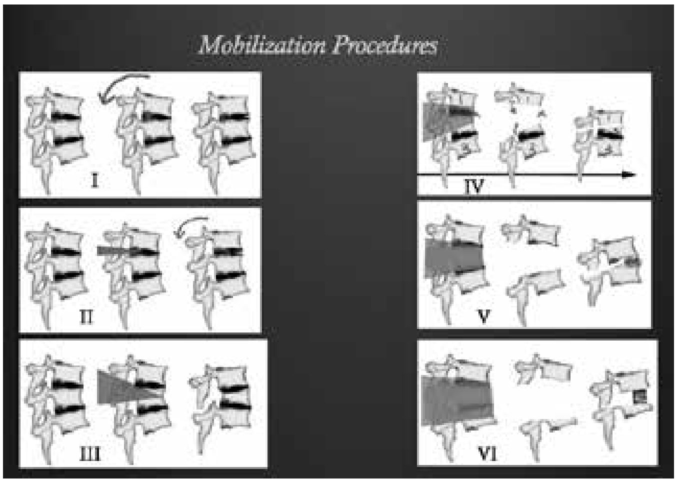
Achieving Excellence in the Management of Severe Pediatric Spinal Deformity
Posterior Releases

Introduction:
The author has employed a systematic progressive series of posterior mobilization procedures for the past twenty years. This consists of facet excision, Ponte osteotomy (occasionally asymmetric) , pedicle subtraction osteotomy (occasionally asymmetric), and lastly vertebral column resection. Rarely, posterior convex release and interbody release has been employed to facilitate mobility, prevent crankshaft phenomenon, and achieve interbody fusion. [5]

Frank Schwab et al [7] have recently described and reported on **The Comprehensive Anatomical Spinal Osteotomy Classification.** Schwab et al's classification representing progressive de-stabilization is depicted below.



Courtesy F. Schwab

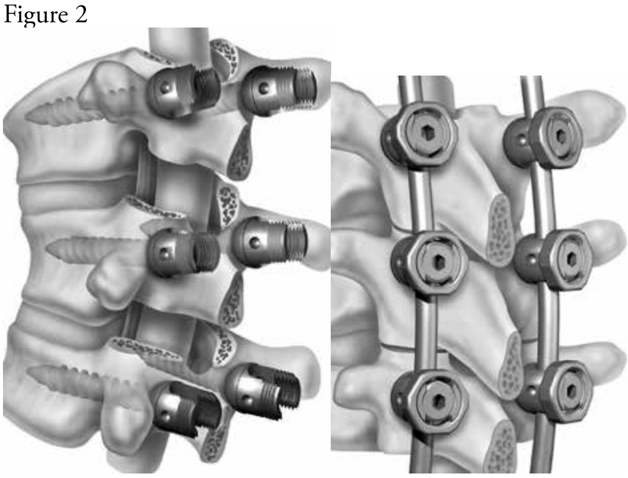
Figure 1. Progressive destabilization.
I. Posterior facet destruction.
II. Complete facet excision (Ponte)
III. Posterior element excision and partial body (pedicle subtraction)
IV. III plus disc above
V. IV plus both discs and complete body (vertebral column resection)
VI. V plus additional portion of adjacent body

Posterior Facet Destruction
This has been a routine accompaniment of posterior spinal fusion for decades. There are a variety of techniques available to accomplish this. These include osteotomes, large caliber electric burr (the author's preference, 9mm diameter), harmonic bone scalpel, and undoubtedly many others. This step should be simple, quick, and relatively bloodless.

Posterior Facet Excision, complete
Complete facet excision, or the Ponte osteotomy [3, 6], has been employed by the author for over 30 years (after personal instruction by Ponte). Several techniques are available to accomplish this. The author prefers Kerrison rongeurs. The osteotomy can be as wide as from pedicle to pedicle (for problems in kyphosis and in the lumbar segment of AIS).

For routine mobilization of thoracic AIS (generally relatively lordotic) all that is required is release of the ligamentum flavum and the anterior capsule of the facet joint. Usually a 3mm Kerrison accomplishes this. Unilateral Ponte osteotomy is preferred on the convex side of the upper curve in Lenke II AIS. Figure 2 depicts a Ponte osteotomy and a completed Ponte osteotomy.

Figure 2



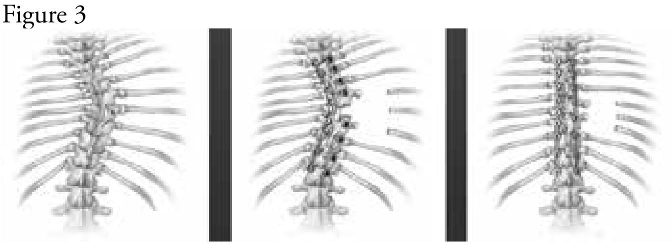
The Ponte osteotomy is useful in improving correction of AIS, and particularly in restoring the sagittal plane in both thoracic and lumbar curvatures. [3] Specific rod placement and tightening sequences are necessary to achieve the maximum benefit. Increased neuro-monitoring alerts has been reported, however this has not been the experience at the author's institution. [1]

Posterior Element Excision and Partial Body Excision (pedicle subtraction osteotomy or PSO)
This was initially described for the posterior treatment of ankylosing spondylitis. [10] This technique is rarely necessary in the treatment of AIS, but is not uncommonly needed in advanced deformity and particularly in congenital spinal deformity. A PSO that extends into an adjacent disc space would be categorized as a class 4 osteotomy.

PSO involves a complete excision of the posterior elements, both pedicles, and a wedge resection of the vertebral body. This requires lateral exposure as well as spinal cord exposure. Needless to say, intra-operative neuro-monitoring is a prerequisite. Temporary stabilizing rod is also a prerequisite. An interbody structural bone graft or cage may be required. The VCR is more commonly utilized in pediatric deformity. In the pediatric thoracic spine, a PSO usually winds up being a VCR.

The author at one time advocated utilizing the PSO (as well as a vertebral column resection) asymmetrically on the convex side, leaving the concave pedicle intact and as a fulcrum. This is depicted in Figure 3. Extreme care is advised, as if the correction is not complete, the remaining concave pedicle may compress the spinal cord.

Figure 3



Vertebral Column Resection (Schwab V and VI) or VCR
The VCR involves the complete removal of at least one vertebral level with both adjacent discs. A temporary stabilizing rod is mandatory. A structural interbody device is also mandatory. This prevents excessive shortening and provides a fulcrum to increase coronal and sagittal correction. Transexemic acid has been shown to diminish blood loss, which can be significant, during the procedure. [2]

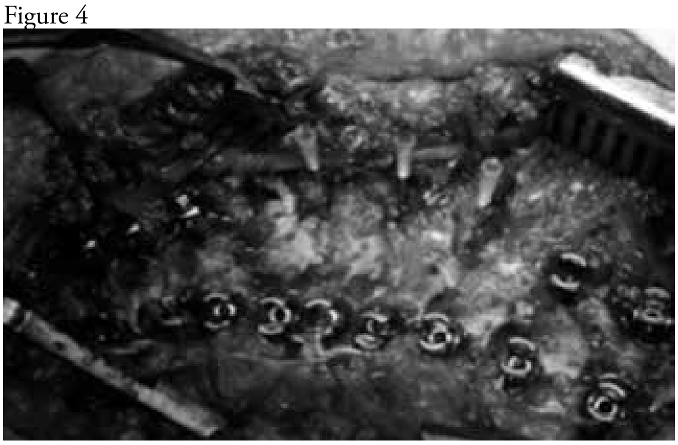
Excision of the concave pedicle prior to the convex side may provide some element of neural decompression and avoid the very common neuro-monitoring alerts. Application of small amounts of convex compression may also provide some element of neural protection. In the event of a significant monitoring alert, the surgeon must have a prepared check list of responses, that must include monitoring personnel, anesthesia, and the surgical team. Monitoring response should be restored to 50% of baseline or better prior to completion.

Although potential risks and complications exist, significant benefits in terms of correction, realignment, and balance are achievable. Several publications attest to this. [4]

Posterior Convex Release and Interbody Fusion (PCRIF)
PCRIF is a rarely indicated but very useful in pediatric deformity. In the larger curve with a large amount of peri-apical rotation, the anterior structures become relatively easily accessed from the convex side of the deformity. The primary indication is a large thoracic curve in an immature patient (Risser 0, tri-radiate cartilages open). In addition to increasing correction, crankshaft can be prevented.

Costo-transversectomy is performed at the levels at which PCRIF is to be performed. This affords easy access to multiple thoracic discs without entering the chest. Discectomy and interbody grafting is accomplished. Figure 4 depicts the exposure with needles in each disc space.

Figure 4



Summary
The deformity surgeon has a large variety of posterior mobilizing procedures available to facilitate the correction of pediatric spinal deformity. Posterior facetectomy is usual. The Ponte osteotomy is the workhorse of the author, and is routine in nearly all cases of pediatric deformity. VCR is frequently required in congenital deformity, preferably not asymmetrical. VCR or PCRIF is helpful in advanced deformity in immature patients.

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Surgical Technique: VCR

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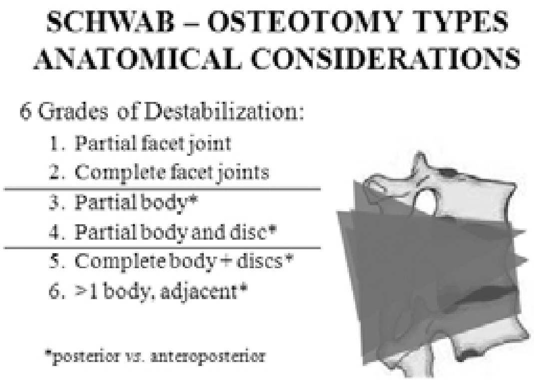
I. INTRODUCTION/TERMINOLOGY

a.



b. Fox VCR Study Group Definition:
"3-column circumferential vertebral osteotomy creating a segmental defect with sufficient instability to require provisional instrumentation

c. Indications
  i. Pathology dependent
    1. Type of deformity (scoliosis, kyphosis, lordosis)
    2. Coronal/sagittal/combined imbalance
    3. Curve magnitude
    4. Stiffness (preop & intraop)
    5. Bone Density (proxy for PS purchase)
  ii. Surgeon dependent
    1. Operative goals
    2. Surgeon experience/comfort level (PSOs, Post HV excision, costotransversectomy approach)
  iii. Risk dependent
    1. Minimization
    2. Avoid complications

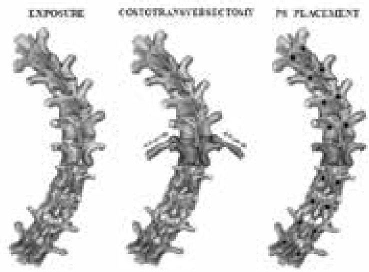
d. Contraindications
  i. VCR → "stuck dura" dorsally and/or ventrally from prior decompression/posterior interbody fusion
  ii. Unfamiliar with technique
  iii. Lack of SCM (?) During the procedure (↑ risk!)

e. Preoperative Planning
  i. Complete radiographic evaluation
  ii. Total spine MRI
  iii. 3D CT scan ± actual model
  iv. Pulmonary/nutrition analyses
  v. Cardiac/anesthesia clearance

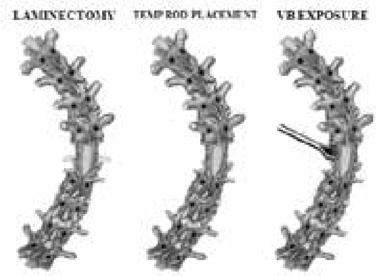
II. SPECIFIC INDICATIONS/TECHNIQUES

a. Posterior VCR
  i. Procedure of "last resort"
  ii. Severe & stiff deformities/autofused spinal columns
  iii. For primary IS → "spine on chest wall" x-rays
  iv. Marked kyphoscoliosis/lordoscoliosis
  v. Performed primarily in thoracic/TL region
  vi. Resection of all posterior elements, facet joints ↑/↓, pedicles, nearly all vertebral body and discs ↑/↓
  vii. Tremendous correction ability as spine is disarticulated at apex & proximal/distal limbs slowly brought together
  viii. Performed *via* staged anterior/posterior approaches or posterior-only (in single or staged fashion)

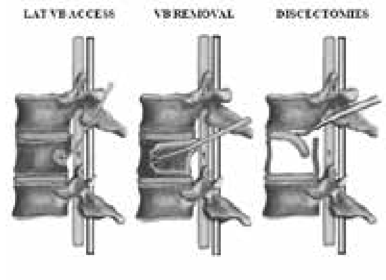
b. Surgical Technique
  i. Exposure, costotransversectomy, pedicle screw placement



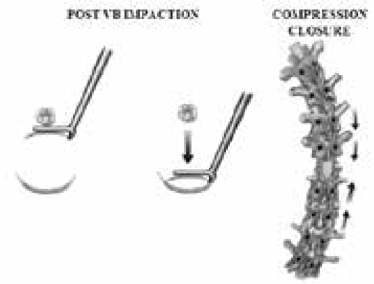
  ii. Laminectomy, temporary rod placement, vertebral body exposure



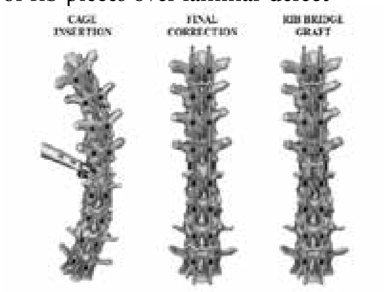
  iii. Lateral vertebral body access and removal, discectomies



iv. Posterior vertebral body impaction, compression closure



v. Anterior cage insertion, final correction, placement of rib pieces over laminar defect



III. OUTCOMES
a. VCR (data from multicenter pediatric VCR "Fox" Consortium) Multicenter analysis of 147 consecutive vertebral column resections for severe pediatric spinal deformity. SRS Annual Meeting, Kyoto, Japan, September 2010
   i. Complications
      1. 86/147 (59%) total complications
      2. 68/147 (46%) intraop
         a. 39/147(26.5%) SCM loss or actual neuro deficit
         b. 33/147(22.4%) EBL >2L
      3. 43/147 = 29% postop
         a. 21/147(14.3%) respiratory
         b. 7/147 (4.8%) infections
   ii. **No** intraop/postop deaths
b. Neurologic Highest Risk (data from Myelopathic Patients Who Lack SCM Data Have the Highest Risk of Spinal Cord Deficits following Posterior VCR Surgery. SRS Annual Meeting, Kyoto, Japan, September 2010)
   i. Postop Neuro Status
      1. 138 pts./8yrs
      2. 112 with intraop SCM same as preop
      3. 4/26 without intraop SCM – (15%) transient paraplegia
   ii. Characteristics
      1. 3 KS & 1 AK – +116.3°
      2. Apex proximal to mid-thoracic – T2-7
      3. 3 prior ASF w/segmental vessel ligation
      4. All preop neuro status acute, progressive myelopathy
   iii. F/U Neuro Status

Age	VCR level(s)	Dx	Secondary Dx	Preop	Postop	F/U
[illegible]	T6-7	KS	[illegible]	Myelopathy	Paraplegia	Ambulatory in brace
12.8	T5-6	KS	[illegible]	Myelopathy	Paraplegia	Ambulatory w/assistance
15.9	T4	KS	Congenital KS	Myelopathy	Paraplegia	Ambulatory
[illegible]	T2-3	AK	Cervicothoracic syringomyelia	Myelopathy	Paraplegia	[illegible] ambulatory w/assistance

All 4 pts. Regained LE motor function and 4/4 ambulatory

c. Benefit of SCM – multicenter pediatric VCR "Fox" Consortium
   i. Prompt response to SCM changes
      1. 147 pts./7 surgeons
      2. 39/147 (27%) critical change/SCM loss or failed WUT
      3. 19 pts. (13%) worsening neuro status immediate postop
      4. 1 permanent neuro decline
d. Intraop SCM reliability (data from Can Intraoperative Spine Cord Monitoring Reliably Help Prevent Paraplegia during Posterior VCR Surgery? SRS Annual Meeting, Louisville, KY, September 2011)
   i. Loss of SCM data
      1. 15/90 pts, either lost (n=13) or had degraded data to meet warning criteria (n=2)
      2. All 15 SCM data returned following prompt intervention
      3. All woke with intact LE function! ("SCM SAVES")

IV. Summary
a. Challenging but safe
b. Simultaneous and circumferential control/access to spinal column/cord
c. Use of SCM, especially some form of motor tract monitoring essential to minimize neuro complications
d. Beneficial alternative to circumferential approach providing dramatic radiographic/clinical correction
e. Current state-of-the-art for severe, stiff pediatric/adult deformity, however, is technically challenging and associated with potentially major neurologic & non-neurologic complications

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Preoperative Construct Planning

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Defining the goals of surgery

The main goal of a posterior Vertebral Column Resection (pVCR) in a severe scoliosis is the restoration of a satisfactory frontal and sagittal spinal balance. Postoperative alignement has been correlated to functional outcomes.

The secondary objective is the improvement of patients self-image, which is often a major concern. Complication rates are high, and should be explained and understood by caretakers.

Indications for pVCR / planning the surgery

Various situations can be encountered, from congenital kyphoscoliosis to iatrogenic postoperative malalignement with anterior imbalance, so preoperative planning is necessary. An experienced medical and paramedical team helps decreasing complications and blood loss. Primary cases should be distinguished from revision ones, often more challenging with potential instrumentation removal, unrecognizable anatomical landmarks and longer operative time. In such cases, staging procedures or having 2 experienced attending surgeons can be considered. Neuromonitoring is mandatory.

Planning postoperative balance

Planning is essential because the operative procedure remains difficult (osteotomy, rod contouring), and intraoperative control is often poor in such a long surgery. The expected « ideal » spinopelvic alignement should be planned and simulated from long-cassette standing radiographs, showing at least C7 and the femoral heads. The objectives of postoperative alignment are :

- Pelvic tilt <25°
- SVA < 5 cm
- Pelvic incidence – Lumbar lordosis < 10°
- Restoration of the physiological local sagittal kyphosis at the osteotomy level
- Frontal imbalance < 2cm

Theoretically, the correction angle to obtain can be calculated by measuring the angle between a line connecting the preoperative location of the center of C7 vertebral body and the osteotomy site, and a second line joining the osteotomy site to the expected postoperative location of C7. Several softwares have been developed to assist surgeons in planning their osteotomies, choosing fusion and osteotomy levels, and therefore simulate postoperative balance.

What can we plan in the construct ?

- Fusion levels
- Osteotomy site (often guided by the preopertive deformity in pVCR)
- Rod material (CoCr+++) and diameter
- Number of rods
- Location and type of instrumentation
- Method to reconstruct the anterior column
- Type of graft

Fusion should extend distally to stable vertebra in both frontal and sagittal plane. For the UIV selection, attention should be paid to preoperative shoulder balance, and the expected effect of the correction at the osteotomy site.

CoCr is often recommended, with a minimum 5.5 diameter. Adding a third or a fourth rod can help reducing pseudarthrosis.

Pedicles can be difficult to find in a mass of fusion, but also in virgin spine in case of congenital deformity. Pedicle channels should therefore be investigated by preoperative CT scans, with preoperative 3D reconstruction. If pedicules are too narrow, sublaminar bands could be considered to increase construct stability.

The proximal fixation x
Can be performed using pedicle screws or bivertebral claws using dedicated hooks, very resistant to pull-out forces. Anterior column reconstruction is mandatory to avoid rod fracture, and Mesh cages are commonly used.

Local autograft is usually sufficient, but allograft and bone substitutes can be considered in revision cases, or when major posterior gap is expected after correction.

VCR remains a complex and long procedure in complicated patients, often fragile and already fused. To perform this surgery, surgeons should be experienced and remember that sometimes « The best is the enemy of the good » (Voltaire)

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Preoperative Optimization

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1. BACKGROUND:
   a. Complication rates reported for these procedures range from 25 to 80 % [1, 2].
   b. General spine surgery, intraoperative adverse event rates reported in the literature reach 10 % [3–9].
   c. Complex spine surgery is a high-risk undertaking and is often quite morbid in nature [10–13].
   d. Surgical complications can be divided into three main categories:
      i. Intraoperative
         1. severe blood loss, surgeon error or misjudgment, coagulopathy, and hypotension [14•, 15].
      ii. Perioperative (within the first 90 days postoperative)
         1. local or systemic infection, thromboembolism, poor wound healing, implant-related problems with neurologic sequelae, post- operative pain requiring reoperation, and complications arising from comorbid conditions
      iii. Long-term (greater than 90 days postoperative).
         1. Long-term complications include pseudarthrosis, latent infection, implant fatigue and failure, and proximal and distal junctional failures [16–20].
2. Preoperative evaluation
   a. NUTRITION
      i. Well nourished patients had a 25% reduction in complication rates compared to patients with 1 abnormality in weight loss, serum albumin level, and arm muscle circumference
      ii. Nutritional Risk Score (NRS), can be utilized in the office setting to screen for malnourishment
      iii. prealbumin, a marker for protein nourishment, accurately predict outcomes for chronically ill patient
         1. Risk stratification based on prealbumin suggests a poor prognosis for those with levels less than 5.0 mg/dL and significant risk for those with levels of 5.0 to 10.9 mg/dL
      iv. RECOMMENDATIONS:
         1. For all preoperative patients, a properly balanced diet of key nutrients, including carbohydrates, fats, protein, vitamins, and minerals, as well as nutrition education, should be part of the preoperative process.
         2. All patients should undergo screening to allow for early detection of malnutrition preoperatively (Pre Albumin). Patients who screen positive should initiate immediate nutritional support and warrant a full assessment by a nutritionist.
         3. Physicians and nutritionists should consider disease-specific formulas when recommending nutritional supplementation if available for the clinical condition.
   b. CARDIAC
      i. Patients with preexisting cardiac complication have a significantly higher morbidity and mortality rate postoperatively
      ii. The optimal approach in management involves assessing a combination of patient-specific risk factors, surgery-specific risk factors, and exercise tolerance
      iii. RECOMMENDATIONS
         1. Patients with known coronary or structural heart disease should be assessed with a 12-lead electrocardiogram.
         2. Assessment of left ventricular function using echocardiography should be performed in patients with dyspnea of unknown origin and for patients with known heart failure or heart failure symptoms.
         3. Exercise stress testing should be employed to assess patients with elevated cardiac risk and poor functional capacity. Those who cannot tolerate exercise stress testing should undergo dobutamine stress echocardiogram or myocardial perfusion imaging.
         4. Patients with cardiac electronic implantable devices should be monitored continuously during any period of perioperative inactivation, and external defibrillators should be available. If inactivation occurs, proper reprogramming after surgery should be ensured.
   c. PULMONARY
      i. Children with severe thoracic deformities commonly have associated pulmonary disorders
      ii. Restrictive lung disease is most common
      iii. Associated diaphragm dysfunction
      iv. RECOMMENDATIONS
         1. Pulmonary Function Tests (PFTs) should be ordered on all patients with suspected pulmonary dysfunction or with thoracic based deformities
         2. Evaluation by Pulmonary medicine should be arranged
   d. BONE HEALTH
      i. Osteopenia and Osteoporosis have been associated with increased perioperative morbidity
      ii. Osteoporosis correlated with increased risk of adjacent segment fracture, PJK and DJK
      iii. RECOMMENDATIONS
         1. Bone density study on all complex cases
         2. Consider obtaining PTH, vit D and Ca2+ levels
         3. T score between –1.5 to –2.5 consider supplementation with Vitamin D and Ca
         4. T score <-2.5 patients should be referred to endocrinology. In adults consider treatment with Teriparatide.

e. HEMATOLOGIC
   i. Identify patients at risk for hypercoagulable states
      1. Van Willinbrands
      2. Other dyscrasias
      3. Family history
   ii. Identify patients at risk for excessive bleeding
      1. Medical comorbidities placing patients at risk such as liver disease, chronic anemia, platelet disorders
   iii. RECOMMENDATION
      1. Labs to order: PT, PTT, and INR
      2. CBC with platelet count
      3. Consider Hematology evaluation with significant clinical concern

3. RISK STRATIFICATION
   a. Many different tools exist
   b. Consider Using a risk calculator
   c. Team approach to clearance of advanced deformity patients
      i. Seattle Spine experience
      ii. Northwestern Spine

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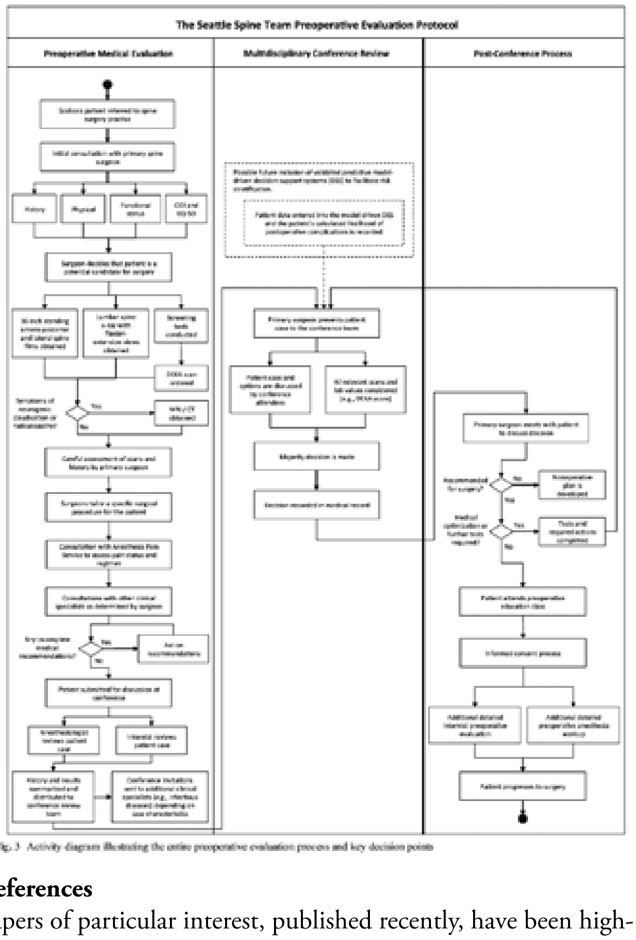

Fig. 3 Activity diagram illustrating the entire preoperative evaluation process and key decision points

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Adult Spinal Deformity: An International Exchange on the Safety and Efficacy of Current Techniques

Room: Europauditorium

Course Chairs:
Munish C. Gupta, MD and Yan Wang, MD

Faculty:
Harry Akoto, MD; Christopher P. Ames, MD; Neel Anand, MD; Saumyajit Basu, MD; Marco Brayda-Bruno, MD; David Clements, MD; Nicholas Fletcher, MD; Azmi Hamzaoglu, MD; Claudio Lamartina, MD; Stephen J. Lewis, MD, MSc, FRCSC; Praveen Mummaneni, MD; Yong Qiu, MD; Jason W. Savage, MD; Juan Uribe, MD; Go Yoshida, MD; ZeZhang Zhu, MD

Adult Spinal Deformity: An International Exchange on the Safety and Efficacy of Current Techniques

Chairs and Moderators: Munish C. Gupta, MD and Yan Wang, MD

Part I: Preoperative and Intraoperative Safety

15:00-15:10 **Preoperative Assessment and Optimization of a Patient with a Complex Deformity**
Jason W. Savage, MD

15:10-15:20 **Preoperative Planning for Treatment: Imaging and use of Halo Traction**
Harry Akoto, MD

15:20-15:30 **Intraoperative Positioning and Neuro-Monitoring to Avoid Complications: Intraoperative Traction**
Stephen J. Lewis, MD, MSc, FRCSC

15:30-15:40 **Discussion**

Part II: MIS Options for Deformity Correction: Safety First

15:41-15:51 **Lateral Approach Can Avoid 3 Column Osteotomies**
Juan Uribe, MD

15:51-16:01 **MIS Adult Deformity: On the Cutting Edge**
Neel Anand, MD

16:01-16:11 **MIS Long Constructs for Spinal Deformity**
Praveen Mummaneni, MD

16:11-16:21 **Discussion**

Part III: Open Spinal Osteotomy Techniques: Detailed Description with Videos: Pitfalls and Tips

16:22-16:32 **Smith Petersen Osteotomy**
Go Yoshida, MD

16:32-16:42 **Corner Osteotomy**
Claudio Lamartina, MD

16:42-16:52 **Pedicle Subtraction Osteotomy**
Yong Qiu, MD

16:52-17:02 **Vertebral Column Decancellation**
Yan Wang, MD

17:02-17:12 **Posterior Vertebral Column Resection**
Azmi Hamzaoglu, MD

17:12-17:27 **Discussion**

Part IV: Case Panel

17:28-17:58 **Four Complex Adult Deformity Cases**

Moderator: Munish Gupta, MD

Panel: *Christopher P. Ames, MD; Saumyajit Basu, MD; Marco Brayda Bruno, MD; David Clements, MD; ZeZhang Zhu, MD*

17:58-18:00 **Closing Remarks**
Munish Gupta, MD

Preoperative Assessment and Optimization of a Patient with a Complex Spinal Deformity

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Introduction

- As the population ages, the incidence of adult spinal deformity, and in particular degenerative scoliosis is going to dramatically increase. It is estimated that approximately 60% of adults will develop scoliosis by age 60.(1)
- Degenerative scoliosis with sagittal plane imbalance is often associated with lower extremity symptoms (neurogenic claudication +/- radiculopathy), debilitating back pain, and the inability to stand upright.
- The goals of ASD surgery are to decompress the neural elements and restore coronal and sagittal plane balance. Surgery to correct ASD has been shown to improved pain and HRQOL outcome measures, but is often associated with significant risk and morbidity.
- It is estimated that complications occur in approximately 40% of patients who undergo deformity correction surgery.(2)
- Appropriate preoperative evaluation and optimization, as well as perioperative management are crucial in minimizing complications and optimizing outcomes in this complex patient population.

The importance of a multi-disciplinary approach

- The successful treatment of patients with adult spinal deformity involves a cohesive multi-disciplinary approach, which includes the surgical team (orthopaedic and neurosurgical deformity surgeons), perioperative medical team, medical consultants (i.e. cardiology, endocrinology, nephrology, etc.), neuroanesthesiology, and rehab specialists.
- The spine surgeon must take "ownership" and direct all aspects of the treatment plan, which starts with developing a well-devised surgical plan based on the patient's symptoms, type and degree of deformity (as determined by plain radiographs, MRI and/or CT), and goals of surgery.
- Age-appropriate alignment objectives must be considered in all adult deformity operations, as over or under-correction are associated with an increased risk of complications and proximal junctional failures.
- An extensive "risk-assessment" should be done for each patient, and modifiable factors must be identified and optimized prior to surgical intervention. (3)
- The "Northwestern High-risk Spine Protocol" and "Seattle Spine Team Approach to Adult Spinal Deformity" are two established protocols that have been shown to decrease the risk of developing complications and improve post-operative outcomes. (4-6)
- The utilization of a preoperative conference involving deformity surgeons, medical physicians, rehab specialists, and anesthesia team helps identify patients who are optimized for surgery, and those who need further work-up or are not "fit" to undergo ASD correction.
- Approximately 25% of patients presented at a multi-disciplinary conference are deemed "unsuitable" for the extent of surgical intervention, and a non-operative treatment plan is then developed and implemented. (5,6)

Preoperative assessment and optimization

- Adult spinal deformity patients must undergo an extensive preoperative medical evaluation prior to surgery. At the Cleveland Clinic, this starts with an evaluation by the IMPACT (Internal Medicine Preoperative Assessment, Consultant and Treatment) team.
- The initial work-up includes lab work (complete blood count (CBC), comprehensive metabolic panel (CMP), hemoglobin A1c, and albumin/pre-albumin levels), chest x-ray, and EKG.
- Consultant physicians are utilized during the preoperative evaluation if necessary. The most common referrals are to cardiology, endocrinology, (bone health), hematology, and nephrology. The common reasons for the referrals are listed below.
  - *Cardiology:* history of coronary artery disease or congestive heart failure, abnormal EKG, history of pacemaker or defibrillator, and angina with exertion; these patients will often have an echocardiogram, stress test, and/or angiography prior to surgery
  - *Endocrinology:* an elevated Hgb A1c (>7.5), history of osteoporosis, abnormal DEXA scan and/or Vitamin D level, malnutrition (defined as albumin < 3.5g/dL or pre-albumin levels < 16mg/dL).
  - *Hematology:* history of coagulopathy, abnormal lab values (hematocrit < 30, plts < 100, elevated PT/PTT/INR, fibrinogen levels).
  - *Nephrology:* a history of chronic kidney disease and/or an elevated creatinine level, patients on hemodialysis
- Every patient undergoing deformity surgery has a work-up for osteoporosis. This includes a DEXA scan and Vitamin D level. Abnormal values in either trigger a referral to a metabolic bone specialist for evaluation and optimization of bone health prior to surgery.
- Patients with osteoporosis are often treated with an anabolic agent (i.e. teriparitade or abaloparatide) for at least 3 months prior to surgery, and for up to 12 months after surgery.
- Smoking cessation is absolutely necessary prior to surgery. At the Cleveland Clinic, a negative nicotine test is required prior to scheduling ASD surgery. Ideally, patients stop smoking at least 12 weeks prior to surgery, and cessation is recommended for 12 months post-op.
- Obesity is associated with poor surgical outcomes and an increased risk of infection. Therefore, patients with a BMI > 40 are referred to a nutritionist and started on a weight-loss program (focusing on diet and exercise). Some patients are referred to bariatric surgery prior to undergoing deformity correction surgery. A BMI < 40 is a necessary prior to surgical intervention.
- Lower extremity duplex scans (LEDs) are performed on patients with a history of thromboembolism, prolonged immobilization, recent hospitalization, history of cancer, and/or unexplained LE swelling or pain.
- Sarcopenia is common in this patient population, and therefore, a rigorous preoperative rehabilitation program ("pre-hab") is implemented during the preoperative planning process. This involves a low impact aerobic exercise program, water therapy, core strengthening, and gait training.

- A psychosocial evaluation should be performed on every patient considering ASD surgery. A history of chronic narcotic use, depression, and/or chronic pain syndrome should raise concern about the "readiness" of the patient to undergo surgery. An evaluation by a pain psychologist can be very helpful in optimizing these patients for surgery.
- Every patient is also seen by a member of the neuroanesthesia team prior to surgery.
- A geriatrics consult should be considered for all patients greater than 70-years-old.

Other perioperative considerations

- Preemptive analgesia: the Cleveland Clinic enhanced recovery after surgery (ERAS) protocol is to give all deformity patients 300mg of gabapentin (oral), and 1000mg of acetaminophen (oral) prior to surgery, 10-20mg of long-acting oxycodone (oral) is also often given before general anesthesia.
- *Ketamine* (0.25mg/kg bolus and 5mcg/kg/min infusion) and *lidocaine* (1.5mg/kg bolus and 1.5/mg/kg/hr infusion) infusions are often used during deformity operations.
- Intraoperative blood management: cell-saver is used for all deformity operations, TXA is used (10mg/kg bolus over 10 minutes followed by a 1mg/kg/hr infusion) in all patients unless there is a contraindication, aggressive fluid resuscitation and the use of blood products are used to treat acute blood loss and coagulopathies that occur during surgery.
- Postoperative mobilization: early mobilization is critical and patients are encouraged to be out of bed on POD#1. A walker is used for 6 weeks post-op to encourage upright posture and to prevent falls in the perioperative period.
- Mechanical dvt prophylaxis is used during and after surgery, Sub-q heparin is started on POD#2 (5000mg tid).
- Pain control: a pain management consult is obtained on all deformity patients, low-dose Ketorolac is given unless the patient has an elevated creatinine (15mg q 8hrs for 3 days), ketamine infusions and/or epidural catheters are considered in certain patients, PCAs are weaned starting POD#2, and oral narcotics, acetaminophen, and muscle relaxants are used to manage postoperative pain.

Conclusions

- A multi-disciplinary approach to managing the complex adult spinal deformity patient helps identify modifiable risk factors and ensures appropriate perioperative optimization of patients undergoing deformity correction surgery
- A systematic approach/protocol has been shown to minimize complications and improve perioperative outcomes

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Preoperative Planning for Treatment: Imaging and use of Halo Traction

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HGT for severe Spine deformity:

Introduction

- Halo gravity traction has been used in patients with severe spine deformity since antiquity.
- Several authors have described the use of HGT (with or without concomitant anterior release) in patients with severe, rigid curves. HGT has been shown to reduce curve magnitude by 30-40% in the coronal and sagittal plane, improve pulmonary function, and significantly lower rates of vertebral column resection. In resource-limited settings and in patients with congenital or neuromuscular scoliosis, the use of HGT also provides time for pre-operative medical and nutritional optimization.
- Successfully avoiding post operative complications requires multidisciplinary management and methods to anticipate and mitigate surgical risk. The FOCOS Score (FS) is a previously-described pediatric spinal deformity risk stratification score that considers patient and procedural variables to estimate the risk of complications. Some of the factors considered by this score include American Society of Anesthesiologists (ASA) Classification, body mass index (BMI), curve etiology, curve magnitude (CM), the need for three-column osteotomies (3CO) and the number of levels being fused. A higher FOCOS score has been correlated to higher rates of neurologic complications, non-neurologic complications, estimated blood loss (EBL) and operative time.

FOCOS SCORE- Surgical Risk Stratification

Procedure Factors Score (PcF)
(Maximum 40 pts)

Fusion Levels	Points
1-4	2
5-7	4
8-10	6
10-12	8
>12	10

Osteotomy Type	Points
Select one	
Facet Osteotomy	1
SPO	5
PSO	10
VCR	20

Procedure	Points
Open anterior procedure for spinal deformity (e.g., thoracotomy, retroperitoneal, thoracoabdominal approaches) done singularly or in combination with posterior rib procedures (thoracoplasty, concave rib resection)	10
Any posterior procedure that violates the chest wall (e.g., thoracoplasty, concave rib resection).	10

- Pick the highest scoring osteotomy variable.
- Eg, patient with a 10 level fusion, SPO, VCR, and Thoracoplasty would get:
    - Fusion Lvls – 8 pts, Osteotomy – 20 pts (for VCR), Thoracoplasty – 10 pts
    - Total: 38 points

Patient Factors Score (PtF)
(Maximum 20 pts)

BMI	Points
Normal BMI (18.5-25)	1
>25	2
16.5-18.5	3
15 - 16.5	4
<15	5

Etiology	Points
Idiopathic	2
Congenital, Neuromuscular, Neurofibromatosis, Syndromic	10

Neuro Status (ASIA)	Points
A (complete)	5
B (incomplete. Sens sparing)	5
C (incomplete, sens & weak motor)	3
D (incomplete, sens and good motor	1
E (normal)	1

Curve Magnitude (CM)
(Maximum 40 pts)

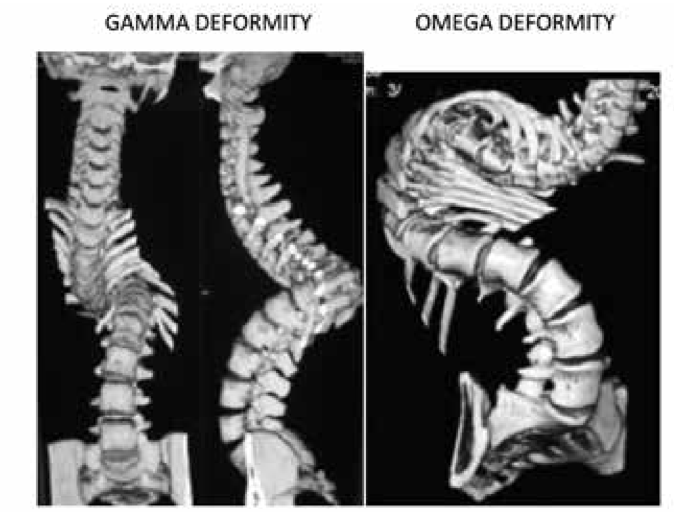
- **Pick the larger of the two curves to assign deformity points**
- Eg if Coronal curve is 60, and sagittal curve is 85, the deformity score is 25 points for the sagittal curve of 85. Do not add 10 points for the coronal curve

Coronal Curve (deg)	Points
<50	5
51-60	10
61-70	15
71-80	20
81-90	25
91-100	30
>100	40

Sagittal Curve (deg)	Points
<50	5
51-60	10
61-70	15
71-80	20
81-90	25
91-100	30
>100	40

Pre-op Assessment

- Patients selected for Halo Gravity traction are screened as per the FOCOS sub-score.
- Coronal or sagittal curves exceeding 100 degrees with less than 20% flexibility on supine hyperextension (Kyphosis) or supine manual traction (coronal) are candidates for HGT.
- If curve magnitude is less than 100 degrees in both planes but patient is malnourished based on BMI criteria then HGT is considered and patient placed on nutritional supplements till optimal BMI is reached. Even though the PFT does not seem to improve in patients with PFT (FVC) above 40% those with lower PFT levels have been shown in our experience to have an improvement of the PFT with long term Halo gravity traction.
- In general, we have shown that maximum correction of both coronal and sagittal curves in patients with kyphoscolios is obtained at an average of 62 days. Additional days in traction are usually relegated to other complex deformities such as the Gamma deformity exceeding180 degrees. In these patients, long term traction averaging 5 months is needed to carefully unwind the multiplanar translational deformity as shown in fig below.



Pre-op Imaging

- A full length upright AP and lateral radiographs are supplemented with 3D CT Scan to better delineate the type and etiology of deformity. For complex spine deformity > 100°, curve classification and characterization becomes more difficult with conventional radiographs. 3-D CT scans add relevant information to categorize and aid in preoperative assessment, in communication and patient evaluation.
- A consecutive series of 78 patients seen at our center with curves exceeding 100° underwent a full radiographic review using conventional X-rays and 3-D CT. A descriptive analysis was performed to categorize curves into 6 main types (1C, 1S, 1CS, 2P, 2D and 2PD) based on the location of the major Cobb angle in the coronal or sagittal planes as well as the location of the apical vertebra.
- There were 38 males and 40 females with an average age of 17.9 ± 4.6yrs. The diagnosis included Idiopathic (48); Congenital (24); Neuromuscular (4) and Neurofibromatosis (2). The mean major coronal and sagittal Cobb (kyphosis) were 131.2±23.4° and 136.9±32.3 respectively. The classification scheme yielded 6 unique types which consisted of Type 1C (n=9), 1S (n=2), 1CS (n=43), 2P (n=21), 2D (n=2) and 2PD (n=1).

<u>Radiographic Classification Principles</u>

- All patients with curve magnitude >100° were classified using a combination of erect AP/lateral x-rays and 3-D CT reconstruction. The 3-D CT reconstruction was a prerequisite for inclusion into this study due to the complex anatomic 3D configuration of the deformities. The first step in the classification scheme was to identify on erect AP and lateral 36-inch radiographs if the major curve >100° exists in either the sagittal (1S) or coronal (1C) plane or both (1CS). The second step required a CT reconstruction to identify the location of the proximal Upper End Vertebra (UEV) and distal Lower End Vertebra (LEV) of the major curve relative to the apical vertebra. If the UEV and LEV remained above and below the apical vertebra respectively, the curve was assigned a prefix of 1 and was classified as either 1C (coronal curve > 100°, Sagittal <100°), 1S (sagittal >100°, coronal <100°) or 1CS (both coronal and sagittal >100°). Any curvature in which the end vertebra was positioned at the level of, above or below the apical vertebra was assigned with a prefix number 2. If the UEV was positioned at the level of or below the apical vertebra, the curve was classified as 2P. If the LEV was positioned at the level of or above the apical vertebra, the curve was classified as 2D. If the UEV was positioned at the level of or below and the LEV was positioned at or above the apical vertebra, the deformity was classified as 2PD. The resulting structure of this 2PD deformity assumes the shape of the Greek Alphabet Omega (Ω) and as such we coined the term "Omega deformity" to describe this subtype of severe kyphoscoliosis. Curves 2P and 2D curves do not form a full Omega sign and as such referred to as "half Omega".

TABLE 1: Summary of Classification types

Type	*Coronal*	*Sagittal*	*UEV at or below apex*	*LEV at above apex*
1C	>100°	<100°	No	No
1S	<100°	>100°	No	No
1CS	>100°	>100°	No	No
2P(half omega)	>100°	>100°	Yes	No
2D(half omega)	>100°	>100°	No	Yes
2PD (full omega)	>100°	>100°	Yes	Yes

<u>Conclusions</u>

We have established the safety and efficacy of HGT in treating pediatric and young adult patients with severe deformity. The complication rate of HGT (34%) but the majority of complications can be managed without a repeat procedure. We have validated the FOCOS score risk stratification and shown that the change in FOCOS score was an accurate measure of surgical risk with acceptable sensitivity and specificity. Using these scoring systems, HGT is capable of significantly lowering the surgical risk. Lastly, patients with large fixed kyphotic deformities were the least likely to respond to HGT and that in this subset of patients, other indications must guide the use of HGT.

Pre op and 5 months post HGT photos and X-rays of an 18 year old male with severe kyphoscoliosis. Note improvement in BMI and Coronal and sagittal curves

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Intra-Operative Positioning and Neuromonitoring to Avoid Complications

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Setting up your surgeries for optimal results starts before knife is put to skin. Proper surgical planning includes the proposed surgery, and ensuring the appropriate equipment, team members and staff are available before, during and after the surgery.

In this section, the focus is on positioning and neuromonitoring. The importance of these components is critical to the smooth running of the procedure.

Intra-Operative Positioning

Prone
The majority of spinal deformity procedures are performed in the prone position. The key components of the positioning include the patient height, ensuring the abdomen is free, the neck is a

Head and neck: Position the neck in a slightly flexed or neutral position. Special pillows are available in different heights with appropriate holes for the eyes, the endotracheal tube, and mouth to provide comfortable support for the face and neck during the often long procedures. Ensure fluids, prep solutions, drain away from the face so that they don't pool in the area during the procedure. These fluids can cause skin maceration or burns during the surgery. Head pins, like the Gardiner Wells tongs with low weight traction, can be used to keep the head and neck just above the pillow and prevent all pressure on the eyes and face.

Body Support: The 4-post bed has been the biggest advent in spinal surgery. Keeping the abdomen free limits pressure on the abdomen, helping to reduce blood loss during the surgeries. The proximal posts must be placed in a way to support the upper body to minimize pressure on the neck, avoiding pressure on the brachial plexus and breasts. The lower posts are placed on the iliac crests. Care needs to be made to ensure they are distal enough to allow the abdomen to be free, and that they are appropriately padded to avoid injury to the lateral femoral cutaneous nerve of the thigh. If the pads are placed too distally, undo pressure on the femoral nerve can result. For wide patients, narrow pads should be exchanged for the wider ones to allow the abdomen to be free, and avoid the excessive pressure on the femoral nerve and breasts.

For taller, thin patients, the Wilson frame can provide comfortable support while keeping the abdomen free. However, postero-anterior radiographs can be affected by the frame as some of the spine may be obscured by the frame.

Arm support: The arms should be well-padded on the arm support with the fingers free, the elbows at a right angle, and the shoulders at a comfortable height with the axilla free. Ensure the arms are proximal enough to allow room for the surgeon and assistant.

Leg support: Positioning the legs will affect the amount of lordosis placed in the lumbar spine. Placing the legs in the knee chest position, ie. flexed hips and knees, will flex the lumbar spine, facilitating lumbar decompressions. However, for fusion pro-

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cedures, it is preferable to have the hips extended to allow the lumbar spine to lordose, so that the fusion will allow sufficient lordosis. With the hips extended, the knees can be flexed slightly to improve venous return from the legs during the procedure. In males, prior to draping, ensure the testicles are hanging free and not trapped between the proximal thighs. Proper padding of the legs is needed to prevent pressure points.

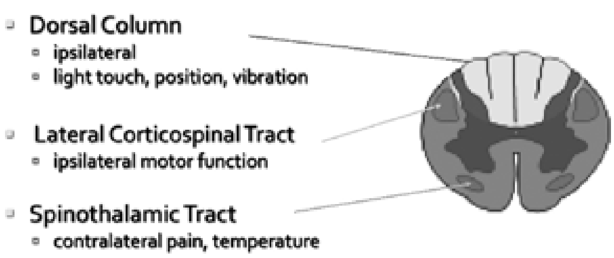
Intra-Operative Neuromonitoring

Multi-modality neuromonitoring is the standard in most centers performing complex spinal deformity corrections. Good cooperation and communication between the anesthesia, surgical, and neuromonitoring teams is needed to achieve reliable monitoring that can provide timely alerts to allow for appropriate maneuvers to prevent neurological injury. To understand how to manage neuromonitoring changes, basic understanding of spinal cord neuroanatomy, incomplete spinal cord injury patterns, and monitoring modalities is needed.

Basic Neuroanatomy

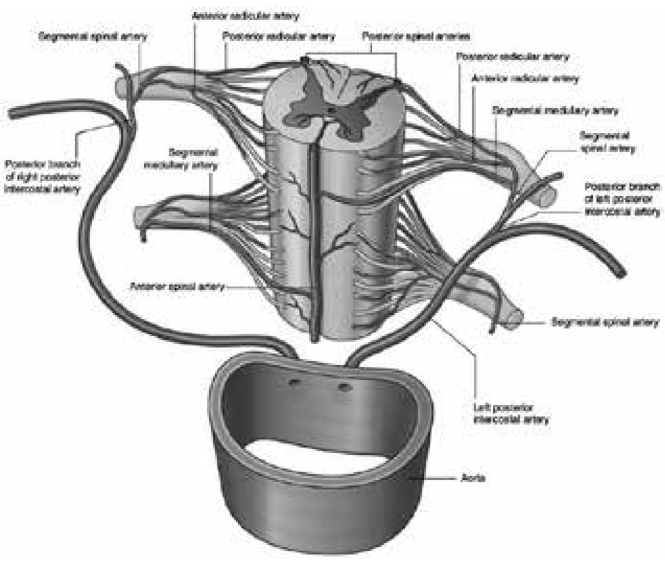
There are three main tracts that are monitored during spinal surgery*:*

- The dorsal columns: located in the dorsal aspect of the spinal cord provide ipsilateral sensation for light touch, position and vibration sense
- Corticospinal tract: located in the anterior part of the spinal cord, provide ipsilateral motor function
- Spinothalamic tract: located in the anterior aspect of the spinal cord provide contralateral sensation for pain and temperature



Blood Supply to the Spinal Cord

The intercostal artery provides the segmental spinal artery that enters the dura through the exiting nerve root sleeve to provide arterial supply to the spinal cord. The segmental spinal artery branches into the segmental medullary branch, which provides supply to the anterior spinal artery, and posterior radicular artery, which supplies the posterior spinal artery. The anterior spinal artery is centrally located and provides blood supply to the anterior two thirds of the spinal cord, depicted in dark in the figure above. Any condition that puts direct pressure (ie. disc, hematoma, tumor) or that causes stretch or kinking of the anterior spinal artery can lead to decrease perfusion to the anterior 2/3 of the spinal cord, leading to an anterior cord syndrome. Recognizing this decrease in perfusion is key to preserving spinal cord function. The posterior supply has right and left posterior spinal arteries providing a more robust blood supply to the posterior 1/3 of the spinal cord, making the posterior columns less susceptible to ischemic insult.



Incomplete Spinal Cord Syndromes

There are 4 common incomplete spinal cord injury patterns that make up the majority of incomplete spinal injuries.

Anterior Cord Syndrome: this represents an ischemic injury to the spinal cord affecting the blood supply provided by the anterior spinal artery. This results in bilateral dysfunction of the tracts in the anterior 2/3 of the spinal cord, ie. the corticospinal and spinothalamic tracts.

Central Cord Syndrome: this represents a central ischemic injury to the spinal cord most often as a result of an extension trauma to the cord.

	CS I	CS C	ST I	ST C	DC I	DC C
Anterior Cord	+	+	+	+	-	-
Central Cord	+	+	+	+	+	+
Posterior Cord	-	-	-	-	+	+
Brown-Sequard	+	-	-	+	+	-

I = Ipsi C = Contralateral
CS = corticospinal ST = spinothalamic DC = Dorsal Columns

Posterior Cord: this represents an isolated injury to the posterior aspect of the spinal cord usually from direct trauma, ie. placing a laminar hook, passing a sublaminar wire. This results in dysfunction of the dorsal columns affecting light touch, position and vibration sense.

Brown-Sequard: this results from an ipsilateral direct trauma to the spinal cord, resulting in injury to the hemicord. This manifests as an ipsilateral loss in motor function and light touch, position and vibration sensation, with contralateral loss of pain and temperature sensation

Neuromonitoring Modalities

Motor evoked potentials (MEP) and somatosensory evoked potential (SSEP) are the two main methods of spinal cord monitoring. The SSEP provide information received from the dorsal columns, while the MEP are direct recordings obtained from specific muscle groups upon stimulation. The MEP provide

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information from the anterior spinal cord and therefore provide indirect measure of the spinothalamic tract. Transcranial MEP (tcMEP) is the preferred method of MEP recordings because of its ability to lateralize right vs left with no cross contamination from the dorsal sensory tracts, but other methods including Direct wave (D-Wave), descending MEP (DNEP), and neurogenic MEP (NMEP), exist but are not preferred and can be used as secondary fall back measures.

To obtain MEP recordings, total intravenous anesthesia (TIVA) is required. Use of inhalation agents will greatly reduce the MEP recordings and should be avoided when MEP monitoring is utilized. MEP are not free-run and recording are obtained only through stimulation by the technologist. Performing these stimulations at key parts of the procedure can help identify causative events when MEP changes occur.

Electromyography (EMG) is used to record function from individual nerve roots. These can be recorded by free-run, direct nerve stimulation, and through pedicle screw stimulation.

Free-run EMG: aggravation of the nerve root will produce a train of EMG activity

Direct nerve stimulation: stimulating a nerve root directly with a probe to determine the value in milliampoules (mA) required to produce a nerve action potential. A normal nerve will stimulate a low value, whereas an injured nerve will require a much greater stimulus to produce an action potential.

Pedicle screw stimulation: directly stimulating a pedicle screw to determine the stimulus required to produce a reaction in the nerve. A screw fully surrounded by the bone of the pedicle will require a high stimulus to provide a recording, whereas a screw with an inferior or medial breach will provide a recording at a much lower threshold. While variation exists in what represents a normal value, most centers use 7 mA as the threshold for what represents an acceptable value for a screw with no medial or inferior breach. Other centers remove and probe the hole of the screw with the lowest recording to determine the threshold value for the specific patient.

Managing Intra-Operative Neuromonitoring Changes

The changes observed in the neuromonitoring can be a result of 3 different scenerios:

- Direct trauma to the spinal cord
- Perfusion deficit to the spinal cord
- Technical issue with the neuromonitoring or anesthesia

Direct Spinal Cord Trauma: direct injury to the cord, either by placement of an implant, instrument, or a maneuver (ie. closing an osteotomy) can result in an acute drop in the neuromonitoring. Depending on the site of injury, this could be unilateral or bilateral, and may involve both the MEP and SSEP monitoring. The majority of these injuries will result in either a Brown Sequard, posterior cord or central cord syndrome depending on the mechanism of injury. For example, using a kerrison to remove the medial portion of the facet during a posterior column osteotomy at the concave apex, may result in a decrease in the MEP and SSEP signal on that side with normal signal on the other. Closing an osteotomy in extension can cause a central cord type injury with varying degrees of bilateral MEP and SSEP signal loss. Reversing the cause (ie. remove the misplaced implant, reopen the osteotomy) is important to perform at this stage to allow for spinal cord recovery. Use of intravenous steroids can be considered as an adjunct to reversing the cause.

Perfusion Injury to the Cord: Any maneuver, whether systemic or locally to the cord can affect the perfusion to the spinal cord. Placement of the rod, intra-operative traction, distraction maneuvers, may lead to stretch on the spinal cord and the anterior spinal artery impairing spinal cord perfusion. Similarly, hypotension, anemia and use of alpha sympathetic drugs can decrease the oxygen carrying capacity and circulation to the anterior spinal artery, impairing the anterior spinal cord perfusion. This will result in an anterior cord syndrome with bilateral decrease in the MEP signal with preservation of the SSEP signal. In this scenario, an attempt at improving the systemic perfusion through increasing the blood pressure, and blood transfusion may improve the spinal cord perfusion. If not, removing the rod, allowing the spinal cord to recover while addressing the systemic needs may allow for successful reimplantaion of the rod and completing the correction of the deformity.

Technical Issues: Issues with anesthetic agents or technical issues with leads or lead placements commonly result in intra-operative neuromonitoring changes. This can lead to significant frustration and may necessitate abandoning the procedure. Ensuring baseline signal is present prior to commencing the procedure, that upper extremity controls are in place, and communicating with the anesthesia team regarding the need for a TIVA anesthetic regimen, can help minimize these false positives that can greatly impact the surgery.

Understanding the basic neuroanatomy, the common patterns of incomplete spinal cord injury, and the modalities of neuromonitoring are key to understanding the meaning of intra-operative signal changes. Recalling the events that preceded the changes greatly helps to understand the causative event that may have resulted in the drop in the neuromonitoring. Addressing the causative factors will provide the safest possible environment in obtaining the desired surgical result.

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Lateral Approach can avoid Three Column Osteotomies: The Anterior Column Release Procedure (ACR).

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Anterior column release (ACR) is a procedure that allows for preservation or restoration of lordosis of the spine. This surgical technique can be performed Minimally invasive (MIS), Mini-open or Open. It provides similar correction outcomes in adult spinal deformity (ASD) as traditional posterior column osteotomy procedures, while at the same time potentially minimizing approach-related morbidities.

Before the introduction of the ACR technique, minimally invasive surgery in adult deformity was considered inadequate in complete restoration of sagittal spinopelvic imbalance and PI-LL mismatch. Circumferential MIS (cMIS) surgery was deemed appropriate only for patients with low pelvic tilt (PT), low pelvic incidence (PI), or purely coronal deformity correction. Since the introduction of ACR, a multitude of studies have shown that cMIS can be used in moderate to severe adult deformity with excellent SVA correction (+/- 5mm SVA) and PI-LL correction (+/- 10 degrees) when hyperlordotic cages are used. Further examination of segmental lordosis restoration showed that a combination of lengthening osteotomies (ACR) with ALL release and varying degrees of adjacent shortening posterior column osteotomies (PCO) can achieve even greater change in segmental lordosis and, therefore, restore regional lordosis and global sagittal balance.

Over the past half decade, an increasing number of publications have described the role of ACR in adult deformity and sagittal balance correction. Several studies have looked at the segmental change in lordosis in ACR with or without PCOs. Depending on the degree of adjacent posterior column resection, varying degrees of segmental correction can be achieved with ALL release and hyperlordotic cages. The biggest effect on the delta (the amount of segmental lordosis change) is the degree of preoperative segmental kyphosis, size of the cage used with ALL release (20 or 30 degree), and the amount of posterior column bony resection.

Traditionally, extensive multicolumn osteotomies were used to restore LL in adult spinal deformity. Recently, Schwab and colleagues organized posterior osteotomies into a comprehensive classification system in progressive order of complexity, destabilization, and gains in segmental lordosis. Within that classification system, 3-column osteotomies, encompassing pedicle subtraction osteotomies and corpectomies, provide the greatest amount of LL, often exceeding 25 degrees per level, but are very morbid. A recent historical review of 573 patients who underwent a 3-column osteotomy revealed that within the most recent time period of 2010 to 2013, major complications had an incidence of 39% and blood loss exceeding 4L occurred 16.7% of the time.

From the authors' patient cohort and within a growing body of literature, lateral ACR has demonstrated the ability to restore significant lordosis at approximately 10 degrees per level without posterior osteotomies. When combined with posterior osteotomies, which can be done in a minimally invasive fashion during placement of pedicle screws, further gains in segmental lordosis can be achieved.

A summary of the literature reporting radiographic changes associated with ACR, with or without various osteotomies, is summarized in Table 1. Depending on the type of osteotomy performed as well as the implant used, the amount of lordosis gained by lateral ACR can match 3-column osteotomies at either a single treated level or through sequential adjacent treated levels with lower blood loss and incidence of major complications. Furthermore, the limited results reported to date from lateral ACR seem durable. The alignment achieved in the authors' patient cohort is maintained over 20-months of follow-up despite a 16.4% incidence of subsidence across all treated levels.

Table 4
Overview of anterior column release segmental lordosis gains

Study	Type of Study	No. of Levels	Size of Interbody (°)	Segmental Lordosis Gained	Posterior Osteotomy
Present study	Clinical	26	30	11.7	None
Turner et al,[13] 2015	Clinical	24	20 and 30	9.9	None
Turner et al,[13] 2015	Clinical	7	30	15.4	Schwab 1
Present study	Clinical	29	30	17.3	Schwab 1
Melikian et al,[20] 2016	Cadveric biomechanical	13	30	10.5	Schwab 1
Melikian et al,[20] 2016	Cadveric biomechanical	13	30	26	Schwab 2
Turner et al,[13] 2015	Clinical	27	20 and 30	18.2	Schwab 2
Berjano et al,[12] 2015	Clinical	12	30	26	Schwab 2
Akbarnia et al,[21] 2014	Clinical	15	30	35	Schwab 2

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MIS Long Construct for Spinal Deformity

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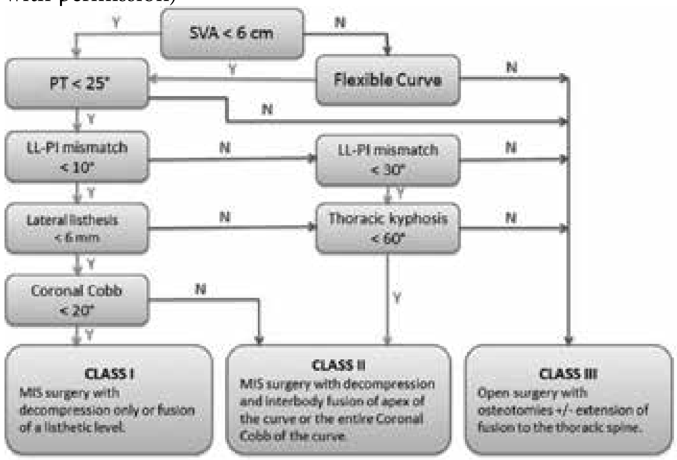
Introduction

- Adult Spinal Deformity (ASD) is becoming increasingly more common as the population ages
- ASD is a significant source of pain, morbidity, and disability
- Goals of treatment include:
  - Restoration of global alignment (both sagittal and coronal)
  - Neural element decompression
  - Solid fusion
- Alignment goals for spinopelvic parameters include:
  - Sagittal vertical axis (SVA) <6 cm
  - Pelvic tilt (PT), 20 degrees
  - Lumbar lordosis to pelvic incidence (LL-PI) mismatch +/- 10 degrees
- Determining which patients are appropriate for a minimally invasive approach vs open surgery can help to improve patient outcomes and hopefully decrease the need for revision surgeries
- MISDEF helps provide framework for surgical approach decision making
- As new MIS techniques are developed there has been opportunity in modify this algorithm to encompass these changes
- MISDEF 2 was developed as a response to the increasing numbers of new MIS approaches
  - Includes options of treatment for rigid and multilevel disease with longer constructs

MISDEF 1 Algorithm

- In 2014, Mummaneni and colleagues proposed MISDEF 1 algorithm
  - Systematically identifies patients appropriate for a minimally invasive approach
- The Dephi approach was used to evaluate agreement between experts
- All patients included were adults with ASD who had failed non-operative treatment
- Outcomes in the algorithm vary based on spinopelvic parameters and include minimally invasive surgery to open surgery
- Based mostly on traditional MIS techniques such as MIS-TLIF or LLIF or ALIF with percutaneous screws

MISDEF algorithm (Neurosurgical Focus 36(5):E6, 2014, used with permission)



Class I

- Patients with radiculopathy or neurogenic claudication
- Have canal stenosis, foraminal stenosis, or lateral recess stenosis
- Treatment involves MIS decompression or fusion at 1 level
- Goal is to treat the stenosis as opposed to treating global alignment

Class II

- Patients have symptoms from Class I, but also have deformity associated back pain
- Patients have disturbances of spinopelvic parameters
- Treatment involves MIS decompression with fusion at more than 1 level
- These constructs may extend over the coronal cobb angle/apex of the major curve

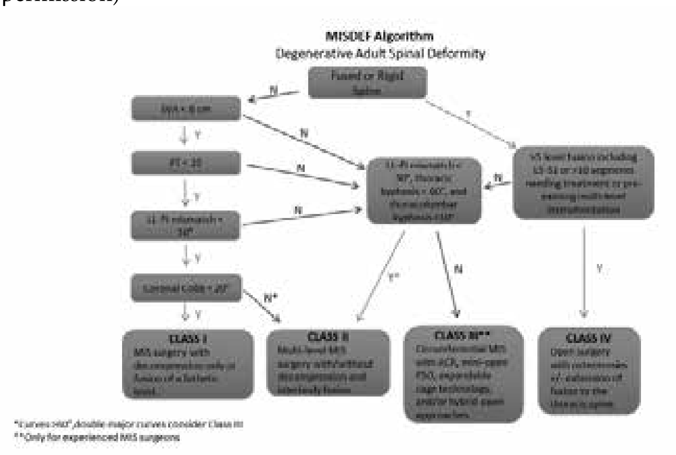
Class III

- Patients may have symptoms from Class I and II, but also have significant back and/or leg pain associated with rigid deformity
- Patients have severe disturbances in the spinopelvic parameters
- MIS approaches are not recommended

MISDEF 2 Algorithm

- Since the MISDEF 1 algorithm was proposed, new techniques have been developed and spinopelvic parameters have become better understood
- The revised algorithm to broaden the range of patients who may be candidates for MIS in light of new information
- The first factor addressed is whether the patient has a fixed or flexible deformity
  - If the deformity is flexible, patients fall into class 1 or 2
  - If the deformity is fixed, patients fall into class 3 or 4
- The Delphi method was used to assess agreement among senior surgeons regarding treatment

MISDEF 2 Algorithm (Neurosurg Clin N, 2018, in press, with permission)



Class I

- ➢ Patient have symptoms of stenosis with significant complaints of radicular pain
- ➢ Patients do not complain of significant back pain and have minimal deformity
- ➢ Typically have normal spinopelvic parameters
- ➢ MIS decompression with or without fusion at the affected level can be used

Class II

- ➢ Patients similar to Class I patients, but with disturbances of spinopelvic parameters
- ➢ Tend to have sagittal imbalance, but normal pelvic parameters
- ➢ Do not typically have a fixed deformity
- ➢ Multi-level MIS techniques can be considered

Class III

- ➢ Patients have more significant disturbances in spinopelvic parameters
- ➢ Tend to have increased SVA with LL-PI mismatch
- ➢ May have fixed deformities
- ➢ Do not have pre-existing hardware from prior surgery that needs revision
- ➢ Do not have a prior fusion of greater than 5 levels that encompasses L5-S1
- ➢ Should have 10 or fewer levels that need treatment
- ➢ May be treated with open surgery or consider circumferential new MIS techniques (like ACR)

Class IV

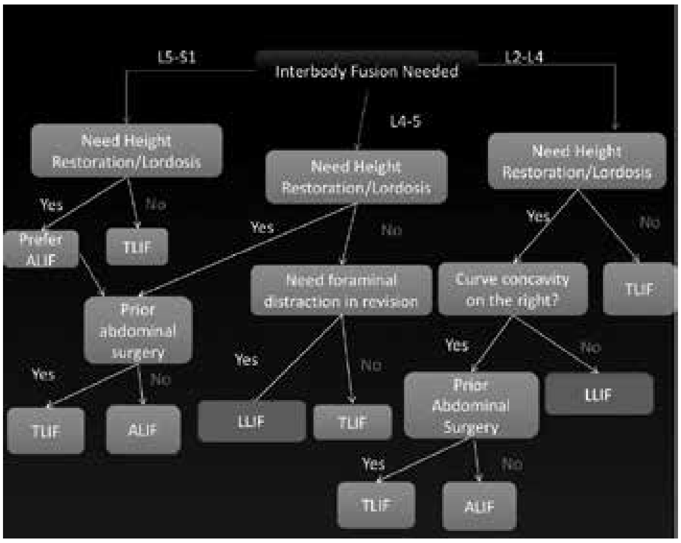
- ➢ Patients have significant deformity and disturbances of spinopelvic parameters
- ➢ Tend to have had prior surgery with hardware that requires revision
- ➢ May have had prior fusion surgery that includes more than 5 levels and incorporates L5-S1 into the construct
- ➢ Tend to require treatment for more than 10 level
- ➢ MIS techniques are not an option for these patients and open surgery should be considered

Long Constructs in MIS surgery

- ➢ Focus on patient from MISDEF 2 in Class II or Class III
- ➢ Goals is to place an interbody graft at every affected level to restore spinopelvic parameters
- ➢ Interbody grafts may be placed with combining MIS techniques
  - TLIF
  - LLIF (transpsoas or prepsoas)
  - ALIF
- ➢ Following interbody placement, percutaneous screws are placed posteriorly and a rod is passed

Technique Selection by Level

- ➢ L5-S1
  - Lateral approaches limited due to iliac crest, but may consider prepsoas on the left
  - Consider ALIF if:
    - Height restoration or lordosis is needed and no prior abdominal surgery
  - Consider TLIF if:
    - History of abdominal surgery
    - Not as effective at restoring disc height/lordosis
- ➢ L4-L5
  - Consider ALIF if:
    - Height restoration or lordosis is needed and no prior abdominal surgery
  - Consider TLIF if:
    - Height restoration/lordosis is needed, but with history of abdominal surgery
    - No height restoration/lordosis or foraminal distraction needed
  - Consider LLIF (transpsoas or prepsoas) if:
    - No height restoration/lordosis is needed, but foraminal distraction is needed
- ➢ L2-L4
  - Consider ALIF if:
    - Height restoration/lordosis is needed and curve concavity is to the right and no prior abdominal surgery
  - Consider TLIF if:
    - Height restoration/lordosis is needed and curve concavity is to the right, but with prior abdominal surgery
    - No need for height restoration/lordosis
  - Consider LLIF (transpsoas or prepsoas) if:
    - Height restoration/lordosis is needed and curve concavity is NOT to the right
    - Prefer lateral techniques if possible
      - ▫ Spares posterior spinal muscles (also)
      - ▫ Avoids retraction of great vessels
      - ▫ Allows rapid postoperative mobilization
      - ▫ Can place a large interbody graft
      - ▫ Can achieve sagittal and coronal deformity correction with high fusion rates



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Circumferential Minimally Invasive Surgery (CMIS) for ASD – The Cutting Edge

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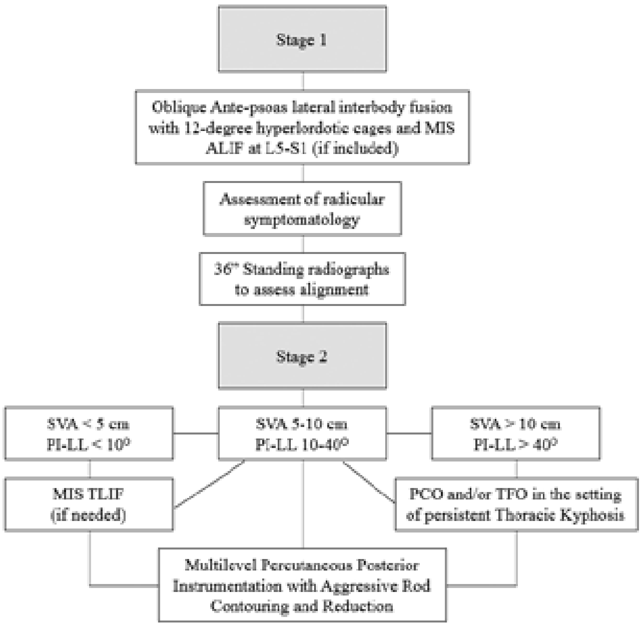
1. **Disclosures**
   - Consultant – Medtronic, Globus, GYS Tech
   - Speaker – DePuy Synthes, Stryker
   - Royalties –, Medtronics, Globus, Elsevier
   - SAB – Globus, GYS Tech, Theracell
   - Editor – Gray's Anatomy
   - Stocks/Stock Options – Medtronics, Globus, Atlas Spine, ParadigmSpine, Thercell, AF cell, Bonovo, GYS Tech
2. **MIS Strategies for Adult Scoliosis**
   - Trans-psoas Lateral (LLIF)
   - Oblique Ante-Psoas IF (OLIF)
   - MIS ACR
   - MIS TLIF
   - MIS ALIF
   - Transaxial lumbosacral interbody fusion
   - Multilevel Percutaneous Pedicle Screws
   - MIS Iliac Screws
   - MIS Transforaminal Osteotomies (TFO)
3. **Indications**
   a. Index ASD – Flexible or Stiff
   b. Avoid Rigid fused spines
   c. Consider Medical Co-Morbidities
   d. Treat the Symptoms
   e. Treat the Patient and not the Xray
4. **Case # 1 L.A.: Jan 2015**
   - 69 yr old Female Retired Singer
   - Severe back Pain 6 years
   - Progressive Deformity
   - Back 60 %, Leg 40 %
   - Neuro intact
   - Tried PT,Epidurals,CHiropractor, Acupuncture, Acupressure,
   - On hydrocodone past 6 montHs
   - On teriparatide 1 year
5. **Investigations**
   - Whole Spine X-rays (witH Femoral Heads) essential for Calculating sagittal and coronal balance and intersegmental deformities
   - MRI lumbar spine – Stenosis, L5-S1 status, UIV, vascular and Renal Anatomy
   - CT if any suspicion of fused levels
     – Vacuum disc, Fused anterior column or Facets)
   - Bone Density
     – If T-Score < -3 : NO MIS Surgery, placed on PTH Analogue
     – If Score between -2 & -3 : PTH Analogue and Surgery
6. **Coronal and Sagittal Parameters with Alignment Goals**
   - CobbT10 to L3 = 65 degrees
   - CVSL = 8 cm
     – Aim would be as close to 0 as possible

- PI / LL Mismatch - 51 degrees
  - – Aim would be to obtain 40 degrees more lordosis
- SVA - 22 cm
  - – Aim would be to bring SVA to 4 to 5 cm
- PT - 42
  - – Aim would be to keep to 20 -25

7. **Since 2011**
   - Trans-psoas to Ante-Psoas
   - Till then Lateral cages were 6^0 or 0^0
   - 12^0 lordotic cages available
   - Eliminated transaxial lumbosacral interbody fusion for L5-S1 ALIF
   - Contouring the rod was critical
   - Incorporated our staged protocol with interval Xray for handling sagittal balance
   - Refined Rod contouring with intra-op Reduction, Translation, and
   - Derotation
8. **Pre-op Planning**
   - 20-25 degrees at L5-S1 with an ALIF
   - 15 - 20 degrees at L4-5 with a 12^0 hyperlordotic lateral cage
   - - 15 degrees at L3-4, L2-3 and L1-2 with a 12^0 hyperlordotic lateral cage
   - We can get an avg of 8 degrees incremental lordosis at each level with 12 degree cages
   - Ref: **Neel Anand**, MD, Ryan B. Cohen, BS, Jason Cohen, BS, Babak Kahndehroo, MD, Sheila Kahwaty, PA-C, Eli Baron, MD: The Influence of Lordotic cages on creating Sagittal Balance in the CMIS treatment of Adult Spinal Deformity. Int. Journal of Spine Surgery, volume 11 issue 3 doi: 10.14444/4023, pages 183 – 192
9. **Stage 1**
   a. Oblique LIF L4-5, L3-4, L2-3 and L1-2 with PEEK cages and 3mg RhBMP2 per level
   b. Oblique LIF L5-S1 with PEEK cage, anterior plate abd fixation screws with 4mg RhBMP2
10. **Intervening Period**
   a. Patient encouraged to ambulate
   b. Indriect reduction confirmed by lack of claudcation or leg symtoms
   c. Standing Full length 36” Xrays taken 48 hrs later
   d. X-ray Coronal and Sagittal Parameters reassesed
   e. Fine Tune planning for Second Stage
11. **Stage 2**
   a. Naviagtion Assist
   b. T10 to Pelvis Posterior percutaneous pedicle Instrumentaion
   c. Rod Contouring, reduction, derotation and Translation
   d. Posterior Pars-Facet-Pars Fusion T10-11, T11-12, T12-L1 with local bone, DBM, 1mg RhBMP2 per pars-Facet-pars complex
12. **Today – Primary Adult Non-Fused Scoliosis - CMIS Rx**
   - Staged Surgical Protocol
   - No PCO
   - 12^0 lordotic Lateral Cages
   - ALL release not needed in Virgin Scoliosis
   - Staged reassessment of Interim Xray
   - Aggressive Rod Contouring and Reduction
13. **Optimal Balance**
   - Individual for Each Patient
   - Should not be a NUMBERS GAME!!!!
   - Calculate your Goals pre op
   - Understand Pelvic Parameters
   - Understand Procedural ability to correct
   - Application of appropriate Strategies
   - Avoid 3 CO in the elderly as much as possible
   - Reserve ACR for Distal Lumbar Fused patients with PJK
14. Optimal Outcome
   - Judicious Selection
   - Meticulous Planning
   - Strict Protocol
   - Precise Execution

Staged Surgical Protocol



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Smith Petersen / Ponte Osteotomy

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Indications and Techniques of SPO for Degenerative Spinal Deformity

Video session (2 SPO videos, 2 associated videos)

INTRODUCTION

1. In 1945, Smith-Peterson et al. first described the technique of posterior element osteotomy and posterior compression. In this technique, they used the disc space as a fulcrum to effect anterior column lengthening and posterior column shortening in the treatment of flexion deformities in individuals with “rheumatoid arthritis” and “ankylosing spondylitis”.
2. This technique involves the resection of posterior elements, including bilateral facet joints, part of the lamina, and the posterior ligaments at the osteotomy site.
3. Hehne et al. also described a “polysegmental lordosis osteotomy” with resection of a portion of the posterior elements at each level, producing a per-segment correction of about 10°.
4. The Ponte osteotomy as a modified technique advanced the SPO one step further removing both superior and inferior facets, the posterior ligaments, and more as indicated for Scheuermann’s kyphosis and adolescent idiopathic scoliosis.
5. Although Ponte osteotomy more directly captures the technique most commonly used today for posterior column osteotomies, the name Smith-Petersen osteotomy seems to have taken hold to describe the spectrum of posterior column osteotomies

INDICATIONS

1. The classic indication would be a long, gradual, rounded kyphosis as in Scheuermann kyphosis
2. Deformity with a mobile anterior column
3. Sagittal plane deformity, such as kyphosis
4. Symmetric shortening of the posterior column
5. Sagittal correction obtained per level
6. 10 to 15 degrees per level
7. 1 degree/mm of bone resected
8. Scoliotic deformity
9. Shorten the concavity, lengthen the convexity, and displace the patient towards the concavity
10. Deformity correction is required over multiple segments
11. Fixed angular deformity a relative contraindication

SURGICAL TECHNIQUE

1. Removal of the posterior ligaments (supraspinous, intraspinous, and ligamentum flavum) and facets to produce a posterior release
2. Compression of the osteotomy brings about kyphosis correction, although it does require a mobile disc space anteriorly
3. Compression leads to contraction of the neural foramina, which necessitates a preceding wide facetectomy to prevent nerve root impingement

4. Correction through rupture of the anterior tension band and resultant profound anterior lengthening
5. The disc space typically compresses posteriorly and expands anteriorly with a fulcrum.
6. Usually coupled with rod rotation maneuver, compression/ distraction and cantilever methods to make coronal or sagittal correction
7. Target lumbar lordosis was calculated by several formula.
8. SPO sometimes used with PLIF/ TLIF or Lateral interbody fusion

Surgical strategy chart for adult spinal deformity surgery

Level	1	2	3	4	5
Lower extremities pain	+	+	+	+	+
Low back pain (LBP)	—	+	+	+	+
Instability	—	+	+	+	+
Lumbar scoliosis >30 °	—	—	+	±	±
Smooth lumbar kyphosis	—	—	+	+	—
Sharp lumbar kyphosis	—	—	—	—	+
Sagittal imbalance (SVA>50mm)	—	—	+	+	+

Level I: Decompression
Level II: Decompression + Fusion
Level III: Ponte + Rod rotation (RR)
LIF+PCO
Level VI: PSO
Level V: PVCR

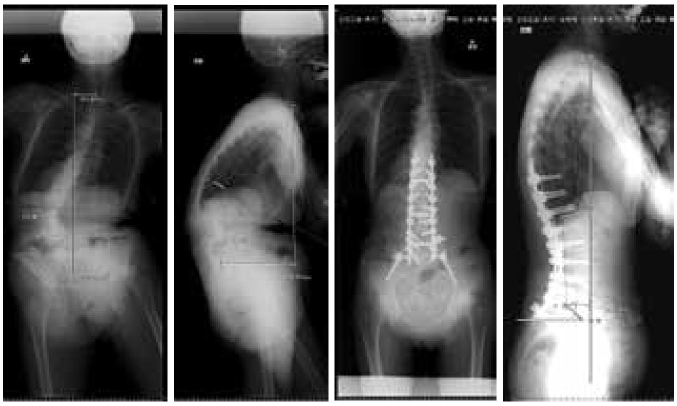

Level 3


Level 4


Level 5

TARGET LUMBER LORDOSIS

1. PI-LL<10
2. Ideal LL =0.45PI + 31.8
3. Ideal PT=0.47PI-7.5



TIPS OF SPO

1. Performing complex adult reconstructive surgery often needs 3CO rather than posterior column osteotomies and 3CO poses significantly more risk of neurological complications because of its complexity, exposure of neural element and spinal cord shortening.
2. Posterior correction after Ponte osteotomy without removal of yellow ligament is one of the reason of neurological complication due to bulking of yellow ligament.
3. Osteotomies should be performed with intraoperative neuromonitoring (MEP, SSEP, D wave etc).
4. Use osteotomy site to palpate medial wall of pedicle to aid in placement of pedicle screws
5. In prior fusion, use the transverse process, if present, to identify pedicle location
6. Clearly identifying the location of the pedicle on the concavity of a severe coronal deformity is critical for performing a Ponte osteotomy. This will prevent resection of the medial wall of the pedicle or resecting across the lamina to the neighboring foramen.

OUTCOME

1. 3 SPOs achieve degree of correction comparable to a single PSO
2. No difference noted in fusion rates
3. No difference in the Oswestry Disability Index
4. Pedicle subtraction osteotomy experienced greater sagittal plane imbalance correction
5. Pedicle subtraction osteotomies had a reduced risk of coronal decompensation
6. Ponte is fast, safe, and effective vs. more complex and destabilizing 3-column osteotomy (ie, pedicle subtraction osteotomy)
   Decreased blood loss
   Decreased OR time
   Decreased neurologic risk

CONCLUSIONS

Ponte / Smith Peterson osteotomy with Rod Rotation maneuver / LLIF achieve good correction and bony fusion for patients with degenerative kyphoscoliosis.

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Corner Osteotomy

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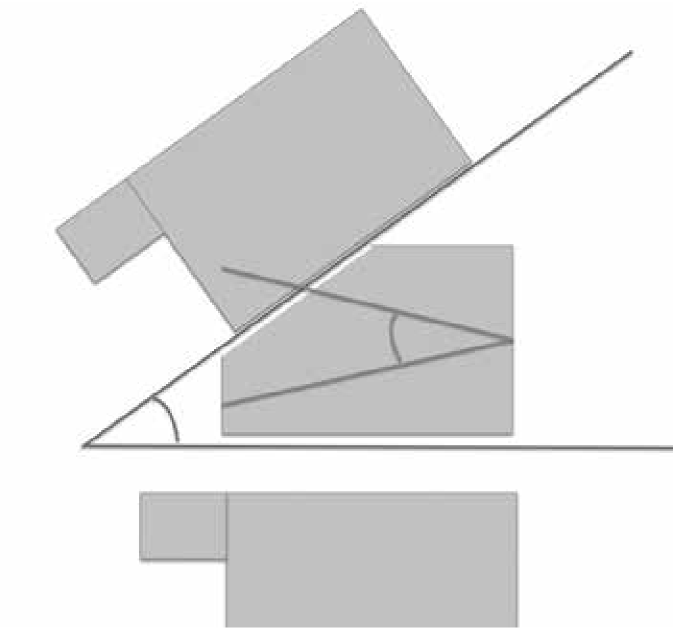
Introduction Sagittal imbalance is a spine deformity with multifactorial etiology, associated with severe low back pain and gait disturbance that worsen deeply patients' quality of life. The amount of correction achievable through PSO is limited by the height of the resection of the posterior wall, causing a ceiling of segmental correction of 30–35_. The aim of this study is to describe and preliminarily evaluate the results of an alternative technique, corner osteotomy (CO), that can increase the amount of correction.

Materials and methods From March 2012, every patient examined in our Division, diagnosed with sagittal imbalance to be treated with PSO, underwent CO and fusion. This technique consists in removing the posterior vertebral arch, the pedicle and the posterior–superior corner of the vertebral body; the inferior endplate of the vertebra above is prepared and the superior adjacent disc removed to obtain, when closing the osteotomy, a direct interbody fusion. Ten patients undergoing CO were compared with 20 patients undergoing PSO regarding spinopelvic parameters, operative variables, complications and degree of correction.

Results Patients undergoing CO obtained higher lordotic angle at the osteotomy than patients undergoing PSO (36.6_ ± 8.2_ vs 16.5_ ± 9.5_, p\0.001) and had lower postoperative PT and SVA and higher average increase in lordosis. Complications were similar between groups. A trend toward longer surgical time, greater bleeding and higher transfusion rate was observed in the CO group, though this finding could be related to higher complexity of cases or incidence of associated anterior approach.

Discussion and conclusions Corner osteotomy technique was more effective than the PSO in increasing segmental and lumbar lordosis with modest increase in blood loss and similar complication rate. The CO technique, in addition, proved a good reproducibility. Further studies with larger populations should confirm these preliminary results.



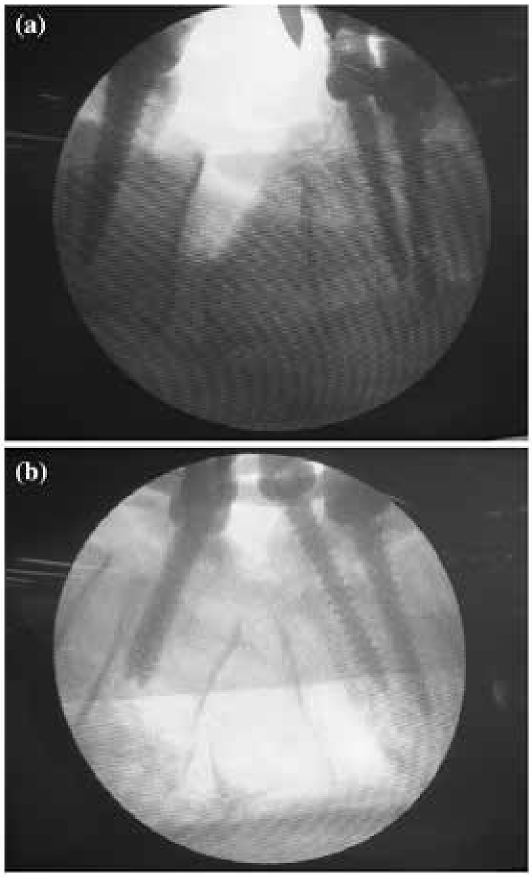


Fig. 5 **a** C-arm view after resection of the corner of L4. **b** After closure of the osteotomy

Asymmetrical Pedicle Subtraction Osteotomy in Ankylosing Spondylitis Patients with Thoracolumbar Kyphoscoliotic Deformity

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Objective To investigate the influence of asymmetrical pedicle subtraction osteotomy (APSO) on the reconstruction of coronal and sagittal balance in ankylosing spondylitis (AS) patients with thoracolumbar kyphoscoliotic deformity.

Methods Between October 2005 and June 2012, sixteen AS patients (13 males and 3 females) with a mean age of 35.4 years (range, 22-48 years) with thoracolumbar kyphoscoliotic deformity undergoing APSO were included in this study. Preoperative, postoperative and last follow-up full-length antero-posterior and lateral spine radiographs were available. Coronal and sagittal parameters were measured, including Cobb angle, central sacral vertical line (CSVL), global kyphosis (GK), sagittal vertical axis (SVA), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic tilt (PT), sacral slope (SS), and pelvic incidence (PI). SF-36 questionnaire was used to evaluate the quality of life of AS patients. The preoperative and postoperative data were compared by paired sample *t* test.

Results The average time of follow-up was 36 months (range, 24-63 months). The mean Cobb angle was improved from 25.8°to 7.6°, and the correction rate was 70.5%. The CSVL was corrected from 5.6 cm to 1.8 cm. The mean GK was corrected from 76.8° to 25.6°, and the correction rate was 66.7%. The SVA was restored from 15.1 cm to 3.8 cm. In addition, LL, PT, and SS were improved from -0.4°, 33.6°, and 10.3° to 44.1°, 22.6°, and 20.9°, respectively. In terms of Cobb angle, CSVL, GK, SVA, LL, PT, and SS, no significant differences were observed. The scores of bodily pain, general health, social and emotional functioning were significantly increased at the last follow-up.

Conclusion AS patients with thoracolumbar kyphoscoliotic deformity have both sagittal and coronal imbalance with impairment in quality of life. APSO can achieve successful realignment of biplanar balance by correcting thoracolumbar kyphosis and scoliosis simultaneously, and improve the quality of life in AS patients with kyphoscoliotic deformity.

Vertebral Column Decancellation

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Background
Milestones in the surgery of complex spine deformity are the introduction of spinal osteotomy techniques. The Main surgical strategies are neurological decompression, deformity correction, and fusion. Over the past decades, osteotomies ranging from smaller facetectomies to major three-column resections have been widely used in clinical practice. Now, Smith-Petersen osteotomy (SPO), Pedicle subtraction osteotomy (PSO) and Vertebral column resection (VCR) are commonly used osteotomy methods[1]. As a combination of several osteotomy techniques, vertebral column decancellation (VCD) is a new spinal osteotomy that incorporates the eggshell technique, SPO, PSO, and VCR.[2] (Fig 1)This technique is characterized by controlled anterior column opening, posterior column closing, and middle column preservation as the hinge, which is a 'Y' -shaped osteotomy.

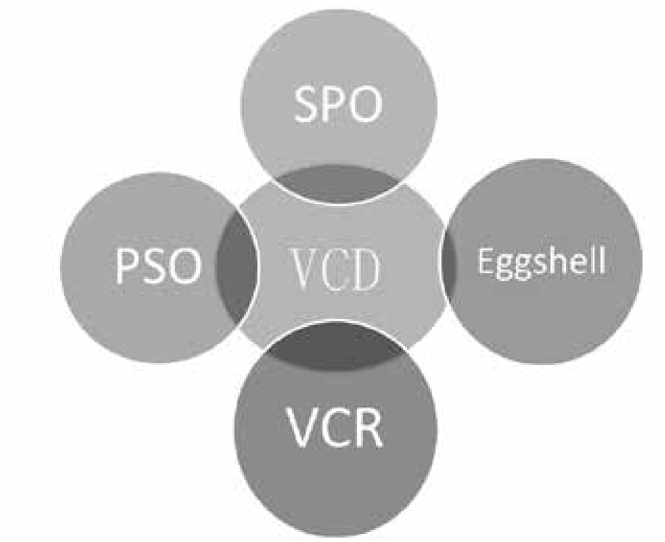

Fig 1. VCD osteotomy is a spinal osteotomy as a combination of several osteotomy techniques including the eggshell technique, SPO, PSO and VCR

Surgical procedures
After confirming the appropriate insertions for osteotomy plane using C-arm fluoroscopy, the spinal canal was opened laterally, and the posterior elements including the spinous process, bilateral lamina, transverse process, and the adjacent facet joints at the vertebra to be osteotomised were removed as needed.

The VCD osteotomy was then performed (Fig 2).

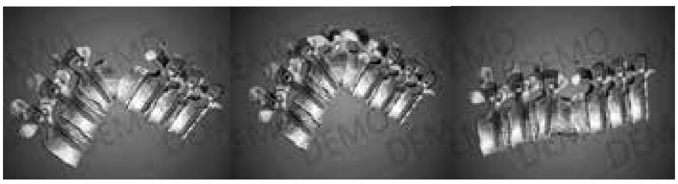

Fig 2. VCD for spinal kyphosis.

The pedicle probe and drill were used to create and enlarge pedicle holes of the target vertebra with both sides of the pedicles. Through the pedicle holes, the decancellous procedure was then performed within the posterior half of target column using rongeur and curette. The posterior cortical bone of the osteotomised vertebra was removed bilaterally with a Kerrison rongeur. A high-speed drill was used to make thinning of the anterior cortex and lateral walls of vertebral body, and osteoclasis of the anterior cortex and lateral walls then achieved using gentle manual extension when closing the posterior wedge space. In this procedure, an anterior opening wedge was created. The middle column was preserved as the hinge.(Fig.3)

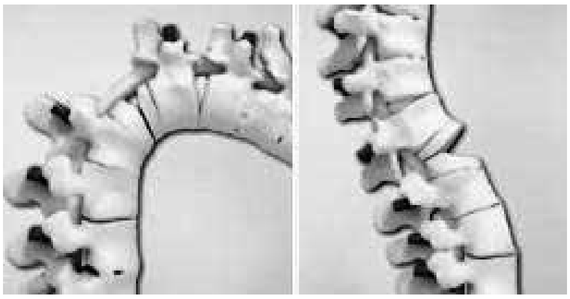

Fig.3. The posterior wedge space was closed and anterior opening wedge created simultaneously.

The operating table and the position of the patient were adjusted for the correction. The technique is a 'Y' –shaped osteotomy rather than 'V'–shaped osteotomy(PSO), which results in relative shortening of the posterior column, and appropriate opening of the anterior column. the residual bone was used to reconstruct a "bony cage" to take the place of metal mesh described in VCR techniques[3].

To close the osteotomy, a precontoured rod (Rod A) was first locked into the inferior screws, and the contralateral rod (Rod B) was locked into the superior screws. Rod A was then cantilevered into the superior screws with gentle manual force by the surgeon, and Rod B was simultaneously cantilevered into the inferior screws by an assistant.(Fig.4) It is worth noting that the bending point of the rods should be in line with the osteotomy site to maintain biomechanical stability.

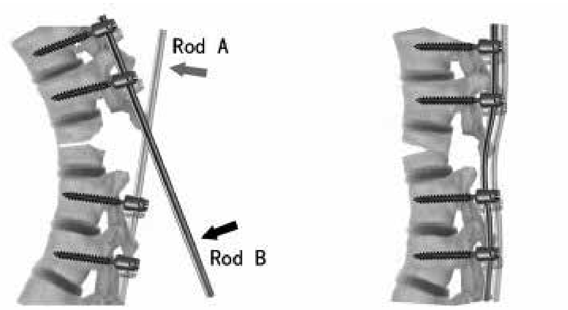

Fig.4. To close the osteotomy, Rod A was cantilevered into the superior screws with gentle manual force and Rod B was simultaneously cantilevered into the inferior screws.

This new spinal osteotomy has been widely used in kyphotic deformity secondary to ankylosing spondylitis[4], sharp angular spinal deformity in Pott's disease[5] ,congenital kyphoscoliosis and so on.(Fig.5 and Fig.6)

Fig 5. vertebral column decancellation for thoracolumbar kyphotic deformity (TLKD) secondary to ankylosing spondylitis (AS).

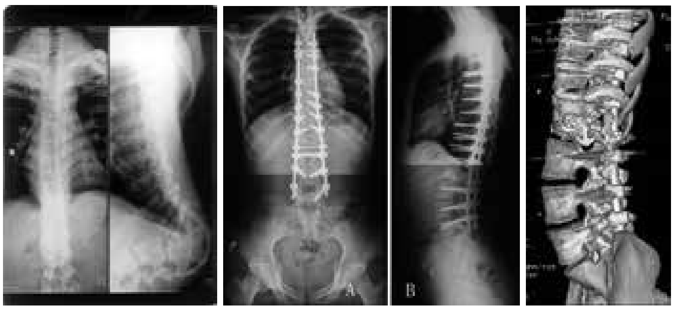

Fig 6. vertebral column decancellation for sharp angular spinal deformity.

Advantage of Vertebral Column Decancellation
During the procedure of vertebral column decancellation technique, The anterior and middle of vertebra was removed as less as possible, the osteotomy gap was decancellated like shape "Y" rather "V", Preserving more middle and posterior column made less bone resection, less spine cord shortening. The residual bone may take the place of metal mesh described in the VCR technique, served as a "bony cage" and leverage , which prevent sagittal translation during reduction.

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2. Wang Y, Zhang YG, Zhang XS, Wang Z, Mao KY, Chen C, et al. Posterior-only multilevel modified vertebral column resection for extremely severe Pott's kyphotic deformity. European Spine Journal. 2009;18(10):1436
3. Zhang X, Zhang Z, Wang J, Lu M, Hu W, Wang Y, et al. Vertebral column decancellation: a new spinal osteotomy technique for correcting rigid thoracolumbar kyphosis in patients with ankylosing spondylitis. Bone Joint J. 2016;98-

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5. Wang Y, Lenke LG. Vertebral column decancellation for the management of sharp angular spinal deformity. European Spine Journal. 2011;20(10):1703-10

POSTERIOR VERTEBRAL COLUMN RESECTION

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Surgical treatment of complex adult spinal deformities (severe, rigid, angular) is challenging. Management of more severe, angular deformity causing severe decompensation warrants more challenging osteotomies that enable correction in all planes. PVCR is the most extreme posterior only approach osteotomy that provides the most complete mobilization of the spine for deformity correction in all planes, and is useful for deformities with very significant sagittal or coronal imbalance.

Indications of the PVCR are;
- Severe rigid congenital scoliosis, kyphosis, kyphoscoliosis, lordosis, lordoscoliosis with or without intraspinal anomalies
- Adult deformities (scoliosis, kyphosis, kyphoscoliosis, lordoscoliosis)
- Posttraumatic, postinfectious kyphosis, kyphoscoliosis
- Vertebral fracture with neurologic deficit
- Resectable spinal tumors
- Spondyloptosis
- Revision surgery;
  - gradual multilevel rigid deformity due to multilevel pseudoarthrosis,
  - flat back syndrome,
  - crankshaft phenomenon,
  - adding on or decompansation due to previous surgery for deformity,
  - postlaminectomy severe sharp angular kyphosis,
  - severe and rigid pelvic obliquity in neglected congenital scoliosis with or without intraspinal anomaly having previous surgery.

Advantages of PVCR
- Avoids the patient from the morbidities of thoracotomy or thoracoabdominal approach
- Technically dificult, but applicable in cervicothoracic and upper thoracic spine
- Safely used in more than one level vertebra resection

Disadvantages of PVCR
- Technically difficult in lumbar spine as nerve root preservation is mandatory
- Especially T11 and T12 nerve roots must be preserved for abdominal muscle innervation
- Bleeding from epidural vessels may be problematic
- The rate of dural tear and related neurological injury is higher compared to combined approach

Surgical Technique
- Insertion of pedicle screws
- One side temporary rod placement without any attempt at correction
- Start from the concave side
- Wide laminectomy (one level above and one level below the resected level), removal of rib heads and pedicles

Half-Day Course

- Sacrification of thoracic nerve roots bilaterally (T2-T10)
- Protect T11&T12 nerve roots for abdominal muscle innervation

Correction Technique;
Different correction techiques must be used for each scoliosis, kyphoscoliosis and lordoscoliosis deformity following PVCR.

Correction of scoliosis deformity;
- We prefer to use reduction (long-arm) screws on both side to correct scoliosis deformity.
- Temporary mesh cage, with height equal to the concave gap distance, is placed at the osteotomy site from the concave side.
- This cage will prevent any sudden shortening and translation of the spinal column, as well as any neurological deficits during correction.
- Temporary rod must be kept loose on the convex side.
- Give proper sagittal contour to the rod
- Place and lock the rod into the most distal 2 screws on the concave side at the exact sagittal plane.
- Scoliosis correction is achieved with translation over the reduction screws segment by segment.
- During translation you can also correct rotation segment by segment
- After concave side reduction, remove the temporary rod on the convex side and place the final convex rod.
- If you need more correction you can change concave rod with a new rod.
- Take control x-ray for alignment and check the resection gap.
- Remove the temporary cage and place the final cage.
- According to control x-ray you can do segmentary compression and distraction for deformity correction.

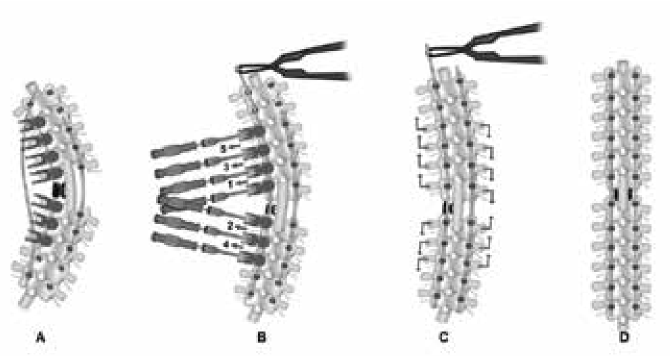

Figure 1: Correction of scoliosis deformity

Correction of kyphoscoliosis deformity;
- Correction technique should include ***anterior column lengthening with gradual sequential posterior compression.***
- Place a temporary rod and a temporary cage on the concave side.
- Placement of a cage anteriorly avoids translation of the spinal cord and column and prevents iatrogenic neurological deficit.
- Following compression from the convex side, the temporary cage is changed with a larger cage and additional compression is applied posteriorly.
- The temporary cage is removed in the next step and the anterior gap is lengthened using the speader from the concave side.
- A larger temporary cage is placed in the distracted anterior gap and additional compression is applied from the convex side to achieve more correction
- Anterior lengthening and posterior compression maneuvers are repeated 3 to 5 times sequentially until ideal correction is achieved.
- Next, expandable cage is placed at the osteotomy site and intraoperative AP and lateral x-rays are taken to confirm the final correction

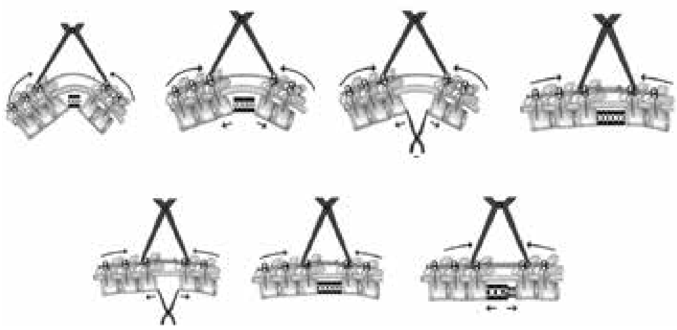

Figure 2: Correction of kyphosis / kyphoscoliosis deformity

Correction of lordosis / lordoscoliosis deformity
- Reduction pedicle screws (long arm) were used for both sides
- A hyperkyphotic rod was placed for the first attempt of correction at the concave side.
- Initial reduction start gradually from concave side at the proximal and distal screws closest to the osteotomy level. This provides lordosis and scoliosis correction.
- Additional kyphosis can be achieved with in-situ benders
- Change the concave side rod couple of times with new more kyphotic rod since adequate correction was achieved.

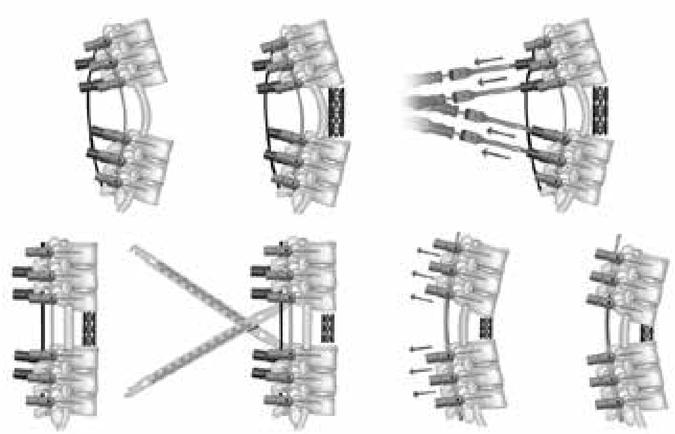

Figure 3: Correction of lordosis / lordoscoliosis deformity

Correction of the severe rigid pelvic obliquity in neglected congenital scoliosis
The rigid pelvic obliquity can be corrected when more than one level vertebrectomy is performed with PVCR at T12-L1 level or lower lumbar level.
- Temporary fixation of the osteotomy level to avoid any translation
- A mesh cage was placed at the osteotomy site to avoid dural buckling
- Distal rods were fixed and pelvic obliquity was corrected with cantilever manevuer as the first step.
- Residual pelvic obliquity was corrected with gradual compres-

sion and in-situ bending maneuvers from the lower side of pelvis.

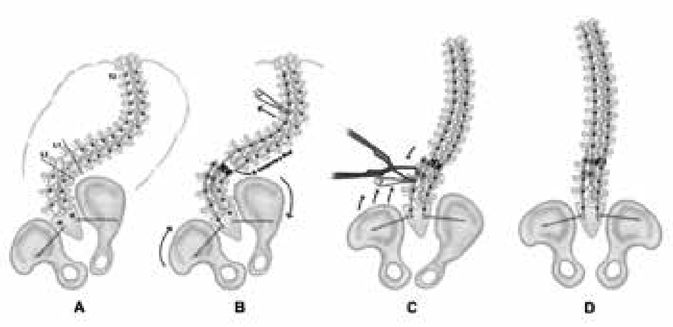

Figure 4: Correction of the severe rigid pelvic obliquity in neglected congenital scoliosis

Reconstruction of laminectomy following PVCR

- H-shaped femoral strut allograft can be placed between the intact spinous processes over the laminectomy defect.
- The cross-bars placed between the rods and over the strut graft increase the stability and prevent the graft dislodgement.
- Local autografts are placed underneath and over both ends of the graft to promote fusion.
- The strut allograft will provide a rigid barrier over the dura and prevent spinal cord compression due to hematoma or scar tissue formation

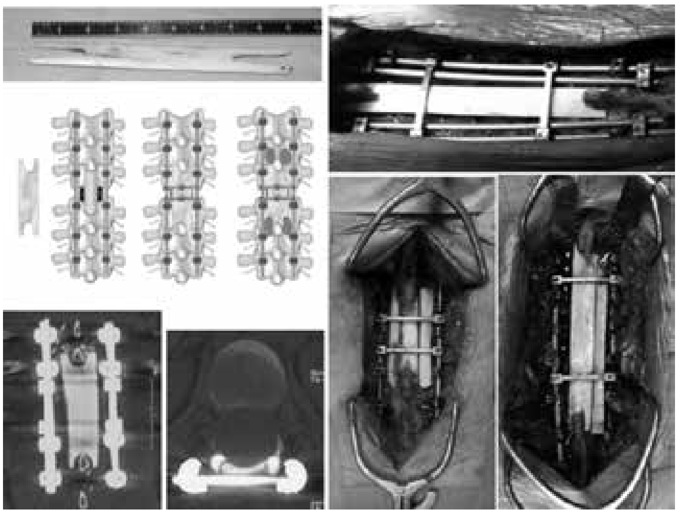

Figure 5: Reconstruction of laminectomy defect following PVCR

Conclusion

Severe spinal deformities can be effectively corrected by PVCR. Among all other osteotomy types, PVCR provides the greatest amount of correction with circumferential subperiosteal exposure of vertebral body and complete resection of one or more vertebral segments. Different corrections techniques must be used to achieve ideal correction for scoliosis, kyphoscoliosis, lordoscoliosis deformity and rigid pelvic obliquity following PVCR. Although PVCR is a technically challenging procedure, complications can be minimized and satisfactory results can be achieved with meticulous surgical technique and appropriate correction technique following PVCR.

Sharing Our Best Global Algorithms for the Treatment of Complex Spinal Deformity

Room: Sala Italia

Course Chairs:
Ahmet Alanay, MD and Rajiv K. Sethi, MD

Faculty:
Todd Albert, MD; Benny T. Dahl, MD, PhD, DMSci; Marinus De Kleuver, MD; John R. Dimar II, MD; Mario Di Silvestre, MD; Ron El-Hawary, MD; Nicholas Fletcher, MD; Sajan K. Hegde, MD; Manubu Ito, MD, PhD; Michael P. Kelly, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Sergey Kolesov, MD; Kenny Kwan, BMBCh(Oxon), FRCSEd; David Marks, FRCS, FRCS (Orth); Jwalant Mehta, FRCS; Luis Munhoz Da Rocha, MD; Francisco Javier Sanchez Perez-Grueso, MD; Bangping Qian, MD; Suken A. Shah, MD; Kushagra Verma, MD, MS; Michael G. Vitale, MD, MPH; Theodore Wagner, MD; J. Michael Wattenbarger, MD

Sharing Our Best Global Algorithms for the Treatment of Complex Spinal Deformity

Chairs: Ahmet Alanay, MD and Rajiv K. Sethi, MD

Part I: Challenges in the Delivery of Complex Spine Care around the World

Moderator: Rajiv K. Sethi, MD

15:00-15:01 **Introduction to the New Paradigms in Global Complex Spine Care**
Rajiv K. Sethi, MD

15:01-15:05 **Perspectives of the SRS Worldwide Course Committee Chair**
Benny T. Dahl, MD, PhD, DMSci

15:06-15:11 **Perspectives of the SRS Safety and Value Committee Chair**
Michael G. Vitale, MD, MPH

15:11-15:16 **The Global Burden of Advanced Spinal Disease: Challenges and Strategies to Increase Access**.
Theodore A. Wagner, MD

15:16-15:21 **When Good Intentions Lead to Bad Results: Avoiding Pitfalls in Global Outreach**
J. Michael Wattenbarger, MD

15:21-15:25 **Discussion**

Establishing Care with Limited Resources: Learning from BRIC

15:25-15:29 **Brazil**
Luis Munhoz Da Rocha, MD

15:29-15:33 **Russia**
Sergey Kolesov, MD, PhD

15:33-15:37 **India**
Sajan K. Hegde, MD

15:37-15:41 **China**
Bangping Qian, MD

15:41-15:55 **BRIC Panel Discussion**
Panel: *Sajan K. Hegde, MD; Luis Munhoz Da Rocha, MD; Kenny Kwan, BMBCh(Oxon), FRCSEd; Bangping Qian, MD; Sergey Kolesov, MD, PhD*

Part II: What Can We Learn From Each Other on Best Practices? A Case Based Discussion

Moderator: Ahmet Alanay, MD

15:55-16:15 **Congenital Scoliosis Case Presentation**
Panel: *John R. Dimar, II, MD; Ron El-Hawary, MD; Sajan K. Hegde, MD, Nicholas Fletcher, MD; J. Michael Wattenbarger, MD*

16:15-16:35 **AIS Case**
Panel: *Luis Munhoz Da Rocha, MD; Mario DiSilvestre, MD; Michael P. Kelly, MD*; *Francisco Javier Sanchez Perez-Grueso, MD*

16:35-16:55 **Adult Deformity Case**
Panel: *Todd J. Albert, MD; Kushagra Verma, MD, MS; Eric O. Klineberg, MD; Jwalant Mehta, FRCS*

Part III: Maintaining Quality and Value Despite Declining Budgets

Moderator: Rajiv K. Sethi, MD

16:55-17:00	**Maintaining High Quality Spine Care Despite Declining Budget: The NHS Example** *David S. Marks, FRCS, FRCS(Orth)*
17:00-17:05	**What Are the Challenges for Quality and Value in a High Performing European Health Care System?** *Marinus De Kleuver, MD, PhD*
17:05-17:10	**What Are the Challenges for Quality and Value in a High Performing Asian Health Care System?** *Manabu Ito, MD, PhD*
17:10-17:15	**What Are the Challenges for Quality and Value in a High Performing North American Health Care System?** *Han Jo Kim, MD*
17:15-17:20	**What Are Some Strategies for Managing AIS in a Bundled System?** *Suken A. Shah, MD*
17:20-17:25	**What Are Some Strategies for Managing ASD in a Bundled System?** *Rajiv K. Sethi, MD*
17:25-18:00	**Panel Discussion/Audience Discussion** Panel: *Todd J. Albert, MD; Benny T. Dahl, MD, PhD, DMSci; Marinus De Kleuver, MD, PhD; Manabu Ito, MD, PhD; Han Jo Kim, MD; David S. Marks, FRCS, FRCS(Orth); Suken A. Shah, MD*

Perspectives of the SRS Worldwide Course Committee Chair

Benny T. Dahl, MD, PhD, DMSci
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Globalization of the SRS
- 1966 37 members, 1 annual meeting, only US members
- 2017 > 1300 members, 61 countries, 1/3 non-US members

Countries represented in the WWC
- Argentina
- Brazil
- Canada
- China
- Czech Republic
- Egypt
- France
- India
- Japan
- Turkey
- UK
- United States

Activities of the WWC
- Traditional WWC courses
- Current Concept Courses
- Hands-on-courses

Primary collaborating partners in SRS
- Core Curriculum Task Force
- Education Committee
- Global Outreach Committee
- Long Range Planning Committee
- Education Council

The SRS Learning Pyramid

Primary changes of the WWC over the last three years
- The safety of complex spine surgery has been prioritized as a recurrent theme.
- The aspect of value-based health care has been implemented in the WWC activities, acknowledging differences in health care systems and ressources around the world

Perspectives for the next 5 years of the WWC activities
- Increasing implementation of needs assessment in the planning phase of each course
- Further implementation of the core curriculum in course activities
- Continue to explore options of WWC activities in regions where the presence of SRS has not been significant

Conclusion

The SRS has successfully implemented the strategy of being the leading global society for treatment of patients with spinal deformities. The activities of the WWC serve as a platform ensuring that the algorithms for the treatment of this patient group can be developed based on the local and regional ressources available.

Perspectives from the Chair of SRS Committee on Safety and Value

Michael Vitale, MD, MPH
Children's Hospital of NY Presbyterian
New York, New York, USA

1) Scope of the Problem / Why Have this Committee?
- Safety
- Value

2) "Adapt or Perish"

3) The Way Forward
- Education
- Standardization
- Organizational Infrastructure
- Benchmarking
- Credentialing

Global Burden of Spine Disease

Theodore Wagner, MD
Department of Orthopaedics &
Sports Medicine
University of Washington
Seattle, Washington, USA

1. **"Burden of Disease"**
   a. How to get at data?
      i. Chris Murray – The Lancet
2. **Classification of spine problems**
   a. Congenital – acquired further deformity
   b. Acquired – scoliosis, kyphosis
   c. Traumatic – with or without spinal cord injury
   d. Associated – Parkinson's, MS, diabetes
   e. Degenerative – cervical, lumbar
3. **Access**
   a. Domestically
   b. Internationally
      i. Privileged world vs. less privileged world
   c. Crises
      i. War
      ii. Earthquake
      iii. Flooding
      iv. Nuclear event/radiation
4. **Cost**
   a. Business of orthopaedics and spine instrumentation
5. **Spine instrumentation**
   a. US and European instrument companies
      i. excellent quality of metallurgy
   b. 2nd world instrumentation
      i. often very adequate BUT:
         1. unoriginal designs
         2. inconsistent metallurgy
         3. poor junctions
   c. solutions at the local level
      i. arise from a "need" + ingenious surgeon with an invention to address problem
      ii. hampered by:
         1. metallurgy
         2. manufacturing facilities
         3. need for non-implantable tools
         4. may be non-original design
      iii. but these are often most cost effective solution
6. **Safety**
   a. Anesthesia
   b. Spinal cord monitoring
   c. Post-op rehab
      i. Wheelchairs
      ii. Crutches
      iii. Medications
   d. Little to no data
7. **Crisis spine**
   a. Big crisis – UN/WHO
      i. But difficult to mix surgeons and instruments
         1. Clever surgeons find a way to learn/relearn a technique while maintaining principles of patient care

8. **Suggestions**
   a. SRS
      i. Colleagues
      ii. Source of expertise
      iii. Source of outcomes and clinical safety
      iv. A global lobby for spine care based on real data

When Good Intentions Lead to Bad Results: Avoiding Pitfalls in Global Outreach

J. Michael Wattenbarger, MD
Shriners Hospitals – Greenville
Greenville, South Carolina, USA

Crisis versus development

- Most Healthcare missions focus on short term trips and provide a crisis response to a situation that needs investment and development.

Where aid has hurt

- Dead Aid
  - In the last 50 years over $1 trillion USD has been given in aid to Africa. Yet, during this time poverty rates have increased in Africa. The author also notes that those countries that have refused or limited aid, South Africa, are in better economic shape. (Moyo 2009)
- Operation Smile(SEAGER 2012)
  - Deaths in malnourished children exposed a lack of quality control and the wrong emphasis – quantitiy over quality
- Effect on local health care
  - Short term outreach trips can cause economic harm and undermine local healthcare delivery
  - Operation smile response
    - The question was asked – "Why is there a different standard of care for these patients than back home."
    - They changed their focus from quantity, e.g. how many children did we operate on to a focus on quality and process.
    - They responded with a change in culture
      - First do no harm
      - A culture of safety and process improvement

Economic Impact of donated services/goods

- Local physicians
  - Free care may impact their ability to take care of private patients which can be a vital source of income.

Cultural

- Haiti experience
- Understand the local economics of healthcare
  - What do the patients have to pay for? Implants? Antibiotics? Diagnostic Testing?

Avoiding pitfalls

- Focus on development
  - Partnership versus paternal approach
  - Involvement of NGO's
  - Involvement of local healthcare infrastructure
  - Asset assessment versus needs based assessment
- Understand the economic impact on the local healthcare community

Spinal Global outreach – Avoiding pitfalls

- Look for mentors
- Invest in development of the local healthcare system.
- Start slowly – First do no harm
- Develop systems and processes
  - Complication recording and reporting
  - Quality control

    - Screening – The right patient in the right place.
- If you are going to do surgery
    - Are there locals who can manage complications after you are gone?
    - Is this surgery you would do at home?
        - Yes
            - Would you do it in another hospital with a team you had never worked with before?
            - Do you have all the support equipment you need?
        - No –
            - Don't do it on an outreach trip.

SRS Global Outreach program definitions

- ***Stable Ortho or Neurosurgical infrastructure****: Site has the minimal infrastructure (OR and immediate postoperative care equipment) required to perform general orthopedic or neurosurgical activity safely. >50 ortho or neurosurgical cases/year done safely.*
- ***Stable Spine Surgery infrastructure****: Site performs >24 spine surgeries / year safely (with or without IONM)*
- ***Stable Spinal Deformity infrastructure****: Site performs >24 deformity surgeries / year safely (IONM)*

References

Moyo, D. (2009). DEAD AID: WHY AID IS NOT WORKING AND HOW THERE IS A BETTER WAY FOR AFRICA. NEW YORK, NEW YORK, FARRAR, STRAUS AND GIROUX.

SEAGER, G. (2012). WHEN HEALTHCARE HURTS: An Evidence Based Guide for Best Practices In Global Health Initiatives. Bloomington, IN USA, AuthorHouse.

Helpful links

SRS – GOP (Description of program with links): - https://www.srs.org/professionals/global-outreach-program

Establishing Care with Limited Resources in Brazil

Luis Munhoz Da Rocha, MD
Hospital Pequeno Principe
Curitiba, Brazil

Giving appropriate care for patients with spine deformity is a challenge for any developing country. I will use as an example our practice at Hospital Pequeno Principe, in the city of Curitiba, state of Parana, south of Brazil. This institution has a peculiarity, because it's a private non profitable charity hospital. There, it is possible to treat private, insured and referred patients from the national health public system, that I will be using as an example of how to take care of patients with safety aiming equality on the treatment given.

The national health service pays a fixed amount for patients being treated of a spine deformity;

- Medical fee is fixed US 300,00 for the whole team including the anesthesiologist and the pediatrician when needed. It doesn't mater the extent of surgery, if it is a 8 level fusion or a 17. Hospital fees are also fixed and if the patient stays longer it is going to generate a deficit.
- The payment of implants is done according to the extent of surgery, and the amount is established at a fixed price of US120,00 per screw that is barely the same value insurance companies pays for private patients. This is a reason why we have the same quality of implants as insured patients.

We manage patient care with complex spine deformity, with appropriate work up before being admitted, checking for malnourishment, pulmonary and heart function, skin problems and urinary tract infection.

The proposal has been to reduce hospital stay, implants used per case, necessity of blood products and complications. How?

- Reducing the need of blood products, using tranexamic acid 50mg/ kg in the beginning of anesthesia and 10 mg/kg per hour until the leave the recovery room to the ward (idiopathic case), decreasing the need of ICU for post operatory care. We now use ICU only for syndromic and neuromuscular patients
- Taking the patient out of bed on the first day, reducing the use of opioids.
- It is a routine to use before starting the skin incision, intrathecal injection of 5mcg/kg morphine associated with 2 mcg/kg of clonidine. Using these measures we have been able to discharge patients between the 3rd and 5th day post operatory depending of how far they live. Obviously the pre, per and post operatory attention to syndromic and neuromuscular patients is higher. There is a physician specialized in taking care of them and when facing any inappropriate evolution a multidisciplinary team will be called. The average hospital stay is 7 days.
- The goal is almost the same as private institutions aim in the US and Europe.

However part of the cost is covered by the foundation that runs the hospital. According to the Brazilian law if a private institution dedicates 70% of its practice to referred national health patients, the institution can receive anticipation of income tax that is going to be paid next year to the federal government, as manner of covering the extra expenses that result in the end.

Establishing Care with Limited Resources: Russia

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<u>Spine surgery in Russia</u>

- ❖ Population of Russia – 147 000 000 with almost 80% urban population.
- ❖ The Constitution of the Russian Federation provides all citizens the right to free healthcare.
- ❖ More than 50 doctors and 100 beds per 10,000 people.

Currently three independent healthcare systems coexist:

- ❖ **Federal** – realizing the federal program aimed at organization, research and monitoring of the wellbeing of the Russian population as well as provision of highly specialized state-of-the-art medical care.
- ❖ **Municipal** – organization and provision of primary and some specialized medical care as well as quality control of medical care offered by other systems.
- ❖ **Private** – privately owned medical care services.

Obligatory and voluntary health insurance create conditions for effective development and coexistence of the three systems.

Administrative structure of healthcare system in Russia

Municipal → City → Regional → Federal
Because most of the healthcare costs are funded by regional budgets, health standards and statistics vary significantly across the country's economically diverse regions.

There is a hierarchy of different types of hospitals and healthcare clinics in use.

First level institutions providing primary health care to the population in cities and rural areas. These are outpatient clinics, precinct rural hospitals, antenatal clinics, paramedical and obstetrical centers, and emergency medical services. The main principle of their work is the provision of outpatient and preventive and counseling services in a certain territorial area. Primary health care facilities are given the main burden for all types of medical prophylactic treatment, providing medical care for 70-80% of patients who seek help with acute conditions and exacerbation of chronic conditions.

Second level can be conditionally designated as medical care in the institutions of a city or district. These are mainly hospital-type institutions: medical centers, district hospitals, city hospitals, dispensaries, general maternity hospitals, rehabilitation facilities, sanatoriums, day hospitals, specialized educational institutions.

Third level constitute the regional medical institutions of republican and regional significance. The typical institutions are large multidisciplinary hospitals, in which medical assistance is provided in 20-30 specialties, as well as specialized obstetric. On the basis of these institutions, there are specialized centers, such as centers for resuscitation, intensive care, rehabilitation treatment, perinatal medicine, etc.

Fourth level institutions are of federal and interregional significance and provide the most complex and expensive types of medical care. They function within scientific research centers of the Ministry of Health, the Academy of Medical Sciences, clinics of medical universities, federal clinical institutions.

Fourth level institutions are generally located in cities with population over 1 000 000

Russia GDP = 1,72 trillion USD
6,5% - 110 billion USD is spent on healthcare each year

- ❖ Almost 50% comes from government sources, which primarily come from compulsory medical insurance deductions from salaries.
- ❖ About 5% of the population, mostly in major cities, have voluntary medical insurance.
- ❖ 30% of the population receive primary care through work related clinics and hospitals.

<u>Surgical treatment is covered through</u>

- ❖ Voluntary medical insurance
- ❖ Compulsory medical insurance
- ❖ Specialized complex surgical treatment
- ❖ Charitable foundations

<u>Clinical research is sponsored by</u>

- ❖ Federal budget
- ❖ Grants

<u>Optimization and lowering healthcare expenditures</u>

- ❖ Using Russian-produced implants and equipment
- ❖ Lowering average length of stay in hospitals
- ❖ Using Russian-produced medications (antibiotics, anticoagulants etc.) and bone replacement materials

Spine surgery is performed by neurosurgeons and orthopedic surgeons.
Every year there are around 70 000 surgical interventions on the spine performed in Russia with 85% involving degenerative spine disease and trauma.
Instrumentation is performed in about 45 000 cases
Deformity surgery – roughly 3 500 per year

Basic degenerative conditions and trauma are treated at second and third-level multidisciplinary hospitals.

Complex spinal reconstruction, deformity surgery, osteotomies, spondylectomies performed at fourth level specialized centers of federal significance, available only in large metropolitan areas: Moscow, Saint-Petersburg, Smolensk, Nizniy Novgorod, Novosibirsk, Saratov, Samara, Khabarovsk, Vladivostok.

Federal centers are fully equipped with state-of-the-art modern technology and highly qualified specialists, offering state-sponsored treatment for patients from all over the country.

Compulsory medical insurance (coverage from $1000 to $4000)
Voluntary medical insurance (unlimited coverage)
Specialized complex surgical treatment (State sponsored)
Orthopedic quota $4000, oncology $16600, neurosurgery $5000, Deformity $7000, neurostimulator $20000

Several philanthropic foundations also exist covering complicated surgical treatment of children with several hundred spinal surgical interventions performed each year.

Waiting lists for surgical treatment can range from 1 month to 2 years, depending on demand and complexity.

All the top US, European, and Asian companies on the orthopedic implant and equipment market are represented in Russia, however domestic Russian orthopedic implant and equipment companies are rapidly taking over the internal market with prices 30% to 50% lower than US-produced equivalents.

Academic scene
Russian Association of Spinal Surgeons (RASS), founded in 2009 involves more than 500 spine surgeons in all of Russia, growing every year, with quarterly publication of the official "Spine Surgery" journal and annual meeting in different cities all over Russia and a rapidly-growing number of multicenter research projects initiated over the last few years.

Two annual meetings have been conducted jointly with the WWC SRS course
5 spinal surgeons are currently members of the SRS

Conclusion
1 In Russia complex specialized medical care is accessible to everyone
2 Resources are not limited in terms of healthcare cost in Russia
3 Spine surgery is going through a phase of active growth and dynamic development

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Establishing Care with Limited Resources Learning from BRIC
- Indian Perspective

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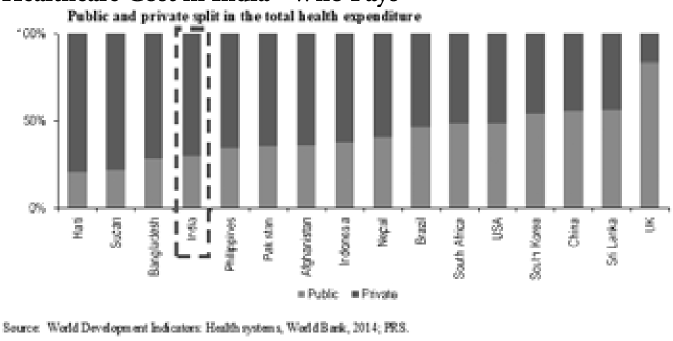
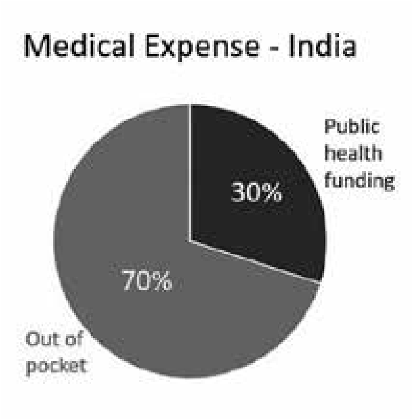
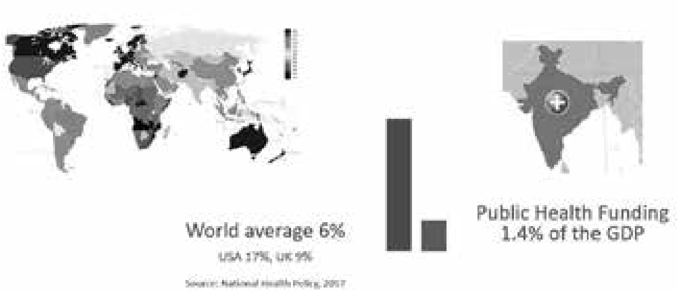
Healthcare Cost in India - Who Pays

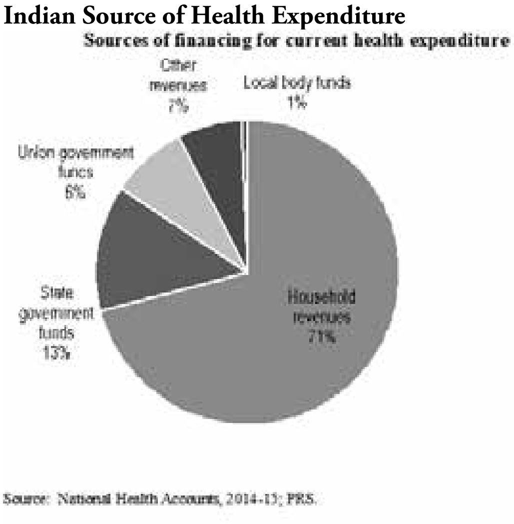




Health Spending – Govt. of India



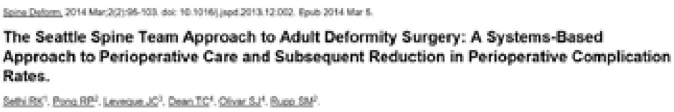
Indian Source of Health Expenditure



Challenges/Hurdles in Establishing Care
- Limited resources
- Almost the entire rural population and significant part of the urban population are not covered under any scheme of health cover
- The vast rural population has poor access to tertiary healthcare
- There is a general reluctance / willingness for change

Healthcare – Private Sector – In India
- Poor availability of healthcare facilities in the public sector has led to the development of flourishing high-end healthcare in private set-ups
- The care available in the private healthcare space is on par with the care available in the developed countries but at a fraction of the cost
- This has made India a popular destination for medical tourism

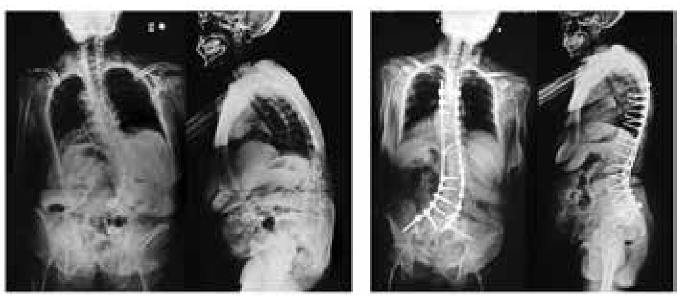
The LEAN Approach: Enhancing Safety and Value of Complex Spinal Care [1]
- Risk stratification approach of spinal surgical patients
- Comprehensive pre-operative multi-disciplinary approach
- Dedicated spinal anaesthesia and neuromonitoring Team
- Dual-attending surgeon
- Rigorous intra-op measures to minimise blood loss and complications


Spine Deform. 2014 Mar;2(2):96-103. doi: 10.1016/j.jspd.2013.12.002. Epub 2014 Mar 6.

The Seattle Spine Team Approach to Adult Deformity Surgery: A Systems-Based Approach to Perioperative Care and Subsequent Reduction in Perioperative Complication Rates.

Sethi RK[1], Pong RP[2], Leveque JC[3], Dean TC[4], Olivar SJ[4], Rupp SM[2].

Case 1
- Female / 67 yrs, Adult degenerative deformity with sagittal imbalance, Severely symptomatic



Cost in a Indian premiere healthcare facility : $ 20,000

Cost at US health care : $ 160,000 – 200,000

Case 2
- Male / 58 years, Ankylosing spondylitis

Preoperative and postoperative X-rays
Cost in a Indian premiere healthcare facility : $ 20,000
Cost at US health care : $ 160,000 – 250,000

Case 3
- Girl / 10 years, Deformity noticed 3 months back, Menarche not attained, MRI normal

Novel non fusion anterior scoliosis surgery
Preoperative and postoperative X-rays

Cost in a Indian premiere healthcare facility: $15,000
Cost at US health care: $250,000!!

Surgical Treatment for Ear-on–Shoulder Deformity Concomitant with Thoracolumbar Kyphosis: Tips and Pearls

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1. Background

Advanced ankylosing spondylitis (AS) patients may have three concomitant deformities: ankylosed hip joint, thoracolumbar kyphosis and cervicothoracic kyphosis, i.e., Chin-on-Chest deformity. Notably, Ear-on–Shoulder deformity concomitant with thoracolumbar kyphosis and severe trunk shift is extremely rare.

2. Tips and Tricks

a. Pre-op evaluation and special consideration in the sequence of osteotomy (cervical or lumbar osteotomy first), the fusion level, UIV stops at occipital or not and the need of sternocleidomastoid muscles release.
b. Awake fiberoptic endotracheal intubation.
c. Patient positioning: Mayfield Frame.
d. Neuromonitoring.
e. Pedicle screws in C_2, $T_{2\text{-}6}$, and lateral mass screws in $C_{3\text{-}6}$.
f. C_7 PSO

✧ C_7 decancellation wedge osteotomy: The technique of C_7 decancellation is similar to the procedure of PSO in lumbar spine. However, special attention should be paid to the decompression of C_8 nerve root; therefore, the C_7-T_1 intervertebral foramina should be significantly enlarged to prevent the potential compression of the C_8 nerve root, and the C_8 nerve root must be checked to be mobile after decancellation.

✧ Reduction and prevention of subluxation of osteotomized vertebra: The rod is pre-contoured to accommodate with the profile of the cervical-thoracic region. The superior part of the rod is affixed to the cervical screws on both sides while the inferior portion of the rod in the thoracic region is allowed to slide during the reduction. One assistant surgeon helps to achieve the correction of the coronal and sagittal deformity simultaneously by translation and elevation of the Mayfield frame.

g. Second-stage lumbar asymmetrical PSO is performed to correct the residual coronal and sagittal deformity of the trunk and to restore the normal horizontal gaze.

3. Surgical results

4. Conclusion

- Successful C7 PSO can be life-changing for Ear-on–Shoulder patient and the surgical results extremely gratifying for the surgeon with the courage to meet the challenge.
- If cervico-thoracic deformity was mainly responsible for cosmetic and functional impairments or manifested as concomitant coronal and sagittal imbalance in cervico-thoracic region, cervical osteotomy should be performed first.
- The residual coronal deformity and thoracolumbar kyphosis can be corrected by the 2-stage lumbar PSO surgery.

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Maintaining High Quality Spine Care Despite Declining Budget: The NHS Example

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The British National Health Service was introduced in 1948 – with the express aim of providing care to all, free at the point of delivery.

With few exceptions, it continues to deliver this to all eligible citizens.

It was (and still is) funded through central Taxation.

Its initial budget in 1948 was **£437 million ($630 million).**

The budget for 2017/18 is £124.7 billion ($163.6 billion) - a 285 fold increase!!

This has occurred, despite a relatively modest increase in patients waiting for in-patient treatment (475,000 in 1948 – 1,568,000 England March 2018) and per capita this is actually a percentage fall.

Much of this budget is allocated to staff salaries (in fact as an employer the NHS is secondary in number only to the armed forces of The PRC as an employer!)

Almost since it's inception, the NHS has tried to limit costs and maximise efficiency and improve care quality. In a global market place, where the demands of patients for ever increasing costly treatments continues, cost improvement programs and procurement deals have become part of daily life for us.

This talk will focus on the current cost pressures faced by The NHS as an entity, and by hospital boards and clinicians as both Corporate bodies (with legal statutory duties to deliver standards of care) and individual Consultant Surgeons in their daily practice.

I will discuss the decisions we face and options we choose in order to assist our hospital trusts in delivering ever greater efficiency savings. This includes participation in implant choice rationalisation, procurement dealing, innovative ideas such as 'virtual clinics' and data registry.

These are very challenging times for the British NHS, not least because, in addition to the regular global trends to quality improvement and cost cutting, we have the very unique prospect of *Brexit* to face, a daunting leap into the unknown, in March 2019!!

What Are the Challenges for Quality and Value in a High Performing European Health Care System?

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The Netherlands has a highly rated health care system, in most rankings it is placed in the top 3 in the world, based on multiple criteria such as quality, affordability, general accessibility, and universal coverage.

A. Health care system

Privatised system.

All hospitals are private, and the large majority are non-for profit. University hospitals also obtain additional government funding, for teaching, research and innovation).

The payers are health care insurance companies.

There is compulsory insurance for basic health care, which includes all of orthopedics and neurosurgery, but for example not for cosmetic surgery or dental care. This results in universal coverage (>98%).

Government oversight & regulated: We are challenged by strong government oversight by multiple bodies:

Netherlands health care institute (somewhat similar to NICE in the UK)

- Determines which types of health care are included in the basic care package. E.g. interspinous implants, Dynamic stabilisation (Dynesis etc), Lumbar disc arthroplasty, Vertebroplasty for osteoporotic fractures, RF nerve root blocks are not insured provisions as defined in the Health Insurance Act
- Assess and determine appropriate care.

Netherlands Health authority

- Sets the treatment descriptions
    - DRG based system, eg there is a code for complex spine surgery
    - Bundled payment (integrated hospital and surgeon fee)
    - Includes all costs during 6 weeks post-op period, incl. complications and readmission
- Regulates health insurers and health care providers

Netherlands Health Inspectorate (Quality assurance)

- Audits hospitals
- Incident reporting
- Clinical trials
- Medical technology

B. Role of health care professionals

Guidelines: the professional associations help develop multidisciplinary practice guidelines (incl. patient representation), e.g.

- Spinal trauma
- Instrumented spinal surgery incl. degenerative scoliosis
- Un-instrumented spinal surgery
- Low back pain
- Spinal metastases
- Etc..

Registries for quality assessment have been shown to improve outcomes and reduce costs (but with quite long time delays)

- National Joint registry
  - Owned by Dutch Orthopedic Association
  - Compulsory (primary and revision total hip & knee),
  - Participation is a requirement for reimbursement (2017: 98% national coverage)
- National cancer registries
- Mandatory from 2021 all implants (incl. spine 2021)

C. Hospital setting

Quality dashboards. Hospitals all develop their own quality metrics and dashboards.

Safety Checklists: Peri-operative safety checklists, time out procedures etc are all mandatory, universally employed, and are audited by the Netherlands Health Inspectorate

Challenges:

Despite the excellent health care facilities and quality of care, there are two major challenges:

1. There is increasing pressure on the system due to limited funds. Care is to some degree "rationed". Expensive pharmacological treatments, and surgical treatments (such as some of the Adult Spine Deformity operations) are questioned. For this reason lumbar disc arthroplasty is not reimbursed. Capital investments (e.g. in robotics, navigation, etc.) are all evaluated for their cost effectiveness. As many innovations do not have proven effectiveness, this is limiting our innovative capacity.
2. Furthermore, the multiple regulating bodies and multiple insurance companies leads to a complex field for health care professionals and administrators to perform their primary task, namely to treat patients.

What are Challenges for Quality and Value in High Performing Asian Health Care System

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- Population statistics of Japan 2017
  Total 126,706 thousand (male: 61,655 thousand, female: 65,051 thousand)
  Population under 15y.o. 12.3%, 15-64 y.o.: 60.0%, **65 y.o and older 27.7%**
  A decrease of 227 thousand compared with the previous year (rate of decrease 0.18%)
  Average length of life in Japan (2016)
  Male: 80.98 y.o., Female: 87.14 y.o. (Male: 77.72, Female: 84.60 in 2000)
  Number of births; 976 thousand,
  Number of deaths; 1,307 thousand (2016)
  Total fertility rate: down after dipping below 2.0 in 1975, 1.26 in 2005, 1.44 in 2016.
  The average mother's age at first childbirth rose from 25.6 in 1970 to 30.7 in 2016.
- Heath care policy
  "**Free access and freedom of practice**" (Patients are free to receive care from the facility of their choosing. Physicians have the freedom to open any medical practices regardless of their specialty)

  Characteristics of Japanese universal health insurance coverage system
  1. Covering all citizens by public medical insurance
  2. Freedom of choice of medical institution (free access)
  3. High-quality medical services with low costs (In the U.S., medical expenses per person are more than double those in Japan. In case of the elderly in Japan, the amount paid at a medical institution is about 40,000 yen if he or she receives 10 million yen of medical services per month.)
  4. Based on the social insurance system, spending the public subsidy to maintain the universal health insurance coverage

  Individual payment to medical services
  - 75 years or older; 10% copayment (Those with income comparable to current workforce have a copayment of 30%)
  - 70 to 74 years old; 20% copayment (Those with income comparable to current workforce have a copayment of 30%)
  - Start of compulsory education to 69 years old; 30% copayment
  - Yet to start compulsory education; 20% copayment

  Proportion of the burden of national medical expenses in Japan (FY2009)
  - ✧ Insurance premium 48.6% (Insured 28.3%, Employer 20.3%) (8.5% of people who are supposed to pay premiums do not pay in 2015 due to expensive premiums and low increase in their income. They do not agree that the money of the younger generations goes to the elderly.)

Half-Day Course

- ✧ Public subsidy 37.5% (state subsidy 25.3%, local government 12.2%)
- ✧ Patients' payment 13.9%

Total medical expenditure to GDP

Health spending averages $4,519 per person (adjusted for local costs), slightly higher than the OECD average. Spending growth has been relatively rapid in recent years. Coupled with modest economic growth, **health spending as a share of National Income is 10.9% in 2015, that of GDP is 7.96%,** the sixth highest among OECD countries. Japan has a high number of beds per capita, often occupied by elderly patients in need of long-term care.

Medical expenditure for different age groups (Japan 2015)

- ✧ For 0- 14y.o. : male:6.8%, female:5.2%
- ✧ For 15-64y.o.: male: 11.8%, Female: 13.3%
- ✧ **For 65y.o. or older: male 56.9% female: 61.6%**

Medical expenditure per capita

- ✧ 0-64 y.o. : Male:186,000 Japanese Yen **($1,646)**, Female: 183,000 Japanese Yen **($1,619)**
- ✧ **65 y.o. or older: Male: 792,000 JY ($7,008), Female: 703,000 JY ($6,221)**

Medical expenditure for different diseases

1. Cardiovascular disease: 19.9% 2. Neoplasms: 13.7% 3. **Muscloskeletal disease: 7.7%** 4. Respiratory disease: 7.4%

- There is a huge shift from infectious diseases to chronic disease and disabilities in the aged population.
- Spinal Implant Market
  Domestic market in Japan
  2012: 31,609 million JY
  2014: 37,352 million JY
  2016: 44,686 million JY
  2020: 53,590 million JY (expected) **(30% of growth in Japan from 2015 to 2020)**

  Government has reduced the spinal implant redemption price (comparing 2018 with 2017)
  Polyaxial pedicle screw 100,000 JY to 97,100JY (-2,900JY: 3% cut)
  Transverse connector 65,500JY to 62,200 JY(-3,300JY: 5% cut)
  Hook 68,900JY to 65,500JY(-2,400JY: 3% cut)
  Bone graft substitutes: 1- 9% cut

  Other restrictions in spine care:
  BMP is not allowed to use in Japan
  Vertical expandable prosthesis for TIS is allowed in only 4 spine deformity centers
  Lumbar lateral interbody fusion cages can be used at limited spine centers.
  Cervical artificial disc prosthesis can be used at limited spine centers.
- Medical cost of surgical treatment for complex spinal surgery for adults
  Japanese government is closely observing high medical costs for patients who underwent complex spinal surgery using costly spinal implants and new medical technologies. Other medical expenditures would be expected if surgery-related complications might occur.

  1. 73y.o. Male. Posterior-only reconstruction from T9-pelvis (No complications)

  Total medical expenditure: 6,375 thousand Japanese Yen **($56,919)**
  Insurance coverage (80%): 5,099 thousand Japanese Yen **($45,123)**
  Personal payment: 1,472 thousand Japanese Yen (**$13,026**)

  2. 64 y.o. Female. Combined anterior-posterior reconstruction from T7-pelvis (staged surgery) (no complication)

  Total medical expenditure: 8,862 thousand Japanese Yen **($78,424)**
  Insurance coverage (70%): 6,203 thousand Japanese Yen **($54,593)**
  Personal payment: 2,706 thousand Japanese yen **($23,946)**

  If the healthcare insurance review committee considered too much procedures or implants for each adult patient, the medical reimbursement would not be paid for these procedures.
- Assessment comorbid medical problems of adult patients requiring complex spinal deformity
  At present, there is no multidisciplinary approach to evaluate the surgical indication and procedure in each patient in Japan, i.e. "professional autonomy". There is a bias among surgeons in selecting patients and surgical treatments. Since there are many nuclear families and may elderly people live alone, there is a tendency that the elderly people are seriously seeking surgeries which may provide them with "independent life".
- To establish sustainable medical treatment for complex spinal surgery
  Clear and appropriate surgical indication (symptoms and neurology)
  Strict criteria of selecting patients for complex spinal surgery (BMD, age, etc)
  Medical assessment of comorbidities (team approach)
  Safe procedures with less complications
  Reduction of medical cost (implant cost, shorter hospital stay, more generics or fewer drugs)
  Cost effective medicine (a system of reimbursement for inpatient care based on diagnosis-procedure-combinations (DPC).
  Higher premiums to maintain the present medical insurance system
  Nationwide registry system of all spinal instrumentation surgery to assess the value and benefits of surgery (Long-term follow-up of clinical results of expensive medical treatment)
- "The community based integrated care system" for the elderly
  To build comprehensive up-to-the-end-of-life support services in each community.
  The new concept of 4 elements in the health care policy for the elderly: self-help (Ji-jo), mutual aid (Go-jo), social solidarity care (Kyo-jo), and government care (Ko-jo)

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What Are the Challenges for Quality and Value in a High Performing North American Health Care System?

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Quality and Value:
Definition of Value → Quality/Cost

Quality Definition → Safety, patient Satisfaction/HRQOL, Outcomes, measured in many ways

Cost Definition → overall cost of care (including direct and indirect costs)

Longer the intervention lasts, the better Quality and Value

Comparative Cost Effectiveness Research → Evaluates and compares health outcomes and the clinical effectiveness, risks, benefits of two or more medical treatments, services and items

- Incremental comparisons should be made between two or more forms of treatment

Incremental Cost-Effectiveness Ratio (ICER)

$$= \frac{\text{Costs}_{\text{intervention}} - \text{Costs}_{\text{comparator}}}{\text{QALYs}_{\text{intervention}} - \text{QALYs}_{\text{comparator}}}$$

Elements in the System that Drive Quality and Cost
Specialty Hospital
- Care Team is well versed in Delivery (Scrub techs, circulators, nurses, physical therapists, all other ancillary)
- Drives Efficiency and Improves Quality

Bringing Costs Down
- Comparative Cost Effectiveness Research
- Complex Case example for relatively common problem
- Degenerative Scoliosis, comparison of two different interventions based on hypothetical costs – Data Driven from In-House Evaluation of Interventions

Limitations
- Difficult Adoption
- Cost is Calculated from the Payer Perspective
- Risk Sharing Models are proposed, While Payments are Cut
- Difficult to Align Entire Faculty

Half-Day Course Program

Strategies for Managing AIS in a Bundled System

Suken A. Shah MD
Nemours/Alfred I. duPont Hospital for Children
Wilmington, Delaware, USA

Surgery for AIS involves a fairly standard procedure performed upon healthy patients…this lends itself to standardization and opportunities for cost reduction

Introduction

- Lean Principles
  - Reduce cost and waste
- Value-Based Healthcare and Competition (Porter)
- Improve value and quality without reduction in safety
- Model costs with time-based cost accounting methods (TB-CAM)
- Administration can commit resources to the spine service line
- Contracting for implants (25% of the hospitalization cost)
  - Price and reliable service
  - Versatile and broad range spine system

Preoperative

- Standard workup
- Minimal testing, labs, etc
- Education of caregivers – set goals and expectations
- Multidisciplinary preoperative conference

Intraoperative

- Standard workflow / operative efficiency
- Teams (OR and anesthesia)
- Two cases a day
- Implant density, disposables, bone graft
- Blood conservation
- Two surgeons – not necessarily cost effective for AIS surgery

Postoperative

- Rapid Recovery Pathway
- Length of stay (LOS) reduction – less cost and more cases
- Limit complications (and reoperations)
- Education of caregivers preop and at discharge
- Follow up phone call
- Telemedicine
- Standardized follow up visits

Practice audit
Registry
Benchmarking
Continuous improvement

Strategies for Managing ASD in a Bundled System

Rajiv K. Sethi MD
Chair of the Virginia Mason Neuroscience Institute
Clinical Professor of Health Services Research
Virginia Mason Medical Center
University of Washington
Seattle, Washington, USA

ECONOMICS AND OUTCOMES PERSPECTIVE

Trends for Spine Surgery for the Elderly: Implications for Access to Healthcare in North America

Thomas M. O'Lynnger, MD, MPH
Scott L. Zuckerman, MD
Peter J. Morone, MD
Michael C. Dewan, MD
Raul A. Vasquez-Castellanos, MD
Joseph S. Cheng, MD, MS

The proportion of the population over age 65 in the United States continues to increase over time, from 12% in 2000 to a projected 20% by 2030. There is an associated rise in the prevalence of degenerative spinal disorders with this aging population. This will lead to an increase in demand for both nonsurgical and surgical treatment for these disabling conditions, which will stress an already overburdened healthcare system. Utilization of spinal procedures and services has grown considerably. Comparing 1999 to 2009, lumbar epidural steroid injections have increased by nearly 900 000 procedures performed per year, while physical therapy evaluations have increased by nearly 1.4 million visits per year. We review the literature regarding the cost-effectiveness of spinal surgery compared to conservative treatment. Decompressive lumbar spinal surgery has been shown to be cost-effective in several studies, while adult spinal deformity surgery has higher total cost per quality-adjusted life year gained in the short term. With an aging population and unsustainable healthcare costs, we may be faced with a shortfall of beneficial spine care as demand for spinal surgery in our elderly population continues to rise.

KEY WORDS: Access to healthcare, Elderly, Spine surgery

See the corresponding editorial in this issue (E4).

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Incremental cost-effectiveness of adult spinal deformity surgery: observed quality-adjusted life years with surgery compared with predicted quality-adjusted life years without surgery

Ian McCarthy, Ph.D.,[1] Michael O'Brien, M.D.,[2] Christopher Ames, M.D.,[3] Chessie Robinson, M.A.,[1] Thomas Errico, M.D.,[4] David W. Polly Jr., M.D.,[5] and Richard Hostin, M.D.,[2] on behalf of The International Spine Study Group

[1]Center for Clinical Effectiveness, Baylor Scott & White Health, Dallas, Texas; [2]Baylor Scoliosis Center, Plano, Texas; [3]Department of Neurosurgery, University of California San Francisco, California; [4]Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, New York; and [5]Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, Minnesota

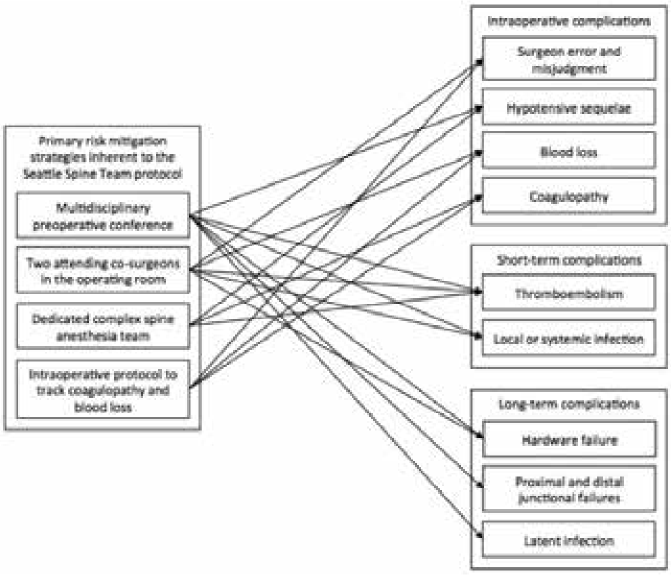
Curr Rev Musculoskelet Med
DOI 10.1007/s12178-016-9351-x

COMPLICATIONS IN SPINE SURGERY (E KLINEBERG, SECTION EDITOR)

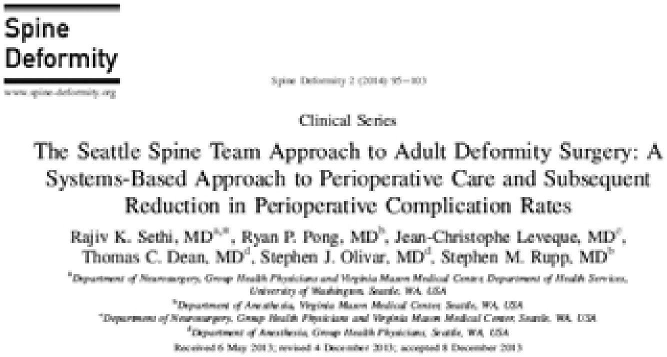
Complication avoidance with pre-operative screening: insights from the Seattle spine team

Quinlan D. Buchlak[1] · Vijay Yanamadala[1] · Jean-Christophe Leveque[1] · Rajiv Sethi[1,2]

Half-Day Course



This diagram reveals the effect of standardization of multiple series of complications seen in spinal deformity surgery.



Spine Deformity
www.spine-deformity.org

Spine Deformity 2 (2014) 95–103

Clinical Series

The Seattle Spine Team Approach to Adult Deformity Surgery: A Systems-Based Approach to Perioperative Care and Subsequent Reduction in Perioperative Complication Rates

Rajiv K. Sethi, MD[a,*], Ryan P. Pong, MD[b], Jean-Christophe Leveque, MD[c], Thomas C. Dean, MD[d], Stephen J. Olivar, MD[d], Stephen M. Rupp, MD[b]

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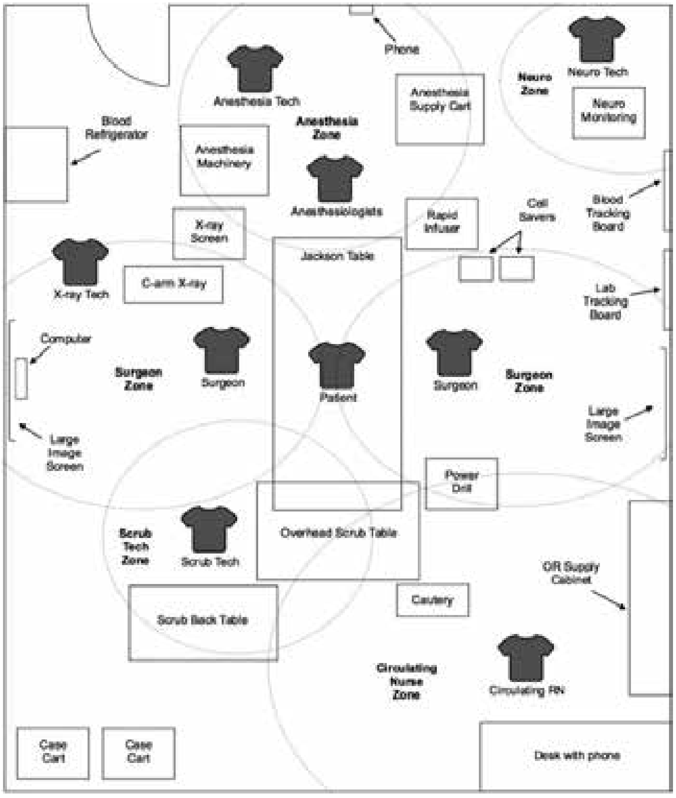
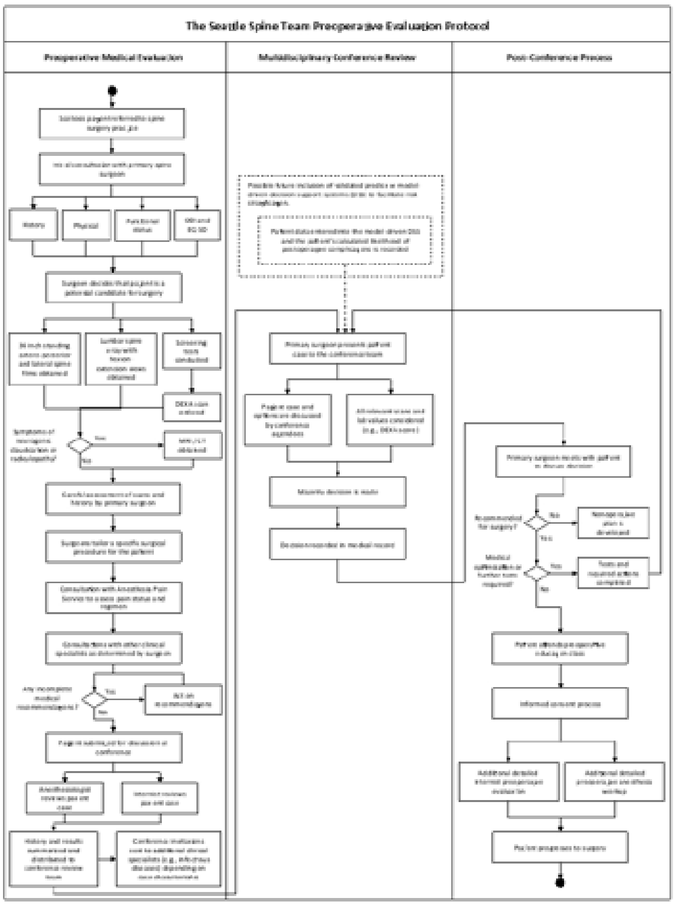
Time	Suction Canister	Cell Saver EBL	Field Irrigation	Total EBL	Hct	pH / BE	PT / INR	Platelet Count	Fibrinogen / D-dimer
9:00	N/A	N/A	N/A	N/A	33	7.38 / -2.9	13.7 / 1.1	188	798 / 2.74
10:03	550	100	0	650	30	7.35 / -4.5	14.2 / 1.1	100	647 / 2.65
11:00	650	550	0	1200	29	7.38 / -3.6	15.3 / 1.2	95	497 / 2.94
12:00	800	1250	0	2050	31	7.34 / -4.2	16.4 / 1.3	90	411 / 2.92
13:04	1300	1700	0	3000	31	7.31 / -4.8	18.1 / 1.5	110	335 / 2.93
14:01	1500	2000	0	3500	31	7.30 / -4.5	17.3 / 1.4	125	280 / 3.95
15:05	1600	2200	0	3800	29	7.33 / -4.1	17.0 / 1.4	103	290 / 7.49

Standardization of all complex spine cases using principles of the Toyota Production System. This is an example of "visual control" as a standard method of communication around coagulopathy and blood loss.



This is an example of enhanced "flow" optimizing position of team members of the complex spine operating room using principles of the Toyota production system.



The Seattle Spine Score (S3)

Input variables:

Age (years)	60	Sex (F = 1, M = 0)	1
History of smoking (1 = yes, 0 = no)	0	BMI	40
Hypertension (1 = yes, 0 = no)	0	Anemia (1 = yes, 0 = no)	1
Diabetes (1 = yes, 0 = no)	1		

Probability of complications occurring within 30 days of complex spine surgery:

S3 = 92%

Important Notes:
1. The predictive algorithm driving the S3 has a validated accuracy of 81.4%.
2. This model should never be used as a substitute for the professional judgement of an experienced medical team.
3. Complex spine surgery is defined as spinal fusion surgery involving 6 or more vertebral levels.

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Tools and techniques

The Seattle spine score: Predicting 30-day complication risk in adult spinal deformity surgery

Quinlan D. Buchlak[a,*], Vijay Yanamadala[a], Jean-Christophe Leveque[a], Alicia Edwards[a], Kellen Nold[a], Rajiv Sethi[a,b]
[a] Neuroscience Institute, Virginia Mason Medical Center, Seattle, WA, USA
[b] Department of Health Services, University of Washington, Seattle, WA, USA

The Seattle Spine Score (S3)

Input variables:

Age (years)	60	Sex (F = 1, M = 0)	1
History of smoking (1 = yes, 0 = no)	0	BMI	26
Hypertension (1 = yes, 0 = no)	0	Anemia (1 = yes, 0 = no)	0
Diabetes (1 = yes, 0 = no)	0		

Probability of complications occurring within 30 days of complex spine surgery:

S3 = 3%

Important Notes:
1. The predictive algorithm driving the S3 has a validated accuracy of 81.4%.
2. This model should never be used as a substitute for the professional judgement of an experienced medical team.
3. Complex spine surgery is defined as spinal fusion surgery involving 6 or more vertebral levels.

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Quality and safety improvement initiatives in complex spine surgery

Rajiv K. Sethi, MD[a,b,c,], Quinlan D. Buchlak, MPsych, MBIS[d], Jean-Christophe Leveque, MD[a,b], Anna K. Wright, PhD[a], and Vijay V. Yanamadala, MD[e]*
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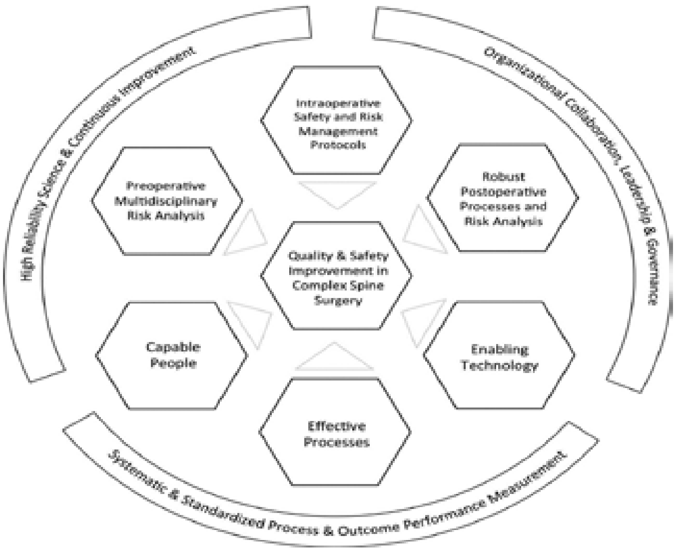
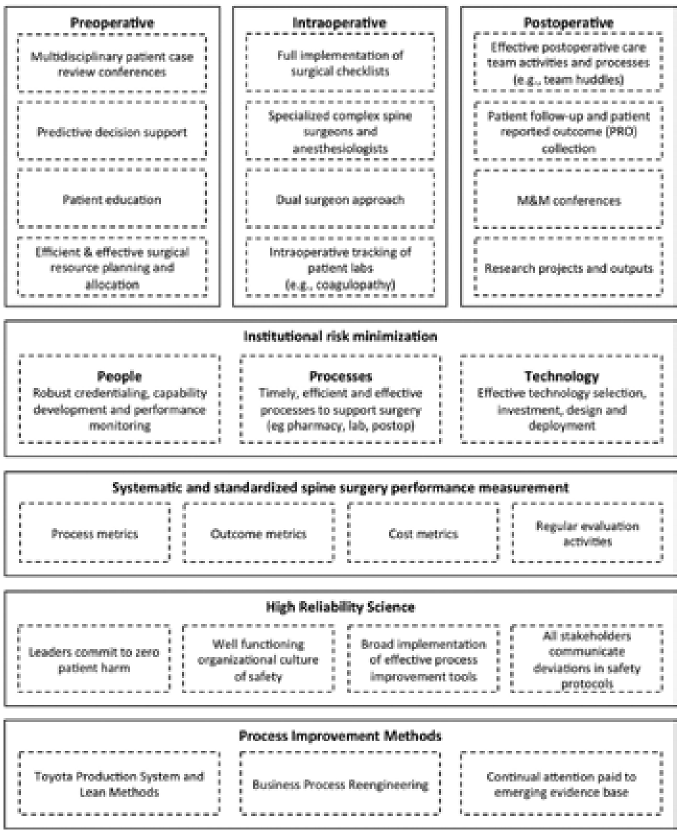
The Spine Safety Improvement Model – Conceptual (SpineSIM-C)



The Spine Safety Improvement Model – Detailed (SpineSIM-D)



Podium Presentation & Case Discussion Abstracts

The Scoliosis Research Society gratefully acknowledges NuVasive for their support of the Annual Meeting Announcement Board, Directional Signage, E-Poster USBs, Newsletter, Pocket Guide, Pre-Meeting Course, and Welcome Reception.

1A. Occiput-to-Pelvis Spinal Arthrodesis: A Case Series Discussion

Matthew J. Hadad, BS; Oussama Abousamra, MD; Brian Sullivan, BS; Paul D. Sponseller, MD

Summary

We present a series of children who underwent occiput-to-pelvis (O-P) spinal arthrodesis. All patients had non-idiopathic scoliosis with cervical instability and/or deformity. O-P arthrodesis was completed in a mean of 2.6 operations (range 2-5 operations), and patients have a mean follow-up of 9.0 years (range 2-19.5 years). No patients had post-operative infections, reported neurological deficits, or needed further corrective spine surgery. These results suggest that O-P arthrodesis is a safe and effective last-resort option for challenging spine deformities.

Hypothesis

Occiput-to-pelvis (O-P) spinal arthrodesis can be a safe and effective treatment for patients with severe non-idiopathic scoliosis with cervical deformity.

Design

Case series at a single center

Introduction

O-P spinal arthrodesis might be needed in some patients with challenging spine deformity. The indications and outcomes of such an extensive procedure are underreported. This study aims to describe a group of patients who underwent O-P arthrodesis.

Methods

Records of children with non-idiopathic spine deformity who underwent O-P arthrodesis were identified. The diagnoses of these children, perioperative course, and surgical and radiographic outcomes are described.

Results

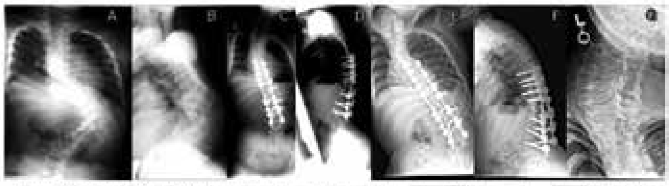
Seven children (1 boy and 6 girls) underwent O-P arthrodesis (Table 1). Diagnoses were neuromuscular (5) or connective tissue disorders (2). Patients presented with cervical instability (2), coronal imbalance (3), or sagittal imbalance (2). Occipitocervical fusion was the last spine surgery for all patients. Mean age at index surgery and completion of O-P arthrodesis was 10.9 ± 2.7 years and 17.5 ± 4.4 years, respectively. Patients underwent a mean of 2.6 operations (range 2-5). Mean follow-up was 9.0 ± 8.4 years (range 2-19.5 years) except for one patient who is scheduled for 5-year follow-up soon. Two patients underwent revision operations for protruding occipital implants. No patients had post-operative infections, reported neurological deficits, or needed further corrective spine surgery. Mean total SRS-22r score was 3.8 ± 0.9. Function was the lowest scoring SRS-22 domain with a mean score of 3.1 ± 0.7. Radiographic Balance Parameters: Mean (± SD) values of radiographic measurements at most recent follow-up included: major coronal curve angles = 23.3 ± 9.3 deg, T2-T12 kyphosis = 19 ± 16.8 deg, T12-S1 lordosis = 40.8 ± 21.8 deg, T1 pelvic angles = 23.8 ± 20.0 deg; pelvic obliquity = 6.1 ± 3.1 deg; coronal balance = 3 ± 3.9 cm.

Conclusion

Imbalance or instability after fusion in pre-pubertal patients may lead to the need for O-P arthrodesis. In these patients, good radiographic and clinical results in the midterm suggests O-P arthrodesis is a safe and effective last resort option that addresses all aspects of the deformity.

Table 1: Underlying diagnoses, medical co-morbidities, number of needed operations, and length of follow up (years) for the study group. Pt. No: Patient number; M: male; F: female; VP: ventriculoperitoneal.

Pt. No.	Sex	Underlying Condition	Medical Co-Morbidities	Number of Operations	Follow Up (yrs.)
1	M	Neonatal Listeria Meningitis	C5 Paralysis; full time ventilator; tracheostomy; g-tube; VP shunt	2	19.5
2	F	Myotonic Muscular Dystrophy Type 1	Full time ventilator; tracheostomy; g-tube	3	19.4
3	F	Diastrophic Dysplasia	None	2	7.9
4	F	Cervical Ganglioglioma, C5 Paralysis	G-tube	2	3.5
5	F	Glutaric Aciduria Type 1	Non-verbal; non-ambulatory	2	–
6	F	Spastic Quadriplegic Cerebral Palsy	Non-verbal; non-ambulatory; full time ventilator; tracheostomy; g-tube; VP shunt; seizures	2	2
7	F	Loeys-Dietz Syndrome	None	5	2



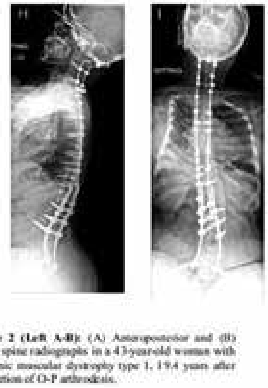


Figure 1 (above and right A-I): (A) Preoperative anteroposterior and (B) lateral radiographs in an 8-year old girl with diastrophic dysplasia. (C) Anteroposterior and (D) lateral radiographs 2 years after T6-L3 arthrodesis. (E) Anteroposterior thoracolumbar, (F) lateral thoracolumbar, and (G) anteroposterior cervical radiographs 6.1 years after T6-L3 arthrodesis. (H) Anteroposterior and (I) lateral radiographs, 7.9 years after O-P arthrodesis.

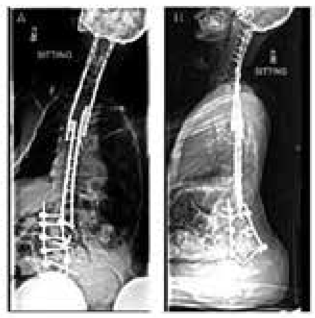


Figure 2 (Left A-B): (A) Anteroposterior and (B) lateral spine radiographs in a 43-year-old woman with myotonic muscular dystrophy type 1, 19.4 years after completion of O-P arthrodesis.

1B. The Challenges of Restoring Sagittal Alignment in Circumferential Minimally Invasive Surgery (MIS) Fusions

Vishal Sarwahi, MBBS; *Ahmad Latefi, DO;* Stephen Wendolowski, BS; Jesse Galina, BS; Melanie Smith, cPNP; Terry D. Amaral, MD

Summary

Lack of sagittal correction in a patient's index surgery led to significant sagittal imbalance secondary to proximal junctional kyphosis. Pedicle subtraction osteotomy, implant revision, and fusion extension were utilized to successfully restore the patient's sagittal balance.

Hypothesis

Restoration of the sagittal profile is essential for desirable outcomes

Design

Case Report

Introduction

Sixty-nine year old female with a history of lung cancer and osteoporosis underwent circumferential MIS surgery for correction of spinal deformity. Three months postoperatively, patient had developed severe sagittal imbalance secondary to proximal junctional kyphosis. Patient required 3 column osteotomies, extension of fusion, hardware removal and revision.

Methods
Index surgery involved circumferential MIS fusion from T10 to sacrum with pelvic fixation. At 3 month follow up, patient complained of severe sagittal imbalance, inability to maintain an upright posture. Radiographic films showed severe proximal junctional kyphosis (35°), sagittal imbalance (177.8mm), and minimal lordosis (10°). Patient has an extensive surgical history with numerous surgeries for scoliosis, spinal stenosis, and bilateral hip replacements. Patient underwent an L2 pedicle subtraction osteotomy and extension of fusion to T4 with revision of pelvic fixation. Four rod constructs were utilized.

Results
Four rod constructs were utilized with a two surgeon team. Surgical time was near 6.5 hours with 1800ml of blood loss and three units of packed red blood cells transfused. Postoperative radiographic films showed 35° of lordosis, 130.1mm sagittal balance, and 43° of kyphosis. Overall, the surgery was uneventful and patient was discharged on post-op day 12.

Conclusion
Restoration of sagittal parameters remains a controversial issue with circumferential MIS surgery. Despite improved understanding and advancements in implant technology, surgeons need to pay greater attention in restoring lumbar lordosis to prevent undesirable outcomes.

1C. "SI Joint At Risk" After Lumbosacral Fixations – Identification Of Risk Factors And Role Of Prophylactic Management For SI Joint Dysfunction.

J. Naresh-Babu, MD; Arun Kumar Viswanadha, MBBS, MS

Summary
Post-operative buttock or leg pain is a common even after successful reduction of pre-operative pain after Lumbo-sacral fixations. SI joint strain is one of the common cause. Pre-operative factors predisposing to SI joint pain (SI joint at risk) were identified . A prospective randomised study was conducted in SI joint at risk patients with and without prophylactic SI joint steroid injection. Prophylactic steroid injection in SI joint At risk patients reduced the occurrence of post-op buttock pain significantly.

Hypothesis
Identification of SI joint at risk patients and prophylactic steroid injection will reduce incidence of new onset-buttuck pain after successful limbo-sacral fixations.

Design
Prospective Randomised control trial

Introduction
Introduction: Sacroiliac joint (SIJ) is one of the potential sources for causing persistent or new pain following lumbar/lumbosacral fixations. Even after careful selection of patients, failure rates following lumbar/lumbosacral fixations range from 5 to 30% with SIJ being one of the most important sources which can be easily misinterpreted.

Methods
A systemic review on the subject was done in the initial phase followed by retrospective evaluation of the lumbar/lumbosacral fixations performed last year in our centre. Based on the results obtained, potential risk factors for SIJ dysfunction were identified. In the final phase, patients with high risk for development of SIJ dysfunction following lumbar/lumbosacral fixation were identified and cases with these factors were prospectively included in a randomised control trial.

Results
Systematic review – After extensive literature search, 9 articles are included for the systematic review. Retrospective evaluation - 113 of 143 patients developed S.I joint syndrome within 3 weeks from the index lumbar/lumbosacral fixation (79%). The incidence is doubled when the fixation was extending into the sacrum (n=75). VAS was significantly improved from 7.4±1.3 before injection to 3.7±0.7 at 3 weeks and 4.5±0.8 at 6 months. ODI was 64.3±8.7 before corticosteroid administration and improved to 35.0±4.6 at long term follow up (6 months). Randomised Control Trial – No patient with prophylactic corticosteroid injection had SI joint dysfunction. Incidence of sacro-iliac joint dysfunction in control group was 61.5%(8 out of 13). These 8 cases were given corticosteroid at the time of presentation and subsequent improvement in VAS and ODI scores was observed at the end of 6 months (p-value<0.05).

Conclusion
Identification of SI joint at risk patients and prophylactic steroid injection will reduce the incidence of new onset-buttuck pain after successful limbo-sacral fixations.

Table: "SI Joint at Risk" factors

1.	Contralateral interbody fusion
2.	Transitional Lumbosacral Vertebra
3.	Dysplastic Sacrum
4.	Cases requiring reduction of spondylolisthesis

1D. Neurologic Deficit During Halo-Gravity Traction in the Treatment of Severe Thoracic Kyphoscoliotic Spinal Deformity

Martin Pham, MD; Meghan Cerpa, BS, MPH; Lawrence G. Lenke, MD

Summary
Halo-gravity traction (HGT) is a safe technique in the multimodal management of severe complex spinal deformity. We present here a case of neurologic decline in a 24-year-old patient with severe kyphoscoliosis who underwent HGT and discuss the management decisions associated with this challenging scenario.

Hypothesis
Although generally safe, halo-gravity traction may rarely cause neurologic complications.

Design
Case report and discussion.

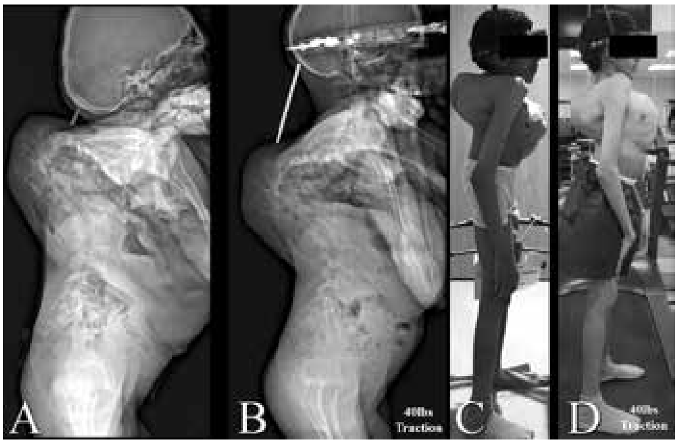
Introduction
Correction of severe spinal deformity is a significant challenge for

spinal surgeons. Although halo-gravity traction has been shown to be well-tolerated, we report here a case of neurologic decline during halo-gravity traction in a patient with severe kyphoscoliosis.

Methods
A chart review was conducted on this single patient regarding his clinical course and outcome.

Results
A 24-year-old male presents with severe thoracic kyphoscoliosis with >180 degrees of 3-dimensional deformity. Magnetic resonance imaging (MRI) showed his thoracic spinal cord to be stretched across the apex of his deformity at T7-9. His neurologic exam showed lower extremity myelopathy. During Week 7 at a goal traction weight of 40 lbs, his distal lower extremity exam declined from 4+/5 to 2/5 and his traction weight was lowered to 25 lbs over several days. He subsequently sustained a ground-level fall and became paraparetic with bilateral lower extremities now 1-2/5 proximally and 1-3/5 distally. He was transferred to the intensive care unit to drive up his mean arterial pressure (MAP) and was started on high-dose dexamethasone. He soon after underwent a T1-L4 posterior spinal instrumentation and fusion with a T7-9 vertebral column resection. Postoperatively, he was noted to have a complete return to his baseline neurologic exam. His total hospital stay was 11 weeks 4 days with the inclusion of halo-gravity traction, with 19 of those days being postoperative recovery. At his four month postoperative visit, he was now full strength in his lower extremities with complete resolution of his myelopathy.

Conclusion
We present here a case of neurologic deficit after the application of halo-gravity traction, subsequently complicated by an inpatient ground-level fall. Although halo-gravity traction is a safe technique for the nonsurgical partial correction of severe rigid deformity, a high index of suspicion for neurological complications needs to be maintained.



2A. Surgical Management of Atlantoaxial Dislocation and Cervical Spinal Cord injury in Craniopagus Twins

Russ Nockels, MD, FAANS

Summary
A case of cervical spinal cord injury in angular craniopagus twins is presented. The injury occurred following a fall resulting in quadriparesis in one of the twins. Imaging revealed severe craniocervical stenosis resulting from a C1-2 dislocation. After custom halo fixation was obtained, a posterior approach was utilized to decompress and instrument the occiput, cervical, and upper thoracic spine with intraoperative reduction of the dislocation. 2 year follow up demonstrated intact instrumentation and neurologic improvement to near baseline.

Hypothesis
The complex management of high cervical spinal cord injury in craniopagus twins is possible with modern imaging and surgical techniques.

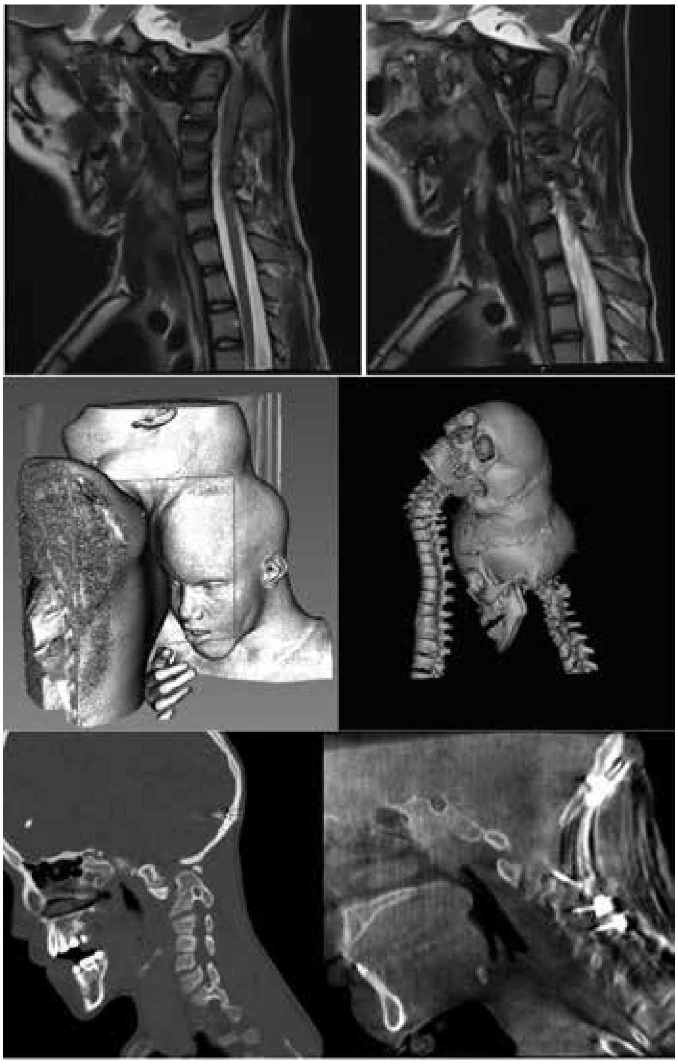
Design
Descriptive case report of craniopagus twins undergoing complex spinal cord injury management inclusive of the surgical, anesthetic, biomechanical and ethical considerations will be described in detail.

Introduction
We believe this is the first reported case of surgical treatment of traumatic craniocervical deformity causing spinal cord injury in craniopagus twins. Endeavoring to operate on craniopagus twins requires a myriad of logistical, technical, and ethical challenges be addressed as well as development of a coordinated care team comprised of surgeons, anesthesiologists, pediatric intensivists, nurses, chaplains, ethicists, and the patient's family. Standardization is not possible due to the paucity of cases in the literature. Ethically, the decision to perform surgery on one twin requires consideration of the inseparable risks to the other. Any fatal consequence to one would prove fatal to the other as they were deemed inseparable.

Methods
The patient presented with severe craniocervical stenosis with posterior angulation of the dens. The altered spinal anatomical issues needed to be accommodated during the procedure utilizing a 3D printed model. Decompression of the spinal canal consisted of removal of the atlas as well as laminectomy of the second cervical vertebra (C2). Screw fixation was obtained bilaterally in the occiput, C2 pars interarticularis, and extended to the 2nd thoracic segment using 3 cobalt-chrome rods.

Results
Post operatively, the affected twin demonstrated improved motor grades in all limbs, and was eventually able to be discharged to an acute inpatient rehabilitation facility. She has since been seen on an outpatient basis, and continues to show stable neurologic improvement to baseline. Imaging at 24-months post-operatively demonstrates intact instrumentation and alignment.

Conclusion
Using 3D modeling, biomechanical principles, complex surgical implants and coordinated operative teams, complex injuries in craniopagus twins can be successfully managed.



2B. Single-Stage Management of a Tumor-Related Curve with Improvement in IONM

Brandon Toll, BA; Amer F. Samdani, MD; Joshua M. Pahys, MD; Steven Hwang, MD

Summary
Scoliosis associated with spinal neoplastic pathology is an uncommon yet well-elucidated phenomenon. Presently, however, there is a paucity of literature outlining the optimal treatment of scoliosis concomitant with intradural-extramedullary (IDEM) lesions with respect to surgical timeline and intraoperative neuromonitoring (IONM). This report documents one such case treated with a single-staged approach under IONM guidance.

Hypothesis
N/A

Design
Case report

Introduction
A 16-year-old female presented to clinic with scoliosis. She reported sporadic back pain without numbness, paresthesia or weakness and normal bowel or bladder function. Radiographic investigation revealed a 75 degree thoracolumbar curve. A routine screening pre-op MRI study showed an intradural extramedullary mass measuring 2x1.6x1.6 cm compressing the cord at the apex of T10-11.

Methods
The patient underwent a single-stage surgical excision of the lesion and a posterior spinal fusion from T4-L4 for deformity correction.

Results
Right motor evoked potentials were initially decreased but improved after decompression and excision of the mass. No complications or neuromonitoring alerts occurred at any juncture. Pathology results confirmed the diagnosis of schwannoma.

Conclusion
Single-stage resection and correction supplemented with IONM resulted in the successful resolution of an uncommon case of neuropathic scoliosis secondary to an IDEM schwannoma. The use of IONM is reassuring and may encourage the surgeon to complete this surgery in one stage.

2C. Preoperative Traction, Riluzole, and 3D Modeling Optimizes the Safety of Correction of a Stiff 150-Degree Kyphoscoliosis Deformity

Michael To, MBBS, FRCS; Jason Pui Yin Cheung, MBBS, FRCS, MS; Feng Zhu, MD, PhD; Kenneth Cheung, MD, FRCS

Summary
Severe deformities run high risk of neurological compromise. Many options have been reported to reduce risk of neurological deterioration. We present a case of a 15-year-old girl with neurofibromatosis, myelopathy and a 150-degree kyphoscoliosis who underwent 7 months of traction and 2 weeks of riluzole prior to surgery by one-stage vertebral column resection (VCR). Using a 3D model and customized jigs for pedicle screw insertion, the surgery was smooth with intraoperative improvements in motor evoked potentials (MEPs).

Hypothesis
Pre-operative traction, riluzole and utilizing 3D model and customized jigs optimizes surgical safety in severe deformity correction.

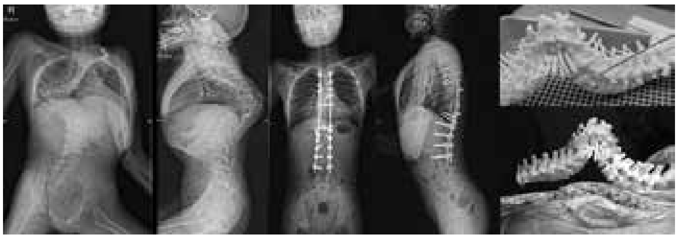
Design
Case report.

Introduction
Severe deformities run high risk of neurological compromise. Many options such as pre-operative traction and riluzole may be helpful in preventing neurological compromise in deformity correction.

Methods
A 15-year-old girl with neurofibromatosis, preoperative myelopathy and a stiff 150-degree kyphoscoliosis underwent 7 months of pre-operative traction up to 44.6% of body weight and 2 weeks of riluzole prior to surgery. A 3D model of the spine with customized jigs were created. Prior to surgery, with traction, there was mild improvement in the myelopathy, with significant improvements of lung function (FEV1=81.9%, FVC=79.9%).

Results
A 1-stage VCR with posterior spinal fusion was performed. The operative time was 9 hours and intraoperatively there was no drop in neuromonitoring signals. Customized jigs allowed easy passage of k-wires followed by pedicle screw insertion without breach. Intraoperatively, there was improvement in MEPs. Postoperatively, the patient was able to walk independently with excellent correction of the deformity to 30 degrees.

Conclusion
Combination of pre-operative traction, neuroprotective agents and 3D model for surgical planning allows for safe surgical correction of severe spinal deformities.



2D. Prune Belly Syndrome: Importance of Anterior Abdominal Musculature in Maintenance of Thoracic Kyphosis

Derek Nhan, BS; Paul D. Sponseller, MD

Summary
The role of the anterior abdominal musculature in providing sagittal balance is not well defined. Our case implicates that these muscles play a vital role in maintaining physiologic thoracic kyphosis. Thus, their absence in prune belly syndrome leads to excessive lumbar compensation and a pronounced early-onset scoliosis. Magnetically controlled growing rods spanning the thoracic region allow for improvement of the thoracolumbar curve and resolution of normal thoracic kyphosis.

Hypothesis
The anterior abdominal musculature helps maintain physiologic thoracic kyphosis, without which leads to a progressive early-onset scoliosis.

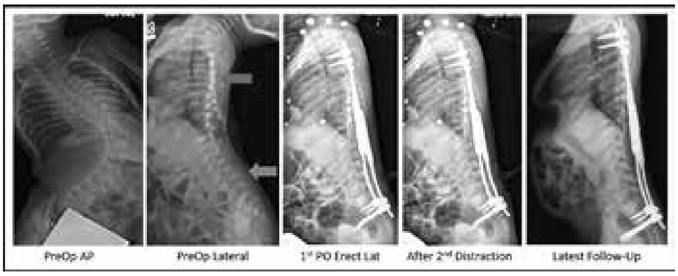
Design
Case Report

Introduction
Prune belly syndrome (PBS) is a rare condition characterized by congenital aplasia of the abdominal musculature, frequently associated with early-onset scoliosis and genitourinary malformations. It is unclear the mechanism but controversy evolves around the role of the abdominal musculature in providing spinal stability, and no data exists on the experience with growing rod constructs for PBS.

Methods
A retrospective chart and radiographic review was performed on a PBS patient, with three years follow-up, who presented with a unique curve profile and underwent magnetically controlled growing rod placement.

Results
Our patient was a 1 years-old male, who presented initially with a 56°collapsing left thoracolumbar curve from T9-L5 and 7° thoracic hypokyphosis from T5-12. Over the next year, his curve rapidly progressed to 115°, and he underwent magnetically-controlled growing rod placement from T2-L5. He has since undergone 5 lengthening procedures with improvement in his thoracolumbar curve by nearly 70% and increase in his thoracic kyphosis to within an appropriate range of 24° from T5-T12 at his latest follow-up.

Conclusion
This case provides support for the importance of the anterior abdominal musculature in maintaining physiologic thoracic kyphosis to provide stability to the spine. As a consequence of their absence in PBS, we propose this leads to excessive compensation of the lumbar musculature and resulting sagittal imbalance. Growing rods spanning the thoracic region can provide resolution of thoracic kyphosis and correction of the thoracolumbar curve.



3A. A Motion-Preserving Surgical Treatment for Neuromuscular Scoliosis: Proof of Concept

Laury Cuddihy, MD; M. Darryl Antonacci, MD; Awais K. Hussain, BS; Khushdeep Vig, BS; MJ Mulcahey, PhD, OTR/L; Randal R. Betz, MD

Summary
Skeletally immature patients with spinal cord injury (SCI) suffer from progressive neuromuscular (NM) scoliosis. Operative treatment has typically been limited to posterior spinal fusion (PSF), but a newer technique as described may be less invasive and preserve more function.

Hypothesis
Anterior Scoliosis Correction (ASC) can be successfully performed in skeletally immature patients with NM scoliosis.

Design
Case report, including review of patient records and imaging.

Introduction
Approximately 98% of skeletally immature children with SCI will develop NM scoliosis, and two-thirds will require surgical fusion. A PSF of the entire spine to the pelvis is standard of care. However, maintenance of spinal flexibility, motion, and potential growth is desirable. We present a case for proof-of-concept of utilizing a surgical motion preserving technique to treat progressive NM scoliosis.

Methods
An 11-year-old girl who sustained a T10 level (AIS A) paraplegia three years prior in a motor vehicle accident presented with a progressive 60° NM scoliosis of the lumbar spine. She had an ASC from T11-L5 without fusion by the second author (MDA).

Results
No significant complications occurred in the perioperative and postoperative follow-up periods. Her initial post-op curve was 25° as planned, and she growth modulated over 24 months to a residual curve of 12°. Her sagittal alignment remained stable in a planned mild 14 to 20° of TL/L kyphosis. She is now 30 months post surgery, Risser 4, Sanders 7. The curve maintained correction in both the coronal and sagittal plane, including pelvic obliquity, without any complications.

Conclusion
This case illustrates proof-of-concept for alternative treatment of children with NM scoliosis. Whereas the ultimate long-term outcome is not known, surgical correction of NM scoliosis without spinal fusion does not eliminate the potential need for future treatment options. However, unlike a permanent PSF, it allows for replacement or any other new treatment in the future.

3B. Outpatient Distraction for Severe Adolescent Idiopathic Scoliosis

Selina C. Poon, MD; Paul Choi, MD

Summary
This is a case report of outpatient gradual distraction with Magnetic Controlled Growing Rod (MCGR) for severe adolescent idiopathic scoliosis.

Hypothesis
MCGR may be a useful alternative to Halo Gravity Traction (HGT) or Temporary Internal Traction (TT) for severe adolescent idiopathic scoliosis

Design
A case report using MCGR for outpatient distraction of severe adolescent idiopathic scoliosis

Introduction
Acute correction of severe deformities of the spine is associated with increased risk of neurologic complications. Preoperative HGT and TT providing gradual correction prior to definitive fusion are accepted methods for minimizing risks and complications of severe spinal deformity correction. HGT often involves the use of a bulky device and inpatient hospital stay for the duration of the traction process. TT requires multiple surgical procedures for the distraction process. Recent case studies concluded that using Magnetically Controlled Growing Rods (MCGR) for gradual inpatient distraction of severe spinal deformity is safe and effective with multiple Ponte osteotomies. The objective of this study is to describe a case of severe adolescent idiopathic scoliosis treated with outpatient distraction.

Methods
16 year old girl with 180 degree adolescent idiopathic scoliosis underwent sub-muscular MCGR placement T2-L5 without complications. No additional osteotomies or exposure of the deformity was performed.

Results
Patient was discharged home on post-operative day 4. Outpatient lengthening was started 2 weeks post surgery. Patient underwent 16 lengthenings over 6 months. At the end of lengthening, the deformity measured 78 degrees and the patient is awaiting final fusion scheduled for February 2018.

Conclusion
This preliminary report demonstrates an outpatient alternative to HGT and TT for treatment of severe adolescent idiopathic scoliosis. The MCGR may be used as an internal distraction device for gradual correction of severe deformities.

3C. Complete Loss of Motor Sensory With Motor Deficits With Instrumentation and Fusion of Severe Juvenile Scoliosis

Terry D. Amaral, MD; Jesse Galina, BS; Stephen Wendolowski, BS; Melanie Smith, cPNP; Vishal Sarwahi, MBBS

Summary
A 12 year old female with 76° and 64° kyphoscoliosis underwent posterior spinal fusion developed PJK, lost signals post-revision and needed complete hardware removal.

Hypothesis
Correction maneuvers can lead to loss of neurological signals in patients who have potential subclinical neurological compromise

Design
Case Report

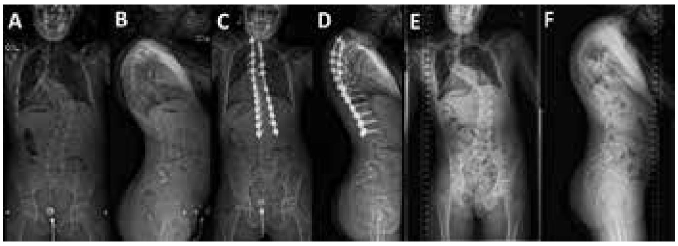
Introduction
Patient is a 12 year old female with juvenile kyphoscoliosis and a possible remote history of cerebral palsy due to her being an

ex-24 week premature birth. A VP shunt had been placed during infancy. Preoperative x-rays showed a 76° (T2-T8) curve and a 64° (T8-L1) curve. She underwent a full workup, including a neurosurgery evaluation for questionable findings in the cervical spine. Patient was cleared by all services. Clinical exam showed no focal deficits or neurological findings.

Methods
Patient underwent posterior spinal fusion with instrumentation. Hooks were placed on the concave side of the upper thoracic spine. Patient responded well, however, two months postop, proximal implant migration and irritation occurred. Patient had PJK measured at 52° and fixation failure. Revision was required. During instrumentation, there were no neuromonitoring changes. During correction, there was a complete loss of SSEPs and MEPs. Neuromonitoring protocol was initiated. There was a complete recovery of neuromonitoring signals and a positive wake-up test, it was felt that the instrumentation could remain. Surgery was completed with patient moving all extremities spontaneously.

Results
After 24 hours, patients experienced gradual loss of motor and sensory on the right side, then the left, before losing motor and sensory completely. CT ruled out pedicle screw misplacement as the cause. Complete removal of implants and decreasing correction was recommended. Laminotomies were performed from T3-T7. She had no detectable neuromonitoring signals before and after removal. Postop, patient had complete return of sensation and motor function on the left lower extremity and approximately 70% return on the right. MRI results immediately, 1 week, and 1 month post-removal could not explain neurological events.

Conclusion
Corrective maneuvers in patient with potentially subclinical neurological issues may potentially be at high risk for neurological compromise. Complete correction may not be warranted in these patients.



3D. Staged Minimally Invasive Neuromuscular Scoliosis Surgery in the Jehovah's Witness Patient Can Safely Achieve Surgical Correction

Vishal Sarwahi, MBBS; Jesse M Galina, BS; Stephen Wendolowski, BS; Benita Liao, MD; Terry D. Amaral, MD

Summary
Staged mimimally invasive approach to a Jehovah's Witness patient with Neuromuscular Scoliosis provides a safe method of addressing the deformity while avoiding the need for blood products.

Hypothesis
Staged minimally invasive scoliosis surgery is a strong alternative for complex neuromuscular patients.

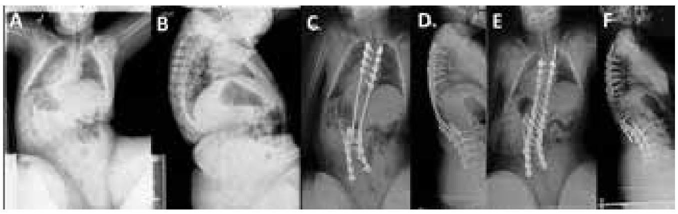
Design
Case Report

Introduction
Patient is a 12 year old anemic male Jehovah's Witness with history of tetrapelegic cerebral palsy, Lennox Gaustaut epilepsy, and progressive neuromuscular scoliosis. X-rays showed a 118° T7-L2 curve. Patient has a history of recurrent pneumonia, pulmonary issues on CPAP, and gastrointestinal issues. Staged posterior spinal fusion and instrumentation was indicated.

Methods
Transfusions were avoided unless lifesaving. Preop Hgb/Hct-14/43. The modified minimally invasive approach was used with single midline incision and paraspinal muscle approach. Patient was fused from T2 to T6, as well as L2 to the sacrum. Non-segmental instrumentation was carried out from T7 to L1. Rods were then introduced and some correction was achieved (from 118° to 68°). Hgb/Hct at that time was 10/31. Second stage was performed eight months later. Dissection was carried out similar to the first stage. Vertebral osteotomies were done from T7-T12 and screws were placed freehand. Rods were introduced. DVR, translation, compression, and distraction were done. Rods were attached to wedding bands at the distal segments, significantly correction the lumbar spine. Hgb/Hct at that time was 11/34.

Results
Initial stage was uneventful. EBL was 550cc. Received 120cc cell saver and 4100 cystalloids. Intraop Hgb/Hct was 10/31 and 12/37 after intraoperative blood salvage. He was extubated POD 2. Lung function improved with less dependence on CPAP. Patient was discharged on POD7. Family was satisfied with the improved sitting balance, pulmonary function, and appetite. Second stage was uneventful. EBL was 200cc and received 3 liters of crystalloids. He was extubated on POD 1 to BiPaP and then RA. Patient was transferred to the floor on POD 4 and discharged on POD 7. Final XR showed 29° curve, 75% correction.

Conclusion
Neuromuscular Jehovah's Witness patient population poses a tremendous challenge for surgical management of their complex issues. The minimally invasive surgical approach may provide a safe solution for giving them the care they need.



Podium Presentation Abstracts

*Hibbs Award Nominee for Best Clinical Paper †Hibbs Award Nominee for Best Basic Research Paper

The Russell A. Hibbs Awards are presented to both the best clinical and basic research papers presented at the Annual Meeting. The nominated abstracts, selected by the Program Committee, are invited to submit manuscripts for consideration. Winners are selected on the basis of manuscripts and podium presentations.

1. Can Pelvic Incidence Change after Surgical Correction in Adult Spinal Deformity Patients with Use of S2 Alar Iliac Screws and Cantilever Correction of the Sagittal Plane?

Chao Wei, MD; James Lin, MD, MS; Hong Ma, MD; Ming Yang, MD, PhD; Suomao Yuan, MD; Meghan Cerpa, BS, MPH; J. Alex Sielatycki, MD; Suthipas Pongmanee, MD; Zachary Messer, MPH; Eric Leung; Takayoshi Shimizu, MD, PhD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary
This radiographic review of 68 consecutive adult spinal deformity (ASD) patients with S2 alar iliac screw (S2AI) placement for spinopelvic fixation demonstrated that the pelvic incidence (PI) can be increased or decreased after long fusions to the pelvis. Patients with high PI are more likely to have a decrease in their PI postoperatively.

Hypothesis
We hypothesize that cantilever correction to induce lordosis during spinal deformity surgery with pelvic fixation using S2AI screws can result in changes in PI value in ASD patients

Design
Single center cohort

Introduction
PI is assumed to be a constant anatomic parameter. However, several studies have reported both increases and decreases in PI in ASD patients with long fusion constructs to the pelvis. We aim to investigate whether the PI changes in the early postoperative period in a cohort of ASD patients with pelvic fixation

Methods
68 consecutive ASD patients who underwent spinal deformity surgery with S2AI screw placement for spinopelvic fixation were analyzed. Patients were categorized into three groups: Group A, high PI (PI≥60⁰); Group B, normal PI (60⁰>PI>40⁰); Group C, low PI (PI≤40⁰). Preoperative and early postoperative (one week) 36-inch lateral spine radiographs were assessed. The PI was measured by two independent experienced spine surgeons

Results
12 males and 56 females, aged 22-75 years were analyzed. PI changed ≥ 5⁰ postoperatively in 28 patients(41.18%). The average change was 4.58⁰±3.05. 11 patients(16.18%) increased PI≥5⁰ and 17 patients(25%) decreased PI≤5⁰. The PI changes for Groups A, B, and C, were 6.18±2.89, 3.75±2.85 and 4.58±2.84, respectively. There was a statistically significant difference in PI changes in between Groups A and B(p=0.001), and Groups A and C(p=0.004). When comparing preoperative PI to postoperative PI there was a significant association at p=.0096 and they were significantly positively correlated (r=0.92, p<0.0001). Interclass (k=0.94) reliability was assessed to validate the measurements

Conclusion
This is the first North American study to show that Pelvic Incidence changes in 41.18% of ASD patients who underwent S2AI screw placement for spinopelvic fixation when comparing preoperative to early postoperative radiographs. PI changes demonstrated in our study likely result from the moment arm of the S2AI screws coupled with the strong cantilever corrections performed to induce low lumbar/lumbosacral lordosis during deformity correction.

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2. Evaluation of Pelvic Incidence (PI) Constancy at Different Physiologic Postures, and Assessment of Confounding Factors that May Affect Stability of this Parameter

Christopher Kleck, MD; Andriy Noshchenko, PhD; Christopher Cain, MD, PhD; Evalina Burger, MD; Vikas Patel, MD, BS, MA

Summary
PI is a dynamic parameter that can change from flexion to extension. These changes are due to mobility of the sacrum relative to the pelvis through the sacroiliac joint. Obesity contributes to greater changes in PI, and correspondingly, higher mobility of the sacrum in the sacroiliac joint. Radiographic test with flexion and extension can be used for evaluation of sacroiliac joint mobility.

Hypothesis
It was hypothesized that PI is a stable parameter without significant changes from flexion to extension.

Design
Single-Center cross-sectional study

Introduction
PI has been considered a static parameter since it was originally described. Recent studies have shown that PI can change with age and after spinal procedures. Changes in PI based on position have not been investigated. To investigate changes/variability of PI from flexion to extension.

Methods
72 patients who had obtained flexion and extension radiographs of the lumbar spine were identified using the following main inclusion and exclusion criteria: age >20 years old; male and female; none of the following: spinal trauma, spinal surgical intervention, inheriting, acute or severe chronic diseases. PI, along with pelvic tilt (PT), sacral slope (SS), and lumbar lordosis (LL) were measured in both flexion and extension by 2 independent measures. Variations in all parameters and inter-observer measurement reliability were analyzed for the entire group; 95% confident interval between 2 independent measurements of the same parameter in the same subject by linear regression was defined as measurement error.

Results
PI changed significantly from flexion to extension with general

tendency to decrease: mean (-0.94°), P<0.044. However, these changes may have had opposite vectors, and exceeded | 6°| (measurement error) in 20% of cases; with the maximum, 12°. Inconsistencies in changes of SS, as opposed to PT from flexion to extension were found to be the major factor determining changes in PI (P>0.001). Obesity significantly contributed to differences in PI between flexion and extension (P=0.003).

Conclusion
PI is a dynamic parameter that changes between flexion and extension. Changes in SS are the main factor involved in these changes, implicating movement through the sacroiliac joints as the cause. Obese patients have greater changes in PI from flexion to extension. Radiographic test with flexion and extension can be used for evaluation of sacroiliac joint mobility.

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3. Sagittal Vertical Axis: A Poor Instrument for Measuring Inappropriate Spinal Correction

Derek Cawley, FRCS; Louis Boissiere, MD; Takashi Fujishiro, MD; Daniel Larrieu, PhD; Ferran Pellisé, MD; Frank S. Kleinstueck, MD; Francisco Javier Perez-Grueso, MD; Emre Acaroglu, MD; Ahmet Alanay, MD; Jean-Marc Vital, MD; Olivier Gille, MD, PhD; <u>Ibrahim Obeid, MD, MS</u>

Summary
Neutral or negative SVA does not correlate with appropriate spino-pelvic alignment.

Hypothesis
With normal or negative SVA the pelvic version can by itself differentiate aligned from malaligned patients.

Design
Multicenter prospective study

Introduction
A positive SVA is the radiographic spinal parameter most highly correlated with adverse health status outcomes. This is an expression of spinopelvic decompensation after the failure of all mechanisms to maintain global alignment. A neutral SVA after spinal deformity correction can yield complications of up to 30%. Negative sagittal balance remains largely undefined. Thus, the validity of a SVA is questionable as an instrument for assessing sagittal plane correction.

Methods
All adult spinal deformity patients who were treated operatively, with a neutral or negative SVA at 6 weeks follow-up were included, and then at 2 years follow-up. These included patients with fusion of over 4 vertebrae with the lowest instrumented vertebra at L5 or below. Outcomes included ODI, SVA, GT, PT, LLI. 6-week subgroups were made regarding pelvis orientation (anteverted, normal or retroverted).

Results
96 patients were identified including 45 aligned, 48 retroverted and 3 with an anteverted pelvis at 6 weeks. 42 patients with aligned pelvic tilt (˚) retroverted over 2 years while maintaining normal SVA(mm) (Pre- 25˚/43mm, 6 weeks 15˚/7mm, 2 years 22˚/16mm), 42 patients with a retroverted pelvis remained retroverted and SVA increased over time (Pre 27˚/65mm, 6 weeks 24˚/12mm, 2 years 24˚/41mm). 3/96 patients with an anteverted pelvis were too small a group for analysis.

Conclusion
With normal SVA the pelvis orientation at 6 weeks was poorly related to proper correction. The aligned pelvis group at 6 weeks increased its pelvic tilt at 2 years whereas the retroverted group increased its SVA. Different compensatory mechanism were involved in the different subgroups but postoperative SVA is inappropriate to consider proper alignment.

		preop	6w/3months	Last FU
ODI	Aligned	40,81		27,79
	Retroverted	43,70		29,47
	Anteverted	51,50		50,00
GT	Aligned	29,40	16,07	25,15
	Retroverted	35,30	23,00	29,05
	Anteverted	29,67	15,67	23,00
PT	Aligned	24,62	15,67	22,11
	Retroverted	26,89	23,91	25,52
	Anteverted	23,00	13,67	19,33
SVA	Aligned	43,23	7,05	16,26
	Retroverted	64,89	12,47	40,51
	Anteverted	59,67	29,00	16,30
LL	Aligned	-38,42	-57,53	-51,32
	Retroverted	-29,83	-45,53	-45,29
	Anteverted	-46,67	-67,33	-65,67
LLI	Aligned	-0,67	-1,00	-0,90
	Retroverted	-0,56	-0,94	-0.93
	Anteverted	-0,71	-1,00	-1,03

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4. The Effect of Open versus Minimally Invasive Approach (MIS) in Instrumentation of the Proximal Spinal Segment in Long Posterior Fusion on the Incidence of Proximal Junctional Kyphosis (PJK): A Prospective Randomized Controlled Study with Minimum 2year Follow Up

<u>Floreana Kebaish, MD;</u> Micheal Raad, MD; Khaled M. Kebaish, MD, FRCS(C)

Summary
PJK is a common complication (25%- 40%) following long posterior spinal fusion (PSF) for adult spinal deformity ASD, which may necessitate revision surgery. The occurrence of PJK is thought to be multifactorial. Disruption of the posterior tension band is believed be and important factor. The aim of this study is to investigate the effect of preserving the paraspinal muscles and ligamentous structures at the UIV using and MIS approach on the incidence of PJK and PJF

Hypothesis
Open surgery in long posterior fusion leads to disruption of the posterior tension band. An MIS approach to placement of the instrumentation at the UIV preserves the soft tissue and lowers the incidence of PJK

Design
Prospective, randomized controlled study

Introduction

PJK is a common complication (25%- 40%) following long posterior spinal fusion (PSF) for adult spinal deformity ASD. The occurrence of PJK is multifactorial; Disruption of the posterior tension band is believed be and important factor. An MIS approach that preserves the posterior soft tissue structures may decrease PJK incidence

Methods

Forty-two patients prospectively randomized into 2 groups, MIS and Open. 35 patients (MIS=15, Open=20, p=0.3) completed 2-year follow-up (28.8 SD 7.6 months, 23–48) (1 died). In the open arm, the UIV was exposed, pedicle screws placed using a free-hand technique; in the MIS arm, the instrumentation placed subcutaneously at the UIV without muscle dissection. PJK defined as a PJA >10° greater than the immediate postoperative PJA or PJK requiring revision surgery

Results

41 patients analyzed (27F, 14M), age (65, 44–81). Baseline PJA measurements were similar in the two groups (p>0.05). MIS group had a higher baseline PI-LL (34 vs 21, p=0.02). The mean change in PJA between immediate postoperative and last follow up was 1.4 (MIS) and 1.3 (Open), (p=0.9). The overall incidence of PJK was higher in the Open group (18.2% vs 10.5%), but not statistically significant (p=0.49). There was a higher rate of revision for PJK in the Open (13.6%) vs MIS (5.3%), (p=0.4). The rates of non-union were similar between the two groups (5.3% MIS vs 4.6% Open, p=0.9). EBL was similar in the 2 groups, operative time was longer in MIS (p=0.01)

Conclusion

The overall incidence of PJK and PJF in this study was low (14.6%). The MIS approach for placement of pedicle screws at the UIV has lower trend for lower PJK and PJF at two years compared with the open approach. A larger sample size may be necessary to validate this trend.

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5. The Offset of the Upper Instrumented Vertebrae to the Gravity Line is a Risk Factor for PJK Onset After 6 Weeks

Jonathan Charles Elysée, BS; Renaud Lafage, MS; Han Jo Kim, MD; Robert A. Hart, MD; Breton G. Line, BS; Christopher Shaffrey, MD; Douglas C. Burton, MD; Christopher Ames, MD; Gregory Mundis, MD; Richard Hostin, MD; Shay Bess, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

Summary

Despite a high incidence of PJK within 6wks, a subset of patients develop delayed onset PJK between 6wks and 2yrs. Comparisons between patients that develop PJK between 6wk and 2yrs and those that do not demonstrated no significant difference in global alignment despite having a larger offset between gravity line and UIV. Prediction of the post-operative angle demonstrated good results with and R2 of 0.6 and showed association between increase posterior alignment and PJK magnitude at 2yrs.

Hypothesis

Thoracolumbar instrumented patients with a UIV distant from the gravity line are more prone to develop PJK.

Design

Retrospective review of a prospective database

Introduction

PJK is a frequent complication following Adult spinal deformity (ASD) occurring in 80% of the patients within the first 6 weeks. Despite numerous PJK related research efforts, little is known regarding the risk factors for new onset PJK after 6 weeks.

Methods

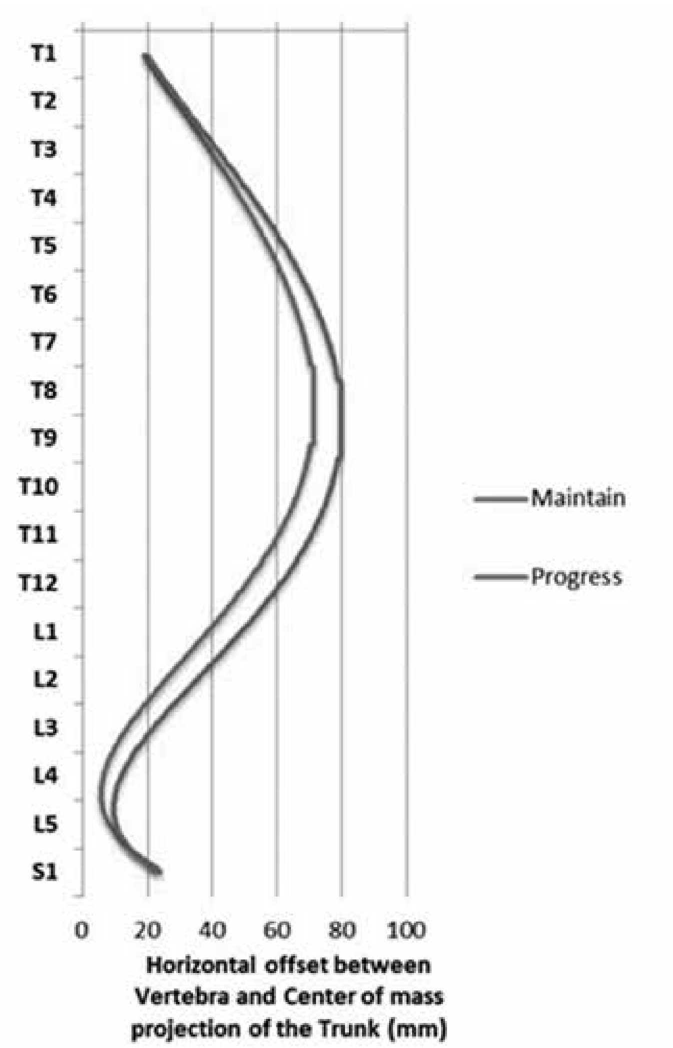
ASD patients with complete fusion of the lumbar spine including the pelvis, and UIV between T8 and L1 were categorized based on the presence of PJK (Glattes) at 6 weeks and 2 yrs FU. Patients with no-PJK at 6 weeks were categorized as Progress (PJK at 2 Years) vs Maintain (no PJK at 2 Years). A validated mechanical model was used to calculate the center of gravity of the trunk and head. Demographic, surgical, gravity line, and radiographic data were compared between Progress and Maintain. Linear correlations and regression were performed to predict change above the instrumentation.

Results

116 patients were included (62 yo, 82% female, 27 kg/m2. At 6 wks there were no differences in classic spino-pelvic parameters. Progress group had more posterior T9SPi (-13.3±3.5 vs -11.5±4.9, p<0.022) and a larger Gravity Line / UIV distance (GL-UIV) (76.5±18.6 vs 65±22.1, p<0.007). At 2 yrs, there was no difference in global alignment, however, Progress had a more kyphotic PJA (-19.6±6 vs -10.4±7.2, p<0.001), a larger TK (-46.9±11.4 vs -41.4±16.5, p<0.006), a more posterior T9SPi (-14.9±4.4 vs -11.7±5.1, p<0.003), and a larger GL-UIV (87.6±20.1 vs 67.3±26.4, p<0.001). The linear regression to predict the 2Y PJK angle yielded an adjusted R2 of 0.596 with independent predictors being 6 weeks GL-UIV, PJA, and L1-S1 lordosis.

Conclusion

As a crucial element of standing posture, unfused segments changed to maintain the GL over the feet. Onset of PJK after 6 weeks postop was associated with a more posterior UIV position relative to the center of mass of the trunk. This increase in distance may lead to increased stress and mechanical loading at the junction, favoring acute reciprocal change.



6. Tether Constructs Used to Prevent Proximal Junctional Kyphosis (PJK) Should Incorporate the UIV+1 and UIV+2; A Finite Element Analysis (FEA)

Shay Bess, MD; Ming Xu, PhD, MS, BS; Virginie Lafage, PhD; Breton G. Line, BS; Regis Haid Jr., MD; Frank J. Schwab, MD; Christopher Shaffrey, MD; Justin Smith, MD, PhD; International Spine Study Group

Summary

Effective prophylaxis to reduce PJK may require progressive dissipation of junctional forces above long instrumented constructs. FEA of tether configurations attached proximal to long pedicle screw constructs demonstrated incorporation of the UIV+1 and UIV+2 and pre-tensioning the tether most effectively tapered ROM at the uninstrumented proximal junctional segments. Additional inclusion of the UIV into the tether construct did not further reduce ROM. Clinical studies evaluating tether implants/constructs to prevent PJK should consider using these findings for research consistency.

Hypothesis

Inclusion of UIV+1 and UIV+2, and pre-tensioning tether constructs will most effectively taper the return of physiological range of motion (ROM) above long fusion

Design

Finite element analysis (FEA)

Introduction

Tapering return of physiological ROM above long fusions may reduce PJK. Prior data indicates tether constructs more effectively dampen junctional ROM than hooks and tapered rods. Optimal vertebrae to include into tether constructs and impact of tether pre-tensioning is unknown.

Methods

FEA model of a T7-L5 spine segment was developed to evaluate theoretical spine ROM. Segmental ROM was evaluated by potting L5 and applying a 5.0 Nm flexion moment to T7. Simulations were undertaken for a) uninstrumented spine, b) spine instrumented with T11-L5 pedicle screw construct, and c) tether constructs created by attaching a polyethylene terephthalate (PET) band into a drill hole through the vertebral spinolaminar junction (TETHER construct). The impact of 1) proximal TETHER attachment to UIV, UIV+1, and/or UIV+2, 2) distal TETHER attachment to spinous process vs rod, and 3) impact of TETHER tensioning was evaluated (Figure 1).

Results

ROM at the junctional segment for the instrumented, non-tethered model abruptly increased from <10% of intact at T11-12, to 99% at T10-11 and T9-10. TETHER constructs reduced ROM up to the T8-9 segment. TETHER attachment to UIV+1 level dissipated ROM from 6% (± 0%) at T11-T12, to 41% (± 2%) at T10-T11. TETHER incorporation of UIV+1 and UIV+2 dissipated ROM from 5% (± 1%) at T11-T12, to 24% (± 3%) at T10-T11, and 28% (± 1%) at T9-T10. TETHER pre-tensioning 50 N preload further decreased ROM 16% at UIV/UIV+1 and 11% at UIV+1/UIV+2. Distal attachment of the TEHER to the rod vs. spinous process and level of distal TETHER attachment had no impact on ROM (Figure 1).

Conclusion

FEA demonstrates tether constructs that include the UIV+1 and UIV+2 and are pre-tensioned most effectively dissipate ROM above long constructs and may help prevent PJK. Clinical studies evaluating TETHERS to prevent PJK should consider using these construct parameters for research consistency.

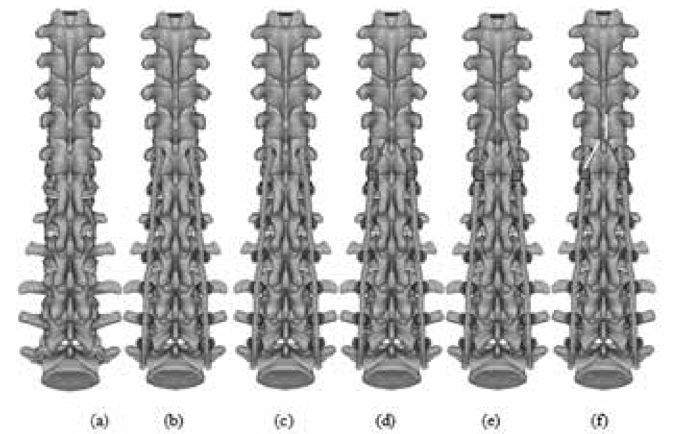


Figure 1. Posterior view of spine models tested: (a) intact; (b) bilateral segmental pedicle screws and rods T11-L5; (c) TETHER attached to UIV+1 proximally and to UIV spinous process distally; (d) TETHER attached to UIV+1 proximally and to rod distally; (e) TETHER attached to UIV+2 proximally and to rod distally; and (f) TETHER attached to UIV+1 and UIV+2 proximally and rod distally.

7. Does Preoperative Opioid Use lead to Poorer Outcomes and Continued Opioid Abuse at 2 Years Postoperative?

Robert Owen, MD; Sami Mardam-Bey, MD; Lawrence G. Lenke, MD; Jeffrey Gum, MD; Michael P. Kelly, MD, MS

Summary

Although patients taking opioids had lower SRS-SS and higher ODI scores before surgery versus opioid naive patients, they actually experienced a greater improvement in these HRQOL scores than the opioid naive group leading to similar overall outcomes at 2 years postoperatively. In addition, 30% of Opioid users had quit taking them while unfortunately 21% of the Opioid naive patients were still using narcotics at 2 yrs postop.

Hypothesis

Preoperative opioid use will be associated with worse outcomes in adult spinal deformity patients.

Design

Prospective, observational cohort

Introduction

The United States is facing an opioid crisis. Opioid use is common in adult spinal deformity (ASD). Pre-operative opioid use is associated with poor outcomes in other areas of surgery. The goal was to evaluate the effect of pre-operative opioid use on health-related quality of life (HRQOL) and opioid cessation after ASD surgery.

Methods

Inclusion criteria: age 18-65, posterior spinal fusion with three-column osteotomy or 6+ level fusion, primary or revision. Exclusion criteria: primary trauma, tumor, or infection. Pre- and 2-year post-operative average SRS-22, ODI, and average self-reported daily opioid use in morphine equivalent dosing (MED) were collected.

Results

33 patients taking opioid pain medicine (OP) (mean daily MED 62mg) and 34 opioid-naive (ON) patients achieved 2-year follow up; 4 patients died. 64% of patients in the OP and 32% of patients in the ON groups were revision surgery (p = 0.03). SRS-subscore (SS) scores were lower pre-operatively for the OP group (2.4 vs 3.1, p<0.01). ODI scores were higher preoperatively for the OP group (53 vs 41, p<0.01). At 2-year follow-up, SRS and ODI scores were similar for the ON and OP groups (SRS 3.6 vs 3.4, p=0.17, ODI 29 vs 37, p = 0.11). Both OP and ON SRS and ODI scores improved significantly (p<0.01), with OP SS showing greater overall improvement (p<0.01). At 2-year follow-up 30% of patients (n = 10) in the OP group had stopped opioids, while 21% of patients (n=7) in the ON group continued opioids.

Conclusion

ASD patients using opioids pre-operatively have worse HRQOL prior to surgery than opioid-naive counterparts. This difference is no longer present at 2-year follow-up, with OP patients showing greater improvements in SRS-SS than ON, despite persistent opioid usage. Nearly one-third of those patients using opioids before surgery had stopped at two years. One-fifth of naïve patients continued opioids at 2-years.

Table 1. Patient Demographics and Outcome Data

	Opioid Use (n=33)	Opioid Naive (n=34)	p-value
Demographics			
Age at Surgery (years)	59.9	55.2	0.03
Male	30% [10]	18% [6]	0.22
MED	61.6	NA	
Operative Data			
Fusion Levels	13.7	13.3	0.66
Revision	21 [64%]	11 [32%]	0.03
Patient Reported Outcomes- Preop			
SRS	2.4	3.1	<0.01
ODI	53	41	<0.01
Patient Reported Outcomes- 2 yr			
SRS	3.4	3.6	0.17
ODI	37	29	0.11
MED – 2 yr	42.1	23.2	0.24

8. The Impact of Surgical Invasiveness and Patient Factors on Long-Term Opioid Use in ASD Surgery

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Summary

Given the substantial amounts of pain and morbid procedures that adult spinal deformity (ASD) patients endure, opioid use is widespread. This study aims to identify risk factors for long-term opioid use in this vulnerable patient population. Our results show that increasing surgical invasiveness increases the risk of perioperative but not long-term opioid use. The latter seems to be associated with patient-specific factors such as mental health, frailty and more importantly preoperative opioid use.

Hypothesis
Increasing surgical invasiveness as well as patient-specific factors are associated with long-term opioid use in ASD patients.

Design
Retrospective review of prospective data

Introduction
Prolonged opioid use can have a deleterious effect on patients and is a significant public health burden. No previous studies have defined risk factors for long-term opioid use in ASD patients.

Methods
A prospective ASD surgical database was retrospectively queried for patients with self-reported data on preoperative, short-term (6 weeks postop), and long-term (2 years postop) opioid use. Patients were categorized as using "narcotics daily" or "weekly or less". The ASD-SR invasiveness index (accounts for surgical and radiographic parameters) was used to divide patients as follows: <80, 80-120, 120-160, >160. Regression analysis, student's t-test and chi2 were used to assess preoperative risk factors for long-term opioid use.

Results
705 patients were eligible and 517 (73%) completed 2-year follow up. Increasing surgical invasiveness was not associated with increased long-term use (p>0.05). However, ASD-SR 120-160 and >160 had higher odds of short-term use irrespective of baseline use (OR=2, p=0.047; OR=2.2, p=0.018, respectively). Subgroup analysis showed that only in the ASD-SR > 160 group, frail patients (OR=3.0, 1.1 , 7.9, p=0.03) and patients with a MCS <50 baseline (OR=2.76, 1.2 – 6.5, p= 0.02) were more likely to have long-term use. Age and gender had no significant influence on post-operative narcotic use. The most consistent risk factor for long-term opioid use was use at baseline. Interestingly, preoperative opioid use was associated with the highest OR for long-term use in the lowest invasiveness group (<80: 14.5 p<0.01; 80-120: OR 5.1 p<0.01;120-160: 6.3 p<0.01; > 160:7.9 p<0.01).

Conclusion
Increasing surgical invasiveness affected perioperative but not long-term opioid use. Long-term opioid use seems to be related to patient-specific factors such as frailty, mental health and most importantly preoperative opioid use.

9. Immediate Postoperative Narcotic Use is Not Associated with Preoperative Opiate Use or Surgery Invasiveness

Portia Steele, MS; Jeffrey Gum, MD; Charles Crawford III, MD; Kirk Owens, MD; Mladen Djurasovic, MD; Morgan Brown, MS; Steven Glassman, MD; Leah Yacat Carreon, MD, MS

Summary
Opiate abuse is at a record high with 116 deaths per day due to overdose. We propensity matched patients undergoing 1- and 2-level MIDLIFs vs TLIFs (33:33) to compare immediate post-operative opiate consumption. No difference was found. Patients who were taking opiates preoperatively (65%) had worse baseline, 1-year postop, and change in ODI scores compared to opiate naive patients.

Hypothesis
We hypothesized that adult patients undergoing minimally Invasive Midline Lumbar Interbody Fusions (MIDLIF) would have reduced opiate consumption in their postoperative course than traditional transforaminal lateral interbody fusion (TLIF) patients.

Design
Propensity matched longitudinal cohort

Introduction
In 2016 alone, there were 19,413 deaths attributed to prescription opioid overdoses. Understanding the drivers of opiate consumption in post-operative lumbar spinal fusion patients is a high priority.

Methods
A single center, multi-surgeon, retrospective review identified patients with degenerative lumbar pathology who underwent an instrumented posterior lumbar decompression and interbody fusion (MIDLIF or TLIF). Patients in each cohort were propensity-matched based on age, sex, smoking status, BMI, diagnosis, ASA grade and levels fused. Morphine equivalent doses (MED) from postoperative day (POD) #0 through POD #4 were calculated. Preoperative opiate prescriptions were recorded to determine baseline opioid use.

Results
Of 214 MIDLIF and 281 TLIF patients undergoing surgery, 33 patients in each cohort were successfully propensity matched with no differences in baseline characteristics. There was no difference in immediate post-operative mean Total MED between the cohorts (MIDLIF=370, TLIF=302, p=0.398). 43 (65%) of patients were taking opiates prior to surgery. Opiate-naïve patients required less narcotics (MED=248) compared to non-opiate naive patients (MED=383, p=0.071) but this was not significant. Patients taking opiates preop had worse baseline ODI (56.5 vs 47.2, p=0.023) and 1-year postop ODI (46.3 vs 30.9, p=0.015).

Conclusion
Neither surgery invasiveness nor preoperative opiate use have an impact on immediate postop opiate consumption. This is likely secondary to non-individualized prescribing patterns. Patients taking preop narcotics have worse baseline, 1-year, and improvement in ODI following 1- and 2-level MIDLIFs or TLIFs.

10. Sagittal Balance In Hyperkyphotic Patients with Growing Rods and the Effect of Preoperative Halo Gravity Traction

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Summary
Hyperkyphosis is a known risk factor for proximal junctional kyphosis (PJK) in growing rods patients. We looked at patients

who were baseline hyperkyphotic (kyphosis > 40°) and confirmed that the amount of preoperative kyphosis and postoperative pelvic incidence were risk factors for developing PJK. However, very hyperkyphotic patients who received preop halo gravity traction (HGT) did not have a significantly higher rate of PJK, indicating that pre-op HGT can mitigate some of the risk of hyperkyphosis.

Hypothesis
Risk factors for PJK in hyperkyphotic growing rods patients are similar to non–hyperkyphotics. Halo gravity traction has protective effect.

Design
Retrospective review

Introduction
Hyperkyphosis has been identified as a major risk factor for proximal junctional kyphosis (PJK) in patients treated for early onset scoliosis (EOS) with growing rods. Our goal was to explore the sagittal parameters in a population of hyperkyphotic patients and determine whether preoperative halo gravity traction (HGT) has an effect on risk for PJK.

Methods
Retrospective review that included all patients at a single center with: EOS treated with growing rods, preoperative kyphosis > 40º and at least 2 years follow-up. Patient demographics, HGT duration if applicable and surgical details were recorded. We measured sagittal parameters on radiographs taken before traction, preop, postop, and at follow-up visits. SPSS was used for t-tests, Chi square and binary logistic regression.

Results
49 patients met criteria. Average age was 7.5 (range 2- 14) years. 17 (35%) of patients developed PJK. Patients with PJK had significantly higher preoperative kyphosis (84 ± 14° vs. 71 ± 15°, p = 0.008) and higher postoperative pelvic incidence (49 ± 14° vs. 40 ± 10°, p = 0.02). There was no significant difference in age, levels fused, apex level, postoperative kyphosis or kyphosis correction index. Patients with > 60º of preoperative kyphosis were 9 times more likely to get PJK (p =0.05). 19 (39%) patients underwent pre-op HGT for average duration of 9.3 (range 4-20) weeks. HGT patients started out with significantly more kyphosis (106 ± 12º vs. 72 ± 17º, p= 0.000), but their kyphosis decreased down to an average of 81 ± 15º after HGT treatment and they did not have a significantly higher rate of PJK at the time of last followup (27% vs 47%, p = 0.12).

Conclusion
Risk factors for PJK in EOS patients include increased preoperative kyphosis and postoperative pelvic incidence. Very hyperkyphotic patients who underwent pre-op HGT did not have a higher rate of PJK, indicating that HGT can be a useful adjunct in those patients to decrease their risk of PJK.

11. Surgical Treatment of Segmental Spinal Dysgenesis. A Report of 18 Cases

Rodrigo Remondino, MD; Carlos Tello, MD, PhD; Lucas Piantoni, MD; Eduardo Galaretto, MD; Ida Alejandra Francheri Wilson, MD; Mariano Augusto Noel, MD

Summary
Spinal dysgenesis is a rare congenital anomaly, usually located in the thoracolumbar or lumbar spine and is characterized by the presence of kyphosis or kyphoscoliosis associated with focally stenotic canal, vertebral subluxation and absence of nerve roots within the involved segments1, is characteristic the indemnity of vertebrae and spinal cord cranial and caudal to the injury segment. Characteristic in spinal dysgenic segment are lack of development of vertebral bodies, posterior arches, absence of emerging nerve roots of the spinal cord

Hypothesis
The progression deformity and neurologic deterioration is a rule.

Design
Retrospective cases series

Introduction
Segmental spinal dysgenesis (SSD) is a congenital spine malformation characterized by spinal stenosis, kyphosis and development fails of spinal cord and nerve root. Neurologic function ranges from normal to complete paraplegia. The progression deformity is a rule. Our goal was described clinical manifestation, surgical treatment, result and complication for this complex congenital anomaly

Methods
The complete record of 18 patients with SSD diagnosis were reviewed by independent spinal surgeons between 1998 and 2014, at a single institution, with average follow up 10+6 years (2+1 - 14).

Results
Eighteen patients (10 male 8 female) with SSD. The average age at the time of diagnosis was 2+5 years (0+3-14+9); the average age at surgery was 2+9 years (0+5-15+1). The kyphosis was the most common deformity 14 cases, kyphoscoliosis 3 and 1 scoliosis. The dysgenesis involved an average of 2.94 vertebral levels (1-5), the upper thoracic region was the most common 9 cases, followed by thoracolumbar 5 cases, lumbar and cervical 2 cases each one. Fourteen cases presented severe spinal canal stenosis, 4 cases moderate stenosis less than 50%. Before surgery 9 patients had paraparesis, 3 paraplegia, 1 cuadriparesis while 4 had normal exams. Eleven patients had renal and cardiac anomalies associated. Five patients have undergone double approach, 4 posterior instrumented fusion, 4 VCR and 5 patients simple fusion. Decompression was performed in 14 patients. A total of 26 surgeries were performed, average 1.76 procedures (1-5) to obtain a solid arthrodesis. Four patients had an improvement in neurologic function, 3 had deterioration and 9 without change. Seven complications 4 related surgery and 3 clinical problem.

Conclusion
We recommend prompt early surgical treatment, decompression and fusion must be indicated as soon as possible to preserve and prevent neurologic deterioration. Intra spinal pathology can be resolved in the same time without increase complications. Despite challenging procedure, it was possible to achieve a spinal cord decompression and solid instrument fusion in our cases.

12. Vertebral Column Resections for Early-Onset Scoliosis: Indications, Utilization and Outcome

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Summary

Use of IOM in treating EOS with a VCR was found to be effective in 100% of the patients; despite 7/33 having a preop neuro deficit. 12/33 with an IOM change, with 42% having a post-op deficit.

Hypothesis

Use of intraoperative neuromonitoring (IOM) during vertebral column resection(VCR) in early onset scoliosis (EOS) is obtainable and reliable.

Design

Retrospective review of two multicenter prospective databases.

Introduction

VCR is reserved for pts with severe spinal deformity and carries an increased risk for neurologic injury. Preventative measures to decrease this risk include the use of IOM.

Methods

A retrospective review was performed to identify patients ≤ 10 years at time of VCR. Data points: IOM utilized, IOM changes, response to changes and postop outcome.

Results

33 were included for analysis with mean follow-up after VCR 1.7±2.0yrs. Age at VCR was 6.1±3.0 yrs. Diagnoses: congenital 23, post-tubercular 6 and other 4. Primary deformity: kyphosis 15, scoliosis 10, and kyphoscoliosis 8.VCR occurred as original surgery in 29, and revision in 4. Pre-op major curve (MC) was 82±25° (MC=largest Cobb, coronal or sagittal). Postop MC %correction 70±23%. 7(21%) had preop neurologic deficit. Transcranial MEPs were obtained in 33, SEP in both upper and lower extremities in 28. VCRs per patient was 1.8; OR time 308±154 minutes, EBL 527±634mL. IOM changes occurred in 12, 6 had preop deficits. IOM change most commonly occurred during the VCR (Table 1). IOM changes: 10 MEP only and 2 both MEP and SEP. For MEP: IOM with < amplitude in 6 and loss in 6; bilateral in 5 and unilateral in 7. Avg MAP was 75mmHg. Most common primary maneuver at IOM change was increase MAP>80mmHg (Table 1). IOM return was complete in 6, partial in 3 and none in 3. New postop deficit in 3 (resolution: complete-1, partial-2), continued from preop in 2 (partial resolution in 1, no change from preop in 1) and no deficit in 7. 2 patients had peri-operative neuro complications that occurred after surgery and were unrelated to IOM changes.

Conclusion

IOM could be reliably attained in VCR in EOS. IOM change was 36% with 25% having a new post op neuro deficit all detected with IOM. 100% of new deficits had either complete or partial recovery. IOM is critical in the safe completion of VCR surgery in EOS.

Table 1

Surgical Maneuver at IOM Change	n	Surgical Response*	Anesthesia Response*
VCR	n=7	Completion VCR (n=5) Reversal of reduction (n=2) Laminectomy (n=1) Compression (n=1)	Mean Arterial Pressure >80mmHg (n=4) Blood Products Administered (n=2) Steroids Administered (n=2) None (n=2)
Laminectomy	n=2	Completion VCR (n=1) Laminectomy (n=1)	Mean Arterial Pressure >80mmHg (n=2) Blood Products Administered (n=1)
Deformity Reduction	n=2	Completion VCR (n=2)	Mean Arterial Pressure >80mmHg (n=1) None (n=1)
Implant Placement	n=1	Implant Removal (n=1)	Mean Arterial Pressure >80mmHg (n=1) Blood Products Administered (n=1) Steroids Administered (n=1)

*More than one type of response was performed on some patients.

13. "Less is More" - Significant Coronal Correction of AIS Deformity Predicts Thoracic Hypokyphosis

Oded Hershkovich, MD, MHA; Areena D'Souza, MBBS, MS; Paul Rushton; Michael P. Grevitt, MBBS, FRCS

Summary

We studied the association between the coronal correction with the sagittal balance in AIS patients after posterior surgical correction. Retrospective series of Lenke 1-2 cases surgically treated with a follow up of 2 years. Univariate and multivariate regressions were performed. Post-operative thoracic hypokyphosis was 5 times more likely in patients with thoracic correction ≥60%. This association was not affected by metal density, thoracic flexibility, LIV, UIV, age or sex. Our data confirms the 'essential lordosis' hypothesis of Roaf and Dickson.

Hypothesis

The coronal balancing is associated to the post-operative kyphotic posture and to the overall sagittal balancing. Understanding of this association will assist in preplanning for AIS correction predicting which patient is at risk and how much correction is acceptable without increasing the risk for failure in the sagittal plane.

Design

Retrospective case series of patients with Lenke 1-2 surgically corrected via posterior approach by standardized surgical technique with a minimum follow up of 2 years.

Introduction

Posterior approach with significant coronal correction of AIS deformity is associated with hypokyphosis in the sagittal plane. Factors such as the pre-operative coronal curve, hooks, number of levels fused, pre-operative kyphosis, screw density and rod type have been implicated. Maintaining the normal thoracic kyphosis is important as hypokyphosis is associated with PJF and early onset degeneration of the spine.

Methods

Pre & post operative X-rays were measured and the operative

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data including UIV, LIV, metal density and thoracic flexibility used. Further analysis of the post-surgical coronal outcome (Group I <60% and Group II ≥60%) of our group were studied for their association with the post-operative kyphosis in the sagittal plane. Uni Multivariate logistic regression were used.

Results

95 cases were included in our study (87% F, a.age 14), 72% had thoracic correction > than 60%. Most cases had metal density < than 80% (97.8%) and thoracic flexibility >50% was found in 31%. Preoperative hypo-kyphosis (<20°) was found in 25.3%. Post-operative thoracic hypokyphosis was 5 times more likely in patients with thoracic correction ≥60% [OR 5.16, p=0.002], after adjusting for cofounding variables. This association was not affected by metal density, thoracic flexibility, LIV, UIV, age or sex.

Conclusion

We confirms the 'essential lordosis' hypothesis of Roaf and Dickson i.e. with greater ability to translate the apical vertebra towards the midline there is a commensurate lengthening of the anterior column due to the vertebral wedging. Lack of association with metal density or flexibility suggests that this is an anatomical derivation rather than surgeon related

Table 1.

N=95

Variables	Categories	Post op Thoracic Kyphosis	
		<20%	>20%
Thoracic correction, n(%)	<60%	6 (13.04)	21 (42.86)
	≥ 60%	40 (86.96)	28 (57.14)
*Sex, n(%)	Female	40 (86.96)	42 (87.75)
	Male	6 (13.04)	6 (12.50)
Mental Density, n(%)	< 80%	45 (97.83)	48 (97.96)
	≥ 80%	1 (2.17)	1 (2.04)
UIV, n(%)	T2-T4	44 (95.65)	44 (89.80)
	T5-T7	2 (4.35)	5 (10.20)
LIV, n(%)	T10-L2	31 (67.39)	37 (75.51)
	L3-L4	15 (32.61)	12 (24.49)
Thoracic flexibility, n(%)	<50%	33(71.74)	33(67.35)
	≥ 50%	13 (28.26)	16 (32.65)
Preop Thoracic Kyphosis, n(%)	<20%	15 (32.61)	9 (18.37)
	≥ 20%	31 (67.39)	40 (81.63)
Age, Median (IQR)	-	14 (11-18)	14 (12-17)
TOTAL		46 (100%)	47(100%)

* missing

14. The Impact of Posterior Spinal Fusion (PSF) on Coronal Balance in Adolescent Idiopathic Scoliosis (AIS): A New Classification and Trends in the Post-Operative Period

Jason Anari, MD; Aaron Tatad, MPH; Patrick Cahill, MD; John M. Flynn, MD; Harms Study Group

Summary

Global balance is among the essential goals of PSF for AIS. Understanding which patients, and which deformity corrections, end up in or out of balance, and the rate of rebalancing, can help surgeons with both pre-operative planning and post-operative care. We present a novel classification system and a longitudinal post-operative analysis of coronal balance after PSF for AIS.

Hypothesis

Most patients who are out of coronal balance following PSF in AIS regain their balance within 2 years.

Design

Retrospective Cohort

Introduction

One of the primary goals of scoliosis surgery is to balance the head over the pelvis (or avoid creating imbalance). Historically, normal coronal balance was defined as the C7 plumb line within 2cm of the central sacral vertical line (CSVL); however, there is limited published information regarding the speed/magnitude and success/failure of balancing, rebalancing or unbalancing in the post-operative period.

Methods

A retrospective review of a prospective multi-center database was analyzed for patients with AIS who had PSF. All patients had standing 2-view, PA and lateral radiographs of the entire spine performed at 1st erect visit, 6, 12, & 24 months. To measure coronal balance a C7 plumb line was measured and compared to the CSVL. A negative value denotes leftward deviation of the C7 plumb line; a positive value a rightward deviation. We then created a novel coronal balance classification system depicted in Table 1.

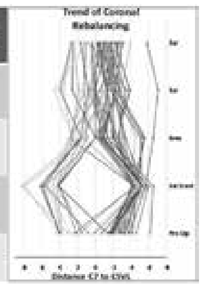
Results

954 patients met the inclusion criteria. There was a strong trend towards improving coronal balance, especially between 1st erect and 6 months; the proportion of out of balance patients declined throughout the 2 year period: pre-op 372/954 (39%), 1st erect 297/954 (31.1%), 6 months 167/954 (17.5%), 1 year 136/954 (14.3%) and 2-year 115/954 (12.1%). Analyzing the patients most out of balance immediately after PSF, 35/50 (70%) in Group 3 regained balance by 2 years (Figure 1). Out of the remaining 15 patients, 12 corrected to Group 1 (24%), 2 patients to Group 2 (4%), and 1 patient remained in Group 3 (2%).

Conclusion

This large, longitudinal post-operative study of coronal balance documents a strong trend towards natural re-balancing, with the largest gains between 1st erect image and 6 months. The 31% of patients out of balance at 1st erect declined to only 12.1% at 2 years. Using our new classification system, 115 patients out of balance fall into the following groups at 2 years: Group 1- 81%, Group 2- 11.3%, & Group 3- 7.7%.

	Pre-Op	1st Erect	6 month	12 month	24 month
Group 0 (-2 to 2)	582	657	787	818	839
Group 1 (-3 to -2.01 & 2.01 to 3)	196	169	129	103	93
Group 2 (-4 to -3.01 & 3.01 to 4)	108	78	22	26	13
Group 3 (<-4 & >4)	68	50	16	7	9



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15. It's Not Just About the Frontal Plane: Spinopelvic Parameters Impact Curve Progression In AIS Patients Undergoing Brace Treatment

Hiroko Matsumoto, PhDc; Shay Warren, BS; Megan Campbell, BA; John Tunney, BOCPO; Nicole Bainton, RN, CPNP; Joshua Hyman, MD; Benjamin Roye, MD, MPH; David Roye, MD; Michael Vitale, MD

Summary

Spinopelvic parameters significantly impact curve progression in patients with AIS undergoing bracing.

Hypothesis

Spinopelvic parameters, including iatrogenic mismatch between in-brace pelvic incidence (PI) and lumbar lordosis (LL), are associated with curve progression at 2 years.

Design

Retrospective cohort study

Introduction

To date, there has been no published research focused on spinopelvic parameters and bracing outcomes in AIS. The primary purpose of this study was to explore the relationship between iatrogenic mismatch between PI and LL and progression.

Methods

This study included AIS patients whose pre-brace major curve was between 20º-45º. The outcome was >10° curve progression at 2 years post-brace initiation. The study period encompassed a time where our group switched from Boston-style thoracolumbar sacral orthosis (BSO) to the Rigo Cheneau-Style Orthosis (RCSO), allowing for comparison. Univariable and multivariable analyses were performed.

Results

We examined 21 (43%) patients treated with a RCSO and 28 patients (57%) treated with BSO. Overall, 15 (31%) patients had curve progression. 38% of patients at Sanders stage 1-4 had progression vs 8% of patients at Sanders stage >4 patients (p=0.07) but there was no difference between two groups in PI-LL mismatch. 14% of RCSO vs 43% of BSO patients had in brace PI-LL mismatch (p=0.05). Interestingly, the risk of progression in each group paralleled these numbers, with 14% and 43% of RCSO and BSO groups progressing respectively (p=0.05). Adjusting for confounders including patient characteristics, brace type, and radiographic parameters, patients who had in-brace PI-LL mismatch had 1.5 times more likely to progress, and patients who had abnormal pre-brace SVA were 3.8 times more likely to progress. (Table).

Conclusion

In this initial exploratory study, mismatched in-brace PT- LL and abnormal pre-brace SVA had independent effects on progression. This data suggests we pay careful attention to spinopelvic parameters prior to and during brace treatment. A multi-center study is underway to further investigate the associated issues including the effect of compliance.

Unadjusted associations between spinopelvic parameters and progression

Parameters	Definitions of Abnormal	% of Patients Who Progressed					
		Pre-Brace			In-Brace		
		Abnormal	Normal	p	Abnormal	Normal	p
PT	< 0° or > 20°	0%	44%	0.054	56%	25%	0.110
SVA	< -35° or > 35°	**71%**	**21%**	**0.022**	44%	28%	0.427
PI—LL mismatch	≤ -10° or ≥ 10°	18%	39%	0.386	**53%**	**21%**	**0.022**

Adjusted association between in-brace PI-LL and progression

Variables	Risk Ratio	95% CI	p	Controlled Confounders	Variance Explained by the Model
In-Brace PI-LL Mismatch	1.5	0.7-3.2	0.247	Brace type, % in-brace correction	19%

Adjusted association between pre-brace SVA and progression

Variables	Risk Ratio	95% CI	p	Controlled Confounders	Variance Explained by the Model
Abnormal Pre-Brace SVA	3.8	1.1-13.1	**0.034**	Pre-brace LL, Sanders	16%

16. Sagittal Balance and Health-Related Quality of Life Three Decades After Fusion in Situ for High-Grade Isthmic Spondylolisthesis

Anders Joelson, MD; Barbro Danielson, MD, PhD; Rune Hedlund, MD, PhD; Per Wretenberg, MD, PhD; Karin Frennered, MD, PhD

Summary

Twenty-eight of thirty-nine consecutive patients went through radiographic examination three decades after in situ fusion for high-grade spondylolisthesis. Radiographic signs of sagittal imbalance were observed only in a few individuals.

Hypothesis

Fusion in situ for high-grade spondylolisthesis results in sagittal imbalance in the long-term.

Design

Long-term follow-up study

Introduction

Since in situ fusion does not reduce the sagittal deformity in high-grade spondylolisthesis, there might be some long-term sagittal balance issues when the degenerative changes of aging alter the sagittal alignment of the spine. Therefore, we evaluated sagittal balance three decades after in situ fusion for high-grade spondylolisthesis.

Methods

Sagittal balance, pelvic parameters and compensatory mechanisms were evaluated on standing lateral radiographs of the spine and pelvis for 28 of 39 consecutive patients, 28 to 41 years after in situ fusion for high-grade spondylolisthesis. The mean age at surgery was 14 years (range 9 to 24) and the mean age at follow-up was 48 years (range 39 to 59). A subset of the radiographic parameters was compared with the corresponding data from an 8-year follow-up of the same patients. Health-related quality of life was evaluated with the SRS-22r questionnaire.

Results

Three of twenty-eight patients had sagittal imbalance (T1 spinopelvic inclination > 0 degrees). Signs of compensatory mechanisms, like reduced thoracic kyphosis and pelvic retroversion, were frequent. There was a statistically significant decrease of sacral slope compared with 8-year data. The median SRS-22r subscore was on the same level as Swedish normative data. We found no correlation between radiographic parameters and SRS-22r outcome.

Conclusion
Three decades after in situ fusion for high-grade spondylolisthesis, radiographic signs of sagittal imbalance were observed only in a few individuals. There was no correlation between any radiographic parameter and SRS-22r outcome. From a long-term functional point of view our results lend no support for surgical reduction of high-grade spondylolisthesis.

17. High Grade Spondylolisthesis (HGS) in Adolescents: Reduction and Circumferential Fusion Improves HRQoL and Sagittal Balance

Hubert Labelle, MD, FRCS(C); Stefan Parent, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD; Julie Joncas, RN; Soraya Barchi, BS

Summary
This is a prospective and consecutive analysis of 30 adolescents with L5-S1 High Grade Spondylolisthesis treated with a standardised surgical technique. Surgical reduction and instrumentation using a posterior approach with circumferential fusion and autogenous bone graft significantly improved Health Related Quality of Life and spino-pelvic balance with minimal complications.

Hypothesis
Surgical reduction and instrumentation of HGS can be done safely and improves both spino-pelvic posture and Health Related Quality of Life (HRQoL) in adolescents.

Design
Prospective single center study in a pediatric university hospital.

Introduction
Reduction vs in situ fusion for adolescent HGS remains controversial.

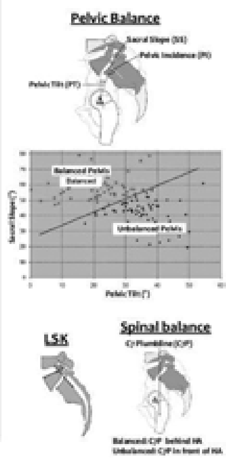
Methods
Thirty adolescents (13 males, 17 females), aged 15±2 y.o., with L5-S1 HGS (15 Grade 3 (G3), 14 G4, 1G5) were treated consecutively between 2006 and 2016 with the same surgical technique: posterior approach, L5 Gill procedure, pedicle screws insertion, L5-S1 PLIF with a polymer cage, reduction using a temporary external fixator affixed to the screws and a disk dilator to reduce L5-S1 kyphosis, rod insertion with compression and iliac crest postero-lateral and anterior bone grafting.

Results
The majority (24) of patients were instrumented at L5-S1, and the others at L4-S1. At greater than 2 year follow-up (2.6±0.7 years), average slip was reduced from 71 to 21% (4 G2, 23 G1, 3G0). The SDSG classification (Table 1) was used to assess spino-pelvic balance: all 14 patients that were well balanced pre-op (type 4) remained well balanced post-op; all other patients except one, that had either pelvic imbalance (types 5A and 5B) or pelvic and spinal imbalance (type 6) improved significantly to either types 4 or 5A. SRS-30 total scores improved significantly from 3.5±0.5 to 3.9±0.5 with the greatest increases in pain, self-image and activity domains. Satisfaction reached 4.7±0.7. Average blood loss was 396±216cc.There were 2 neurological complications: one unilateral L5 sensory and 4/5 motor weakness which resolved completely, and one patient presented a dural tear repaired per-op and a post-op stitch abscess and left radicular pain which also resolved completely. One patient was re-operated at 2 years for PJK and extension to L4.

Conclusion
In this prospective and consecutive cohort of 30 adolescents with HGS, reduction and instrumentation using a posterior approach with circumferential autogenous fusion significantly improved HRQoL and spino-pelvic balance with minimal complications.

Classification of pediatric lumbosacral spondylolisthesis

Slip	Pelvic Balance	Spinal Balance	Type
Low Grade Slip<50%	PI<45°	-	1
	PI=45-60°	-	2
	PI≥60°	-	3
High Grade Slip≥50%	Balanced Pelvis	-	4
	Unbalanced Pelvis	Balanced Spine	5 5A (LSK≥80°) 5B (LSK<80°)
	Unbalanced Pelvis	Unbalanced Spine	6



Adapted from Labelle et al. Eur Spine J 2011;20(Suppl 5): S641-S646

18. Spondylolisthesis Classification Based on Prognostic and Treatment Principles

Farhaan Altaf, MBBS, FRCS; Amer Sebaaly, MD, BS; Pierre Roussouly, MD

Summary
We describe a classification for L5/S1 spondylolisthesis which provides both prognostic and therapeutic guidance. The age of onset of spondylolisthesis, remaining skeletal growth and the morphology of the sacrum are of particular importance. Our therapeutic recommendations are based on prognostic elements which are reinforced by the results of our retrospective study.

Hypothesis
We hypothesise that depending on a combination of risk factors described in our classification, the occurance of vertebral slipping in L5/S1 spondylolisthesis will be more or less frequent, and time–dependent.

Design
We describe our classification for L5/S1 spondylolisthesis and describe the outcomes of a retrospective analysis of patients with both high grade and low grade spondylolisthesis.

Introduction
The main objective of our classification on L5/S1 spondylolisthesis is to discuss the risk of progression and thereafter discuss the optimal therapeutic strategy. Three major elements are taken into account in our classification: local anatomical abnormalities, spinal pelvic morphology, and the potential risk of evolution with skeletal growth.

Methods
We describe our classification and performed a retrospective study looking at 344 patients with spondylolisthesis. Patients

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were divided into those with a flat sacrum and those with a rounded sacrum. Patients with a flat sacrum, we divided into those patients with a normal/low pelvic incidence (<60 degrees) and those with a high pelvic incidence (>60 degrees). The following measurements were made: slip percentage, L5 incidence, lumbar lordosis, pelvic tilt and correlation between L5 incidence and Lumbar Lordosis.

Results

The mean age of the patients was 17.7 years (6.5-74 years). Patients with a dome shaped sacrum had a significantly higher percentage slip as compared with patients with a flat sacrum. Patients with a dome shaped sacrum also had a significantly higher L5 incidence, pelvic tilt, and lumbar lordosis as compared to patients with a flat sacrum. When distinguishing between patients with a flat sacrum based on their pelvic incidence, those patients with a high pelvic incidence had a significantly higher percentage slip, lumbar lordosis, L5 incidence, and pelvic tilt as compared with patients with a normal/low pelvic incidence.

Conclusion

The shape of the sacrum before and after growth spurt, dome shaped or flat sacrum will determine the prognosis in L5/S1 spondylolisthesis. The decision between fusing in-situ vs reduction is based on whether the spine is balanced or is imbalanced with compensation (increased pelvic tilt)

Mean Values	Dome shaped sacrum	Flat sacrum. High pelvic incidence greater than 60°	Flat sacrum. Low pelvic Incidence less than 60°
PI	In dome PI cannot be calculated	75.08	50.71
L5 incidence	70.2	46	22.07
Percentage slipping	65.3	47.24	32.23
Lumbar lordosis	79	66.33	49.5
Pelvic tilt	31.5	22.5	9.4
Correlation L5 incidence/Lumbar lordosis	0.29	0.51	0.53

Table 1. Table comparing the mean values between groups and also description of correlation between L5 tilt and Lumbar lordosis. Pearson's correlation test was used to evaluate the correlation between L5 incidence and the Lumbar lordosis. In accordance to Cohen, ststistically significant correlation were considered large clinically of R>0.5, moderate if 0.3<R<0.5 and small if R<0.3.

19. The Surgical Volume, More Than The Number of Surgeons or Surgeon Experience, Drives Patient Outcomes in Pediatric Scoliosis

Vishal Sarwahi, MBBS; Jesse M Galina, BS; Stephen Wendolowski, BS; Jon-Paul DiMauro, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary

The dual surgeon approach can be beneficial for less experienced surgeons. However, for a high volume surgeon, having a secondary surgeon has no significant benefits in terms of perioperative outcomes.

Hypothesis

Highly experienced and/or high volume surgeons do not benefit from a dual surgeon approach.

Design

Ambispective Chart Review

Introduction

Recent literature suggests that utilizing two surgeons for spine deformity correction surgery can improve perioperative outcomes. However, the surgeon's experience and surgical volume are likely as important. This study seeks to evaluate effect of these factors for spine deformity correction through posterior spinal fusion (PSF).

Methods

All pediatric spinal deformity patients undergoing spinal deformity surgeon from 2012-2017 were included. Patient demographics, XR and periop parameters were collected. Surgical cases were collated based on primary surgeon. Analysis was performed for single vs dual attending surgeons, surgical experience (<,> 10 yrs), and surgical volume (<,> 70 cases/yr.). Median values, Wilcoxon Rank Sums test, Kruskal-Wallis test, and Fisher's exact test were utilized.

Results

260 cases, performed by 4 attendings, had complete records. 2 surgeons were highly experienced, 1 of whom is also high volume. The four cohorts were a highly experienced/high volume surgeon operating alone (n=91), two junior surgeons (n=80), a highly experienced surgeon with a junior surgeon (n=30), and the highly experience and high volume surgeon together (n=26). Preop Cobb (p=0.13), kyphosis (p=0.61), coronal balance (p=0.75) were similar between the groups. Sagittal balance was significantly higher for the highly experienced and high volume surgeon group (p=0.011). The high volume surgeon had significantly lower EBL (475 vs 600 vs 700 vs 400cc,p < 0.001), shorter length of surgery (251 vs 300 vs 300.5 vs 241,p <0.001), and anesthesia times (414.5 vs 420 vs 434 vs 369,p<0.001). Highly experienced surgeons fused significantly fewer levels compared to less experienced surgeons (12 vs 13, p=0.05). When the high volume surgeon operated with another attending, there were no significant changes in outcomes.

Conclusion

High volume surgeons have better outcomes than dual surgeons, irrespective of the experience of the dual surgeons. High volume surgeons do not benefit from the addition of a second surgeon.

20. Variation in Adolescent Idiopathic Scoliosis (AIS) Surgery: Implications for Improving Healthcare Value

John Smith, MD; Angela Presson, PhD; John A. Heflin, MD

Summary
We compared costs of treating AIS at 44 Children's Hospitals using the Pediatric Health Information System database. There was significant variability in cost and resource utilization between hospitals. The single largest cost was surgical implants. Understanding costs offers the opportunity to improve healthcare value.

Hypothesis
Understanding variability in institutional costs for the treatment of AIS will identify opportunities for improving value.

Design
Retrospective cohort study of the Pediatric Health Information Systems database, including children 11-18 years with AIS who underwent spinal fusion surgery between 2004-2015. Multivariable regression was used to evaluate the relationships between hospital cost, patient outcomes, and resource utilization.

Introduction
Surgical management of AIS is a common and costly reason for pediatric hospital admission in the US, ranking the 5th most expensive and 48th most common indication for hospitalization. Average charges for AIS surgery have more than tripled from $55,495 in 1997 to over $177,000 in 2012, totaling over $1 billion in health care expenditures annually (adjusted for 2012 dollars). The purpose of this study is to investigate the variability in cost of spinal fusion surgery for AIS, to identify the drivers of cost, and to determine if there is a consistent relationship between cost and outcomes.

Methods
This is a retrospective cohort study of the Pediatric Health Information System (PHIS) database representing 49 free standing Children's Hospitals in the US. 16,992 cases of AIS surgery from 44 of 49 PHIS hospitals were analyzed for patient demographics, resource utilization, and cost.

Results
The PHIS cohort includes 16,992 cases of AIS surgery from 44 of 49 PHIS hospitals. Hospital costs ranged from $31,278 to $90,379. Total costs were higher for hospitals that routinely admit AIS patients to the ICU, and those with higher case volumes. LOS was shorter in hospitals with higher volumes and ICU utilization. The largest single component of cost were surgical implants. There was no association between surgical complication rates and total hospital cost.

Conclusion
Correction of AIS is a common, expensive procedure marked by variation in practice, outcome and cost. Further analysis of cost variation offers the opportunity to improve healthcare cost and value. Reducing implant costs offers a significant chance of lowering overall cost without reducing value.

21. The "Touched Vertebra" Method and Progression of the Non-Fused Lumbar Curve in Patients with Lenke Type I in AIS: A Prospective Randomized Study

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Summary
When the risk factors are assessed, the Lenke I type curve fixation distal level can be done above the "touched vertebra" and thus save more non-fused vertebrae. In the case of lower skeletal maturity of a patient, there still is a likelihood of intensive growth of the spine and progression of the non-fused curve of the lumbar spine; therefore, fixation of the spine should end at the level of the "touched vertebra".

Hypothesis
Fixation of the spine in Lenke I AIS should end at the "touched vertebra".

Design
Prospective study

Introduction
Selection of instrumentation levels in adolescent idiopathic scoliosis (AIS) surgery remains one of the most heatedly discussed subjects of the past 20-30 years. Therefore, it is crucial for spinal surgery practice to define better criteria for the selection of appropriate levels to achieve a balanced spine. The purpose of this prospective randomized study was to identify risk factors for progression of non-fused lumbar curve (NFLC) according fixation level selecting „touched vertebra" method.

Methods
The clinical study was carried in single institution from 2014-2017. The study subjects were randomly assigned into three groups according to the type of lumbar spine fixation method on the concept of the "touched vertebra". Randomization was carried out by applying the envelope technique with the sequence of digits 1, 2 and 3. Risk factors identification for NFLC progression were evaluated before surgery, 3-6 month and 2 years post op.

Results
In the final stage, we entered the logistic regression "stepwise" model of all significant parameters and fixation levels according "touched vertebra" method, aiming to find the strongest correlation between the risk factors and progression of non-fused lumbar curve. We identified 3 factors for an NFLC progression before surgery: Risser 0 before surgery, the OR for progression is 40.14 (95% CI 3.074 to 524.141, $p = 0.005$), LIV + 1 distance the OR for progression is 1.11 (95% PI 1.012 to 1.212, $p = 0.03$) and lumbar curve flexibility the OR is 0.96 (95% PI 0.929 to 0.996, $p = 0.03$). Total area under ROC curve of this logistic regression model is 0.96.($\chi 2=51.028$, $p < 0.0001$, Nagelkerke $R^2 = 0.7183$). Due to this logistic regression model, fixation levels according „touched vertebra" method don't reached significant level as risk factors for NFLC progression, p=0.2.

Conclusion
The biggest concern in the planning of surgical treatment for AIS should be the skeletal maturity of a patient before surgery.

22. Touched Vertebra (TV) on Standing XR is a Good Predictor for Lowest Instrumented Vertebra (LIV): TV on Prone XR is Better.

Vishal Sarwahi, MBBS; Stephen Wendolowski, BS; Jesse M Galina, BS; Yungtai Lo, PhD; Beverly Thornhill, MD; Kathleen Maguire, MD; Terry D. Amaral, MD

Summary
TV on prone xray is an effective and better way to determine the lowest instrumented vertebra. At 2-year follow up, this study did not find coronal decompensation.

Hypothesis
Using TVP to determine LIV saves fusion levels with good correction and coronal balance.

Design
Ambispective cohort study

Introduction
Minimizing the fusion levels in PSF for AIS is important. Previous studies have shown good results utilizing TV as the LIV. TV is the 'touched' vertebra determined by central sacral vertical line on standing AP XRs (TVS). We have found that TV moves proximally on supine/prone XRs. Thus utilizing TV on prone XRs (TVP) in LIV decision making may allow even shorter fusion.

Methods
There were three groups. Group I: patients where TVP was used to determine LIV. Group II: patients where TVS was used to determine LIV. Group III: non-operative AIS (Risser 4/5, Cobb <30) to determine 'acceptable' end vertebra tilt and disc wedging. Patients with only thoracic fusion were excluded. Cobb angle, coronal balance (CB) , LIV tilt angle and translation, and disc wedging were collected at preop and postop.Median values and interquartile were collected for the subsets.

Results
The control group had 132 patients with a median (IQR) Cobb of 20° (16-26), age of 16 (14.8-17), coronal balance 1.4 (0.5-2.2), disc wedging of 4° (2-5), and LIV tilt of 10° (7-13). In Group I (n=102), median preoperative Cobb was 53.8° (47-64°) and coronal balance was 1.8 (1.0-2.8). Final Cobb was 12.4° (7.0-19.6°) and coronal balance was 0.9 (0.4-1.6). Compared to controls, Group I patients had significantly less coronal imbalance (0.9 vs 1.4, p =0.023), lower disc wedging (1.2° vs 4, p>0.001) and LIV tilt (5° vs 10 p<0.001). In Group II (n=26), preoperative Cobb was 53.5° (50-60.7°) and coronal balance was 2 (0.9-2.9). Final Cobb was 20° (15-26°) and coronal balance was 0.7 (0-1.3). Group II patients could have saved an average 2.24 (0-4) levels, if fused to TVP.

Conclusion
In AIS, using TVP to determine LIV allows for shorter fusion. LIV tilt and disc wedging is also within 'acceptable' levels determined on controls. TVP is an effective and better way to determine the lowest instrumented vertebra.

23. Defining Two Subtypes of Lenke 1 Curve: An Analysis of Pre-Operative Shoulder Balance and Post-Operative Outcome Following Posterior Spinal Fusion (PSF) in Adolescent Idiopathic Scoliosis (AIS) Patients

Chris Yin Wei Chan, MD, MS; Chee Kidd Chiu, MBBS, MS; Yun Hui Ng, MBBS; Saw Huan Goh, MBBS; Xin Yi Ler, MBBS; Sherwin Johan Ng, MBBS; Xue Han Chian, MBBS; Pheng Hian Tan, MBBS; Mun Keong Kwan, MBBS, MS

Summary
Post-operative Shoulder Imbalance (PSI) is common for Lenke 1 curves. We classified 50 patients as Lenke 1-ve (flexible) curves and 61 patients as Lenke 1 +ve (stiff) curves. Lenke 1-ve and Lenke 1+ve curves had distinct pre-operative medial shoulder balance (T1 tilt and Cervical Axis). Following PSF, we noted +ve T1 tilt in 40% of Lenke 1+ve patients vs. 2.0% in Lenke 1-ve patients. We also noted significant difference in post-operative RSH and Clavicle Angle measurements.

Hypothesis
Lenke 1 +ve and Lenke 1 –ve have distinct pre-operative shoulder balance and post-operative outcome following PSF.

Design
Retrospective study

Introduction
Selection of the upper-instrumented vertebra (UIV) in Lenke 1 curves is controversial. 55.4% of patients will still experience Post-operative Shoulder Imbalance (PSI) following surgery.

Methods
111 Lenke 1 AIS patients who underwent PSF were recruited. We grouped patients as Lenke 1 –ve (flexible) curves when their pre-operative proximal thoracic side bending (PTSB) Cobb angle was < 15° and as Lenke 1 +ve (stiff) curves when the PTSB Cobb angle was 15° to 24.9°. Fifty patients had Lenke 1-ve curves and 61 had Lenke 1 +ve curves. We compared these two subgroups in terms of pre-operative radiological parameters (curve characteristics and shoulder balance parameters) and post-operative outcome (shoulder balance) at final follow up.

Results
We found significant differences between Lenke 1–ve vs. Lenke 1+ve subtypes for pre-operative T1 tilt and Cervical Axis (CA) measurements. Mean T1 tilt for Lenke 1-ve patients was -4.9 ± 5.3 while for Lenke 1+ve patients was -1.0 ± 5.3 (p<0.001). Mean CA was -0.1 ± 3.2 for Lenke 1-ve and 2.3 ± 3.5 for Lenke 1+ve (p<0.001). RSH and Cla-A were similar in these two groups. Following surgery, there were significant differences comparing T1 tilt (p<0.001), RSH (p=0.019) and Clavicle Angle (p=0.029). 40.0% of patients with Lenke 1 +ve curve types had +ve T1 tilt compared to 2.0% in Lenke 1-ve group. 22.4% of Lenke 1+ve patients had +ve RSH compared to 10.2% for Lenke 1 –ve curves. 22.0% of Lenke 1+ve patients had +ve Cla-A compared to 8.2% for Lenke 1 –ve curves.

Conclusion
Lenke 1-ve and Lenke 1+ve curves had distinct pre-operative T1

tilt and Cervical Axis measurements. Following PSF, we noted +ve T1 tilt in 40% of Lenke 1+ve patients vs. 2% in Lenke 1-ve patients. We also noted significant difference in post-operative RSH and Clavicle Angle measurements.

Table 1: Preoperative Demographics and General Radiological Parameters

Parameters	Lenke 1-ve (n = 50)	Lenke 1 +ve (n = 61)	P value
Age (years)	16.1 ± 5.5	17.0 ± 6.3	0.464
Gender (n (%))			
Male	8(16.0%)	10 (16.4%)	0.955
Female	42 (84.0%)	51 (83.6%)	
Follow up duration (months)	38.4 ± 8.7	37.7 ± 7.0	0.616
PT Cobb angle (°)	21.6 ± 7.1	32.2 ± 6.8	<0.001*
PT SB Cobb angle(°)	8.4 ± 3.8	18.8 ± 2.9	<0.001*
MT Cobb angle(°)	57.2 ± 8.9	63.1 ± 10.5	0.003*
MT SB Cobb angle (°)	23.9 ± 8.7	28.3 ± 12.0	0.035*
Lumbar Cobb angle (°)	36.5 ± 9.8	35.1 ± 12.0	0.528
Lumbar SB Cobb angle (°)	8.2 ± 6.3	8.2 ± 5.6	0.984
Coronal balance(mm)	7.9 ± 14.9	4.4 ± 16.6	0.259
T1 tilt (°)	-4.9 ± 5.3	-1.0 ± 5.3	<0.001*
Cervical axis (°)	-0.1 ± 3.2	2.3 ± 3.5	<0.001*
Radiological shoulder height (mm)	-13.7 ± 12.5	-11.0 ± 17.1	0.367
Clavicle angle (°)	-2.4 ± 2.5	-2.0 ± 3.7	0.553
Final Follow Up Radiological Parameters			
Parameters	Lenke 1-ve (n = 50)	Lenke 1 +ve (n = 61)	P value
PT Cobb angle (°)	10.7 ± 6.1	16.9 ± 5.6	<0.001*
PT SB correction index (%)	89.5 ± 63.2	129.4 ± 74.4	0.004*
T1 tilt(°)	-1.7 ± 2.9	2.4 ± 3.9	<0.001*
Cervical axis(°)	0.2 ± 3.4	2.4 ± 3.7	0.002*
Radiological shoulder height (mm)	-2.9 ± 10.0	3.1 ± 9.7	0.002*
Clavicle angle (°)	-0.3 ± 2.2	0.8 ± 2.1	0.011*

24. The Comparison between Cervical Supine Side Bending versus Cervical Supine Traction Radiographs in Predicting Proximal Thoracic Flexibility for Lenke 1 and 2 Adolescent Idiopathic Scoliosis

Chee Kidd Chiu, MBBS, MS; Chris Yin Wei Chan, MD, MS; Mun Keong Kwan, MBBS, MS

Summary
This study compared between Cervical Supine Side Bending (CSSB) radiographs and Cervical Supine Traction (CST) radiographs in their ability to assess the flexibility of the proximal thoracic curve for adolescent idiopathic scoliosis (AIS) Lenke 1 and 2 patients who underwent posterior spinal fusion (PSF) surgery.

Hypothesis
There is no difference between CSSB and CST radiographs in the assessment of proximal thoracic flexibility.

Design
Prospective Study

Introduction
CST radiographs are widely used to assess the proximal thoracic flexibility in AIS patients. However, there were no reports comparing CSSB and CST radiographs in the assessment of this parameter. The knowledge regarding the proximal thoracic flexibility is crucial in surgical planning.

Methods
Thirty Lenke 1 and 2 AIS patients scheduled for PSF surgery were recruited. A standing whole spine radiograph, a physician supervised CSSB radiograph (which included the cervical and proximal thoracic segment) and a supervised CST radiograph (using a Halter traction device) were performed in every patient. The main thoracic Cobb angle and proximal thoracic Cobb angle were measured in all radiographs. After PSF surgery, these parameters were re-measured and recorded. From the data collected, curve flexibility and curve correction index were calculated and compared.

Results
The CSSB Cobb angle (16.6±10.4) was significantly lower than CST cobb angle (23.8±10). The CSSB flexibility (45.4±20.0) was significantly higher than CST flexibility (21.1±17.6). The CSSB Correction Index was closer to 1 compared to CST Correction Index. When stratified into Cobb angle < 25°, 25° - 35° and > 35°, all parameters showed significant difference except for correction index when Cobb angle was less than 25°.

Conclusion
CSSB radiographs were more accurate than CST radiographs in the prediction of proximal thoracic curve correction for Lenke 1 and 2 AIS.

Cobb angle, flexibility and correction index comparing CSSB and CST radiographs.

Parameters	Cobb <25° (n=10)	P-value	Cobb 25°-35° (n=9)	P-value	Cobb >35° (n=11)	P-value	Whole group (n=30)	P-value
PO PT Cobb	8.4±5.6	-	18.9±1.8	-	20.7±6.4	-	16.1±7.5	-
CSSB Cobb	7.7±3.6	0.002	14.2±5.3	0.001	26.6±9.2	0.002	16.6±10.4	<0.001
CST Cobb	13.5±6.4		23.0±3.4		33.8±8.0		23.8±10.6	
CSSB F	51.7±16.0	0.026	51.4±17.0	<0.001	34.7±22.4	0.001	45.4±20.0	<0.001
CST F	24.8±22.6		21.6±10.7		17.4±17.7		21.1±17.6	
CSSB CI	1.0±0.5	0.064	0.8±0.4	0.002	1.9±1.1	0.048	1.3±0.9	0.003
CST CI	3.4±1.2		1.9±0.8		6.8±7.4		4.2±5.3	

MT = Main thoracic, PO = Postoperative, PT = Proximal Thoracic, CSSB = Cervical Supine Side Bending, CST = Cervical Traction, F = Flexibility, CI = Correction Index

25. Pre-Operative Prone Radiographs Can Reliably Determine Spinal Curve Flexibility in Adolescent Idiopathic Scoliosis

Tej Joshi, BS; Regina Hanstein, PhD; Jaime Gomez, MD; Jacob Schulz, MD

Summary
The purpose of this study was to determine if prone position radiographs can be a surrogate for bending position radiographs to determine the degree of spinal flexibility in AIS. Analysis of radiographs of 226 AIS patients showed that prone positioning radiographs had a moderate to strong correlation with bending radiographs for determining the degree of spinal flexibility. Prone positioning radiographs can be a surrogate for bending positioning radiographs to determine degree of spinal flexibility.

Hypothesis
Prone position radiographs can be used as a surrogate for bending position radiographs to determine the degree of spinal flexibility.

Design
retrospective review

Introduction
Classifying AIS via the Lenke classification requires full spine standing and bending radiographs. In addition, prone imaging

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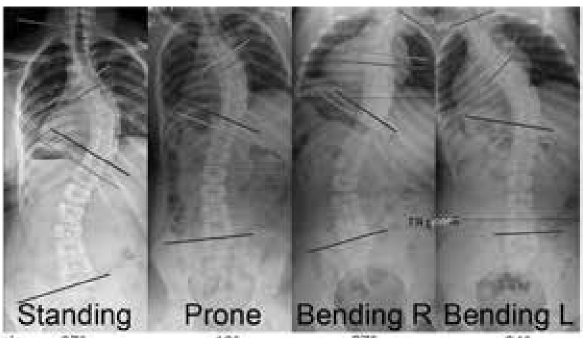
can also be used for pre-operative assessment . Few studies have addressed the correlation of different radiographic positions to assess spinal flexibility.

Methods
A retrospective review of AIS patients who underwent pre-operative full spine radiographic imaging from 2006 to 2016 was performed. Cobb angle (CA) of the proximal thoracic, thoracic, and thoracolumbar/lumbar curves on standing, prone and bending radiographs were measured. Based on the Lenke classification, a curve is considered nonstructural if the bending CA ≤25°. Statistical analysis included Pearson correlation, Fisher's exact and Chi-squared tests.

Results
226 AIS patients, 77% female, with a mean age of 15 years (range:10.3-23.2 years) were identified. A strong correlation existed between the prone and bending CA for the proximal thoracic (rs=0.736, p<0.01) and thoracic curves (rs=0.707, p<0.01). A moderate correlation existed between the prone and bending CA for the thoracolumbar/lumbar curve (rs = 0.553, p<0.01). For a nonstructural proximal thoracic curve, a prone CA ≤25° correctly identified a bending CA ≤25 ° 95.7% of the time (p<0.005). For a nonstructural thoracic curve, a prone CA ≤35 ° correctly identified a bending CA ≤25 ° 93.3% of the time (p<0.005). For a nonstructural thoracolumbar/lumbar curve, a prone CA ≤35 ° correctly identified a bending CA ≤25 ° 95.8% of the time (p<0.005).

Conclusion
Prone positioning radiographs demonstrated a moderate to strong correlation with bending radiographs for determining the degree of spinal flexibility. Prone position radiographs may be used as a proxy for determining spinal flexibility and are especially useful if bending films are deemed unreliable by the surgeon. Bending radiographs are still needed if the prone CA measures >25° for minor thoracic curves and >35° for minor thoracolumbar/lumbar curves.



	Standing	Prone	Bending R	Bending L
Prox. Thoracic	37°	16°	27°	24°
Main Thoracic	63°	46°	25°	52°
Thoracolumbar/ Lumbar	47°	24°	36°	13°

26. The Supine Flexibility: Prediction of Flexibility in Adolescent Idiopathic Scoliosis Using Standard Standing and Supine Radiographs

Caglar Yilgor, MD; Kenny Kwan, FRCS; Kadir Abul, MD; Suna Lahut, PhD; Umut Karaarslan; Peri Kindan; Yasemin Yavuz, PhD; Kenneth Cheung, MD, FRCS; Ahmet Alanay, MD

Summary
Using standard standing and supine AP radiographs, a formula was developed to evaluate the maximum possible inherent flexibility (demonstrated by various flexibility radiographs) of main thoracic and thoracolumbar/lumbar AIS curves. The supine flexibility (SUFLEX) predicted curve structurality with comparable or higher accuracy compared to technician-dependent flexibility radiographs. The use of SUFLEX may help decrease radiation exposure to AIS patients, enabling reproducible flexibility assessment by only standard standing and supine radiographs.

Hypothesis
The flexibility of AIS curves can consistently be evaluated by standard standing and supine xrays without the need for obtaining technician-dependent flexibility radiographs.

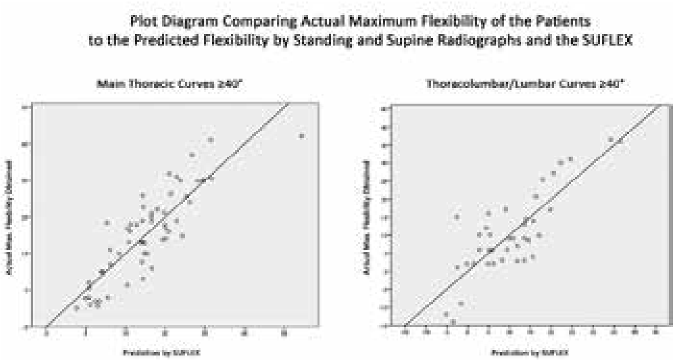
Design
Retrospective analysis of a prospectively collected data of AIS patients from 2 spine centres.

Introduction
To date, a standard in flexibility assessment of AIS curves has not been set due to variability and technician-dependent nature of the use of side bending, fulcrum and traction radiographs. The aim of this study was to propose a novel method of reproducible spinal flexibility prediction based on modelling all available flexibility assessments.

Methods
Inclusion criteria were having standing, supine, side bending, fulcrum and traction (awake or under general anesthesia) radiographs. Flexibility was assessed for each method. The Supine Flexibility (SUFLEX) was defined as the maximum possible inherent flexibility obtained from all methods. Using standard standing and supine Cobb angles, 2 separate multiple linear regressions were run to formulate SUFLEX for MT and TL/L curves ≥40°. Error intervals and performance measures were calculated for the ability of predicting curves that will bend <25°.

Results
75 pts (65F, 10M) were included. Mean age: 14.1±1.5(12-18) yrs. The mean major MT and TL/L curve Cobb were 61.3°±11.3° and 51.6°±15.9°, respectively. Multiple linear regression models revealed significant relationship between Standing and Supine Cobb angles and SUFLEX. For MT curves, the formula predicted 63.8% of the cases within ±5°, while 22.4% and 13.8% were within ±5-10° and ±10-13°, respectively. For TL/L curves, the formula predicted 56.4% of the cases within ±5°, while 30.8% and 12.8% were within ±5-10° and ±10-13°, respectively (Fig 1). SUFLEX was 81.0% and 89.7% accurate in predicting curves that will bend <25°, for MT and TL/L curves, respectively.

Conclusion
Using standard standing and supine radiographs, and the SUFLEX formula, curve flexibility can be assessed with a comparable or better accuracy than side bending. This may help decreasing radiation hazard to children eliminating the need for technician-dependent flexibility radiographs.



27. Brace Wearing Time is the Strongest Predictor of Final Reults: A Regression Model in 1457 High Risk Consecutive Adolescents With Idiopathic Scoliosis

Stefano Negrini, MD; Sabrina Donzelli, MD; Francesca Di Felice, MD; Fabio Zaina, MD

Summary

A personalised conservative approach (PCA) to Adolescents with Idiopathic Scoliosis (AIS) is based on different treatment protocols according to risk groups (11-20, 21-30, 31-40, 41-45). We developed a model to predict PCA end results from baseline clinical data, risk groups and brace wearing time. Time of brace wearing is the strongest predictor of final results whether end<50, end<30 or no-progression outcomes are considered. Risk groups on which PCA is based are also good predictors.

Hypothesis

It is possible to develop a model to predict end results of a personalised conservative approach (PCA) to Adolescents with Idiopathic Scoliosis (AIS) from baseline clinical data, risk groups and treatment protocols

Design

Secondary analysis with regression modeling of the data coming from a retrospective observational study nested in a prospective database including all outpatients of an Institute with 26 Centres

Introduction

Current Guidelines propose PCA, but there are no large studies to check final results, and predict which patients will respond better.

Methods

Inclusion criteria: AIS, 11-45°, Risser 0-2, age 10-16, first consultation, no previous bracing, reached end of observation (Risser 3, medical prescription). Treatments followed a personalised conservative approach (PCA) following the step-by-step theory (Negrini 2018): intensity increases with estimated risk factors, from observation to PSSE to soft, rigid and very rigid bracing. We considered the SOSORT-SRS Consensus outcomes: end Cobb angle <50° and <30° and no-progression. A backward selection regression modelling weas used to assess the effect of 7 covariates on the main outcomes: age, BMI, ATR, TRACE (Trunk Aesthetic Clinical Evaluation) score, Risser and Cobb angle at baseline; referred brace wear (RBW) and risk groups according to which different PCA are provided (11-20; 21-30; 31-40 and 41-45)

Results

We had 1457 patients, 82.6% females, age 12.11+-1.05. End<50° was predicted by BMI and RBW (0.21 and 0.10 probability respectively) while age, Cobb and ATR were statistically significant but weighting <0.005. End30° is predicted by RBW (0.37), and Cobb (0.03), while age counts <0.0005. No-progression was predicted by RBW (0.33); Cobb, TRACE and ATR counted <0.02, and age <0.0002. The models Between 0.31 and 0.37 of the final results. Considering the 4 risk groups, end<30° and end<50° probability decreases with the groups (R2=0.3 and 0.04 respectively)

Conclusion

Time of brace wearing is the strongest predictor of final results whether a <50, <30 or stability outcomes are considered. Risk groups on which PCA is based are also good predictors

		Results		Treatments performed							
				Observation	PSSE	Brace + PSSE		Type of bracing			
Groups	N	Improved	Progressed					Soft	Rigid	Very rigid	
Total	1458	32,5%	18,8%	1,3%	25,0%	73,7%		9,6%	46,4%	44,0%	
11-20°	522	13,6%	27,8%	3,1%	60,5%	36,4%	*	32,4%	62,2%	5,4%	*
21-30°	539	36,7%	14,3%	0,4%	10,9%	88,7%	*	14,0%	65,4%	20,6%	*
31-40°	315	50,8%	12,4%	0,3%	0,7%	99,0%	#	0,6%	26,8%	72,6%	*
41-45°	82	56,1%	15,9%	0,0%	0,0%	100,0%	#	0,0%	3,8%	96,2%	*
N	Time	Below 30°	Above 50°								
Total 1458	Start	69,3%	0,0%	1,3%	25,0%	73,7%		14,0%	65,4%	20,6%	
	End	78,3%	1,6%								

N=number; PCA=Personalised Conservative Approach; PSSE=Physiotherapic Scoliosis Specific Exercises
Statistically significant difference: * from all other groups; # from groups 11-20° and 21-30°

28. SRS Survey: Brace Management in Adolescent Idiopathic Scoliosis

Matthew Halsey, MD; Lori Dolan, PhD; Richard Hostin, MD; Raphael Adobor, MD, PhD; Romain Dayer, MD; Eugenio Dema, MD; Olavo Letaif, MD, MSc

Summary

Brace utilization by SRS members caring for AIS patients is nearly universal, but post-prescription management is highly variable. Most members use SRS criteria for brace initiation but there is little consensus in other aspects of bracing utilization. The SRS may consider studying, identifying, and publishing other brace management best practices and criteria. This, in turn, may decrease practice variability and improve patient outcomes.

Hypothesis

Brace management for AIS is quite variable within the SRS membership.

Design

Online survey of entire SRS membership

Introduction

While the SRS has established criteria for brace initiation in AIS, there are no recommendations with respect to other management issues: when and how to discontinue bracing, monitoring, prescription hours, assessment of adequacy, and how to assess skeletal maturity. As the BrAIST study appeared to reinforce the utility of bracing, the SRS Non-Operative Management Committee decided to evaluate the consensus, or lack thereof, in AIS brace management practices.

Methods

1,200 SRS members were sent an online survey in 2017: The survey included 21 items concerning demographics, bracing indications, management, and monitoring. Free-text responses were analyzed and collated into common themes. When reasonable, free-text under "other" were mapped onto the existing responses. Data were analyzed using Microsoft Excel 2013 and SAS 9.4.

Results
There were 210 respondents (18% response rate) who stated that they regularly evaluate and manage patients with AIS. 99% of respondents use bracing for AIS and the majority (89.4%) use the published SRS criteria, or a modified version, to initiate bracing. 85% do not use brace monitoring and 66.3% use both %-Cobb correction and fit criteria to evaluate brace adequacy. Other aspects of brace management demonstrated a high degree of practice variability. This was seen with x-ray assessment of maturity level (51% use Risser exclusively, 33% use Risser and Sanders), hours prescribed (21% recommend full-time; 47% recommend 16-24 hours; 10% recommend nighttime only), timing and frequency of x-ray evaluation (e.g. 61% check brace x-ray after a "break-in" period; 29% check immediately), and the method and timing of brace discontinuation (54% use a weaning period; 46% do not).

Conclusion
There is consensus in brace management among SRS members with respect to brace initiation and evaluation of adequacy. There is little consensus with most other aspects of brace management. This variability in practice management may impair the overall efficacy of brace treatment but it may be decreased with more robust bracing guidelines from the SRS.

29. Optimizing Non-Operative Management in Adolescent Idiopathic Scoliosis: Increased Body Mass Associated with Decreased Bracing Outcomes

Adam Margalit, MD; Derek Nhan, BS; Walter Klyce, BA; Kristen Venuti, MS; Paul D. Sponseller, MD

Summary
Bracing reduces the need for surgical intervention in patients with adolescent idiopathic scoliosis (AIS) by significantly decreasing curve progression during growth. We hypothesized that AIS patients with larger BMIs would have decreased results with bracing. This retrospective cohort included 104 patients, 87 were underweight/normal weight and 17 were overweight/obese. The odds of having a curve ≥45 degrees after bracing were 3.5 (95%CI: 1.2-10.3, P=0.021) times higher for overweight/obese patients compared to underweight/normal weight patients.

Hypothesis
Adolescent idiopathic (AIS) patients with larger BMIs would have decreased results with bracing.

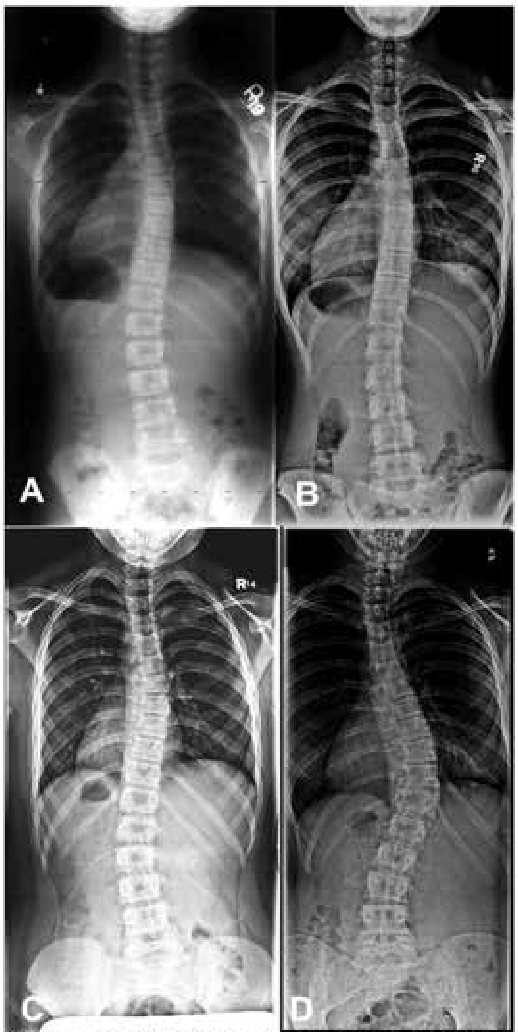
Design
Retrospective cohort

Introduction
Bracing reduces the need for surgical intervention in patients with adolescent idiopathic scoliosis (AIS) by significantly decreasing curve progression during growth. Brace wear for at least 13 hours/day is associated with a success rate of 90%. The purpose of this study is to determine the association of body mass index (BMI) with bracing outcomes.

Methods
This study included 104 patients (94 girls) aged 10 to 15 years (mean age, 12 ± 1 years) with AIS presenting to one orthopaedic surgeon from 2000 to 2016. All patients presented with no prior curve treatment, initial curve of 20-40 degrees, Risser 0-2 at time of bracing, premenarchal or <1-year post menarche at time of bracing in females, reported brace wear of at least 13 hours/day, and followed until skeletal maturity. Records were reviewed for BMI percentile for age and sex and primary curve magnitude pre- and post-bracing.

Results
Of the 104 patients, 87 were underweight/normal weight and 17 were overweight/obese. There was no difference between years of brace wear (2.9 ± 2.1 vs. 2.5 ± 1.0 years, P=0.252) or primary curve magnitude at time of presentation (32 ± 6 vs. 32 ± 5 degrees, P=0.931) in the underweight/normal weight and overweight/obese cohorts. Overall, 29% (25/87) of underweight/normal weight patients and 59% (10/17) of overweight/obese patients had curves ≥45 degrees at the end of bracing, P=0.016. The odds of having a curve ≥45 degrees after bracing were 3.5 (95%CI: 1.2-10.3, P=0.021) times higher for overweight/obese patients compared to underweight/normal weight patients.

Conclusion
Overweight/obese patients with AIS are 3.5 times more likely to present with curves ≥45 degrees after bracing compared to underweight/normal weight patients. Obese and overweight patients with AIS managed non-operatively with bracing should be counseled on an increased likelihood of requiring surgery. The increased overlying adipose tissue may reduce the corrective forces required to straighten the spine.



A. 10.2-year-old female with 55 percentile BMI presenting with an initial pre-bracing thoracic Cobb angle of 15 degrees and a **B.** post-bracing Cobb angle of 13 degrees after 4.3 years of TLSO brace wear reported at 22 hours/day on average. **C.** 10.1-year-old female with 90 percentile BMI presenting with an initial pre-bracing thoracic Cobb angle of 15 degrees and a **D.** post-bracing Cobb angle of 45 degrees after 4.1 years of TLSO brace wear reported at 23 hours/day on average.

30. The Demographics and Epidemiology of Idiopathic Scoliosis in Children and Incidence of Scoliosis in the U.S

Jeffrey Kessler, MD; Kevin Bondar; Annie Tram Anh Nguyen; Jasmine Vatani, BS

Summary
The incidence of idiopathic scoliosis(IS) in this population of 937,254 children was 3.9, 28.6, and 393 per 100,000, respectively, for the infantile, juvenile, and adolescent groups, and was highest in 13yo girls at 0.96% per year. Females had double the odds ratio(OR) and incidence of scoliosis versus males, and Asians and Whites had the highest incidence and OR of scoliosis. Underweight patients had the highest OR(1.50) of scoliosis and overweight, obese, and extremely obese had OR of 0.51,0.35, and 0.30.

Hypothesis
It currently is not known what the true incidence is of idiopathic scoliosis(IS) in children in America is, nor is it known what the risk of development of IS is by race/ethnicity or BMI. Establishing the incidence and risk of IS by age, sex, ethnicity, and BMI is an important step in understanding this disorder.

Design
Retrospective, cross-sectional analysis of a population of nearly 1 million children

Introduction
Most historical epidemiologic assessments of IS estimate its prevalence in small populations that are not self-contained. The purpose of this study is to assess the incidence of IS in the U.S., in addition to risk of IS based on all patient demographics in a massive, self-contained population.

Methods
A retrospective chart review was performed on all pts with IS under age 18 in the year 2013. Recorded demographics included sex, race, BMI, age at diagnosis, and charts were reviewed to ensure IS and Cobb angle > 10 degrees. IS incidence was determined by sex, age, and ethnicity. Age groups included infantile age 0-3, juvenile 4-10 yo, and adolescent 10-17 yo. Multivariable logistic regression analysis(MVLRA) determined associations between age, sex, race, BMI and IS diagnosis.

Results
IS Incidence was 3.9, 28.6, and 393 per 100,000(100K), respectively, for the infantile, juvenile, and adolescent group. The female incidence was more than 2x that of males in all ages. The highest incidence was in 14 year-olds at 633.7 per 100K. Based on ethnicity, Asians and Whites had the highest incidence at 256.6 and 232 per 100K. MVLRA showed Asians and Whites had the highest odds ratio(OR) of IS (OR 1.54 and 1.32, respectively). Overall, females had a 2.31 OR of IS vs males. In terms of BMI, underweight pts had a 50% increased OR of IS vs normal weight, whereas overweight and obese pts had progressively decreased OR of IS.

Conclusion
This represents the largest study on the demographics of IS, in a closed population of 4.5 million pts. It demonstrates an annual incidence of 393 per 100K for AIS and as high as 1% per year for 13yo girls. It also shows Asians have the highest OR of IS, and the IS risk decreases stepwise with increasing weight/obesity.

Table 1. Incidence Rates of Idiopathic Scoliosis by Age and Sex for the Year of 2013

	Incidence Population			Incidence Number			Incidence Rate (per 100,000)		
Age Group	Female	Male	Total	Female	Male	Total	Female	Male	Total
Age 0 – 3	87,064	90,950	178,014	5	2	7	5.7	2.2	3.9
Age 4 – 9	146,953	154,214	301,167	59	27	86	40.1	17.5	28.6
Age 10 – 17	224,035	234,038	458,073	1238	562	1,800	552.6	240.1	393.0
Total	458,052	479,202	937,254	1,302	591	1,893	272.0	123.3	202.0
Age 10	25,598	26,994	52,592	51	13	64	199.2	48.2	121.7
Age 11	25,569	26,879	52,448	116	29	145	453.7	107.9	276.5
Age 12	26,920	28,135	55,055	183	44	227	679.8	156.4	412.3
Age 13	27,883	29,372	57,255	267	93	360	957.6	316.6	628.8
Age 14	28,698	29,848	58,546	222	149	371	773.6	499.2	633.7
Age 15	29,166	30,337	59,503	175	112	287	600.0	369.2	482.3
Age 16	29,716	31,039	60,755	154	74	228	518.2	238.4	375.3
Age 17	30,485	31,434	61,919	70	48	118	229.6	152.7	190.6

Table 2. Incidence Rates of Idiopathic Scoliosis by Race/Ethnicity and Age for the Year of 2013

	White	Black	Hispanic	Asian/Pacific Islander	Other/Unknown
Age 0-3					
Incidence Number	4	0	2	0	1
Incidence Population	50,256	14,679	81,325	19,478	12,276
Incidence population (per 100,000)	8.0	0	2.5	0	8.1
Age 4-9					
Incidence Number	23	6	45	9	3
Incidence Population	71,127	25,077	151,619	28,159	25,185
Incidence population (per 100,000)	32.3	23.9	29.7	32.0	11.9
Age 10-17					
Incidence Number	495	131	851	208	115
Incidence Population	103,591	40,106	236,144	36,931	41,301
Incidence population (per 100,000)	477.8	326.6	360.4	563.2	278.4
Total					
Incidence Number	522	137	898	217	119
Incidence Population	22,4974	79,862	46,9088	84,568	78,762
Incidence population (per 100,000)	232.0	171.5	191.4	256.6	151.1

31. Determination of Growth Remaining From Humeral Head Periphyseal Ossification

Stephen DeVries, BS; Don Li; Allen Nicholson, MD; Eric Li; Jonathan Cui, BS; James Sanders, MD; Raymond Liu, MD; Daniel Cooperman, MD; Brian G. Smith, MD

Summary
We introduce a new five-stage classification system of the extent of periphyseal ossification of the humeral head. Because the humeral head is often included in standard scoliosis radiographs, this proximal humeral physeal ossification can be easily evaluated without exposing patients to additional radiation. The novel classification system serves as a proxy for percent growth remaining and can inform clinical decision-making in managing idiopathic adolescent scoliosis, particularly in patients who are pre-Risser 1 but beyond peak height velocity.

Hypothesis
We hypothesize that this new classification system will enable better prediction of peak height velocity, particularly in patients who are pre-Risser 1.

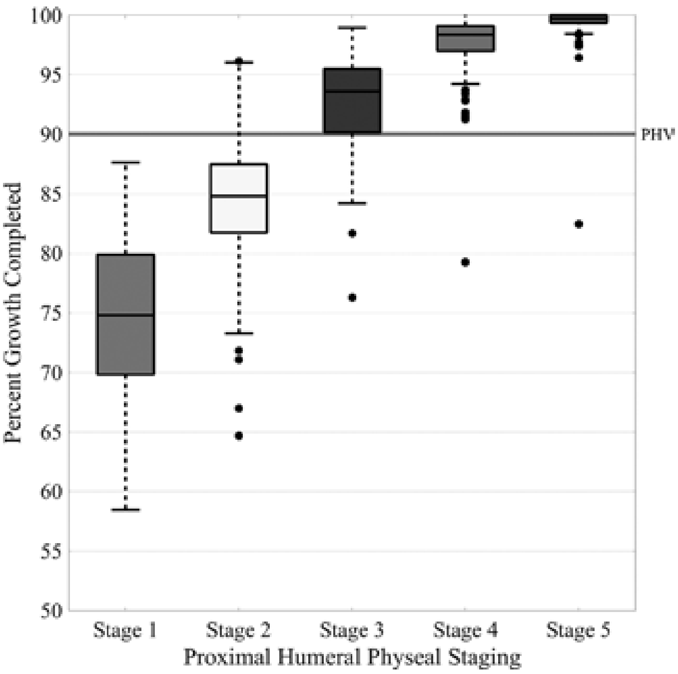
Design
This study is based on the analysis of 606 serial radiographs and yearly physical examinations from 49 girls and 45 boys, ages three to eighteen.

Introduction
Accurate assessment of skeletal maturity is required to manage adolescent idiopathic scoliosis. The Risser sign is perhaps the most widely used osteologic marker of skeletal development in idiopathic adolescent scoliosis, but it has been shown to have limits to its utility. Patients who are pre-Risser 1 and pre-menarchal but beyond their peak height velocity are particularly difficult to identify with existing markers.

Methods
We developed a classification system for the extent of periphyseal ossification of the humeral head. To assess the efficacy of this system as a proxy for growth remaining, each patient's percent growth remaining at the time of the x-rays (calculated retrospectively based on height at the time of the x-ray and height at maturity) was compared to their estimated stage within the classification system.

Results
On average, patients with x-rays categorized as stage 1 had 25.58% (standard deviation, SD = 6.67%) of their growth remaining while patients with x-rays categorized as stage 2 had 15.54% growth remaining on average (SD=5.04%). Stage 3 patients had an average of 7.32% growth remaining (SD=4.17%,), stage 4 patients had 2.41% of growth remaining (SD=2.69%) on average, and stage 5 patients had only an average of 0.54% growth remaining (SD=1.50%). Remarkably, there was no overlap in the interquartile ranges of the percent growth remaining for patients categorized into the five stages (see figure). For intraobserver comparisons, Kappa was 0.80 and ICC was 0.96. For interobserver comparisons, Kappa was 0.78 and ICC was 0.95.

Conclusion
The ossification of the proximal humeral physis proceeds in a predicable manner through the majority of skeletal development. With the classification system developed here, the extent of physeal closure of the proximal humerus can be used as an effective marker for the remaining growth present in an immature patient.



32. Cervical Vertebral Maturation (CVM) Stage in Adolescent Idiopathic Scoliosis: Is it an Alternative Option in Determining Peak Height Velocity (PHV)?

Hongda Bao, MD, PhD; Shibin Shu, PhD; Yuancheng Zhang, MS; Qi Gu, MS; Zezhang Zhu, MD; Zhen Liu, MD; Yong Qiu, MD

Podium Presentation Abstracts

Summary
The longitudinal study showed that the CVM stages strongly correlated to Risser sign and 68% patients at PHV presented CVM stage 3, indicating that CVM stage provides an alternative option for the assessment of skeletal maturity of subjects with idiopathic scoliosis.

Hypothesis
The CVM stages could be used as an alternative option compared to Risser sign in determining PHV.

Design
A retrospective longitudinal study

Introduction
Commonly used clinical or radiographic methods including Risser sign, digital skeletal age (DSA) score, are inadequate or too complex for rapid application in a busy clinic setting. CVM stage is commonly used in Orthodontics but was less acknowledged in studies of spinal growth.

Methods
AIS pts were included with the following inclusion criteria: female, age between 9 to 16 y/o, have full spine images with clear visibility of cervical spine. AIS pts for growth validation also need more than 4 follow-ups with interval of at least 6 months. Reliability test of CVM stage was performed at first with a fellow and a resident. The relationship between CVM and Risser sign was analyzed. The stature, arm span, spinal length, spinal height and pelvic height were measured at each follow-up, the growth velocity of each parameter were also calculated. The velocity at each CVM stage was compared.

Results
170 AIS pts were included for the first analysis (mean age 10.62 y/o). The distribution of CVM stage and Risser sign was shown in Figure. The CVM stages were found to correlate strongly with Risser sign (r=0.85, p<0.01). In Risser 0 pts with open triradiate cartilage (TC), 39% was CVM 2 and 22% CVM 3; In Risser 0 pts with closed TC, 71% was CVM 3. 32 pts were included for growth validation study. The growth velocity of stature averaged 5.4 cm/yr in CVM 2 pts and 6.3cm/yr in CVM 3 pts, significantly larger than that in CVM 4 pts (3.3cm/yr, both p<0.001); similarly, the growth velocity of arm span and spinal length were also significantly higher in CVM 3 pts (6.2cm/yr and 4.0cm/yr). 68% pts showed CVM 3 at the time of PHV. The higher ratio of spinal length vs. pelvic height in CVM 3 also indicated the high growth velocity.

Conclusion
The new CVM stage could provide an alternative option for the assessment of skeletal maturity of subjects with idiopathic scoliosis. The index needs to be subjected to further multicenter validation in different ethnic groups.

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33. Predictive Capability of a Surgical Planning Tool for Anterior Vertebral Body Growth Modulation: Two-Year Follow-Up

Nikita Cobetto, PhD; Stefan Parent, MD, PhD; <u>Carl-Eric Aubin, PhD</u>

Summary
AVBGM is used for pediatric patients with remaining growth potential to progressively correct scoliosis. The study`s objective was to evaluate the predictive capability of a planning tool based on a patient-specific finite element model for immediate and 2-year post-operative correction. Different instrumentation configurations were assessed and the strategy offering the best 2-year correction was selected to perform the surgery. This study demonstrates the numerical model`s clinical usefulness to rationalize surgical planning with clinically relevant correction predictions.

Hypothesis
Numerical surgical planning tool can be used to rationalize surgical planning.

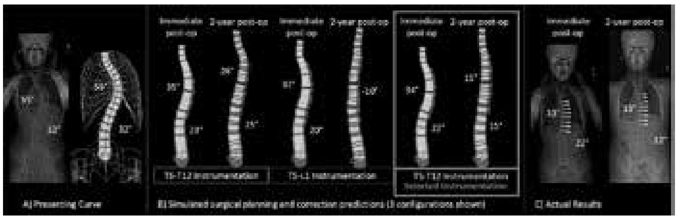
Design
Numerical surgical planning of immediate and after 2 years effects of Anterior Vertebral Body Growth Modulation for 40 patients.

Introduction
For pediatric scoliotic patients with progressive curves and remaining growth potential, AVBGM is a recent option to progressively correct the deformity. As surgical planning remains empirical, a planning tool based on a patient-specific finite element model (FEM) of pediatric scoliosis integrating growth was previously developed to simulate installation, growth and growth modulation effect of AVBGM. The objective was to evaluate the planning tool predictive capability for immediate and 2-year post-operative correction.ection.

Methods
40 consecutive patients to be instrumented with AVBGM were recruited. For each case, a patient-specific FEM was pre-operatively generated using a 3D reconstruction obtained from calibrated bi-planar radiographs. The FEM was used to assess different instrumentation configurations (instrumented levels/cable tensioning). The strategy offering the best coronal plane correction after 2 years of simulated growth was selected to perform the surgery. Simulated 3D correction indices were computed for immediate post-operative, and after 2 years of growth (Cobb angles, kyphosis/lordosis angles, apical axial rotation, spinal height T1-L5). Stresses applied on vertebral epiphyseal growth plates and intervertebral discs were computed using the FEM.

Results
On average, 6 configurations per case were tested. For the chosen configuration, immediate and 2-year post-operative Cobb angles, kyphosis/lordosis angles and apical axial rotation were predicted within 5° of that of actual results, while it was within 8 mm (± 2%) for the spinal height. The difference between convex and concave side computed forces at the apical level showed an average decrease in asymmetric loadings of 39% on growth plates and 46% on intervertebral discs.

Conclusion
This study demonstrates the clinical usefulness of FEM to rationalize surgical planning by providing clinically relevant correction predictions.



34. Tridimensional Changes Following Anterior Vertebral Growth Modulation After Two Years of Follow-Up

Olivier Turcot, BS; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BS; Christian Bellefleur, MSCA; Vincent Cunin, MD; Stefan Parent, MD, PhD

Summary

Clinical and radiological data of Anterior Vertebral Growth Modulation (AVBGM) was evaluated. AVBGM is a safe technique that offers a progressive correction using growth modulation in the coronal and transverse planes over a two years follow-up. Although the correction was achieved through an anterior compression approach, the procedure was not found to be kyphogenic. This may be due to the coupling effect of derotation and coronal correction minimizing the impact on the sagittal plane.

Hypothesis

AVBGM immediate 3D correction of the scoliosis can be improved with growth modulation without significant changes in the sagittal plane.

Design

Prospective developmental study

Introduction

Anterior Vertebral Growth Modulation (AVBGM) aims to gradually correct scoliosis, using the patient's growth, while preserving spine motion. One of the concerns is the risk of creating kyphosis. The objective was to evaluate the 3D correction of scoliosis and the effect of growth modulation at one year and at two years postoperatively.

Methods

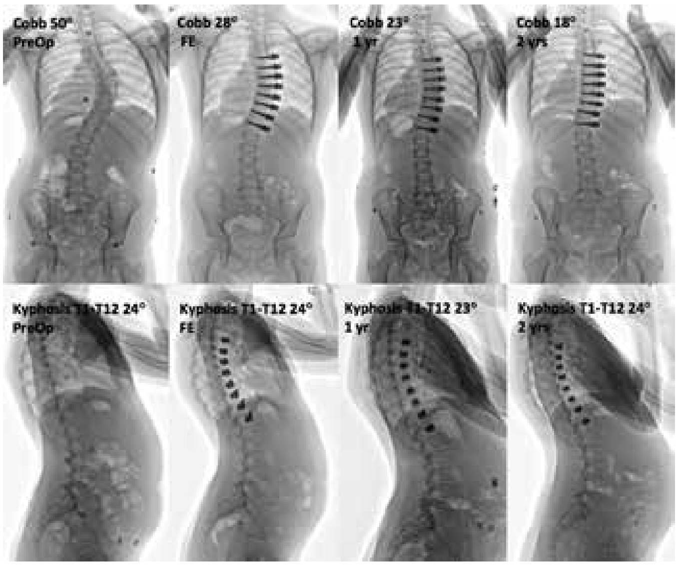
We reviewed the clinical, perioperative and radiological prospectively collected data of the first 23 patients who received the AVBGM at our institution. The preoperative, 1st erect visit (FE), one year and two-year follow-up data were analyzed. Computerized measurements were done on reconstructed 3D spines radiographs. Means, standard deviation and paired t test of specific parameters were calculated.

Results

All 23 patients were skeletally immature (mean age 11.8 yo). Tethering was done on an average of 7.2 vertebral levels. Cobb angle was 52.6°±9.4° preoperatively and 32.3°±9.2° at the FE visit ($p<0.001$) with progressive correction at one year (26.3°±12.6°) and two years (27.0°±9.6°). Patients with more than 5° between FE and 2 years had a difference between the height of the apical vertebra at two years and FE that was significantly different between convex (-0,0036mm) and concave (0,8736mm) side ($p=0.017$). In the sagittal plane, preop kyphosis was unchanged after two years (26.1°±13.1° and 25.4°±17.1°, $p=0.77$). The mean segmental kyphosis of T5-T12 was 2.2°±9.5° preop, 8.9°±10.6° at the FE visit and 11.5°±13.6° after two years. In the transverse plane, apical vertebral rotation of 14.3°±5.0° was corrected to 11.1°±9.4° after two years ($p=0.03$).

Conclusion

AVBGM offers a significant correction in the coronal and transverse planes. Although the correction was achieved through an anterior compression approach, there was no impact on the kyphosis of the patient at two years follow-up. The progressive improvement in the Cobb angle in this cohort confirms that growth has a role in the correction of scoliosis with AVBGM at two years follow-up.



35. Non-Fusion Thoracoscopic Anterior Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Preliminary Results of a Single European Center

Caglar Yilgor, MD; Barbaros Cebeci; Kadir Abul, MD; Suna Lahut, PhD; Gokhan Ergene, MD; Sahin Senay, MD; Ahmet Alanay, MD

Summary

A single European center experience on first 19 thoracoscopic anterior vertebral body tethering (VBT) cases for adolescent idiopathic scoliosis since 2014 suggests that surgical correction is followed by correction attained during follow-up in rapid growing cases (i.e., Sanders ≤4). Spontaneous correction in the non-operated compensatory lumbar levels were also recorded. Application of VBT in steady growing cases (i.e., Sanders 5-7) was also demonstrated to be safe maintaining curve correction after minimum 1 year follow-up.

Hypothesis

Significant major and compensatory curve correction can be achieved with Anterior vertebral body tethering (VBT).

Design

Retrospective analysis of a prospectively collected data of a single surgeon experience.

Introduction

Anterior VBT has been reported to be safe and effective in 2 published clinical series of a single center. This technique has been used in our center since April 2014 for rapid growing adolescent (Sanders ≤4) patients. With experience, in Jan 2016, the indications were extended to include steady growing (Sanders 5-7) pts. The aim was to report our experience after ≥1 year follow-up.

Methods

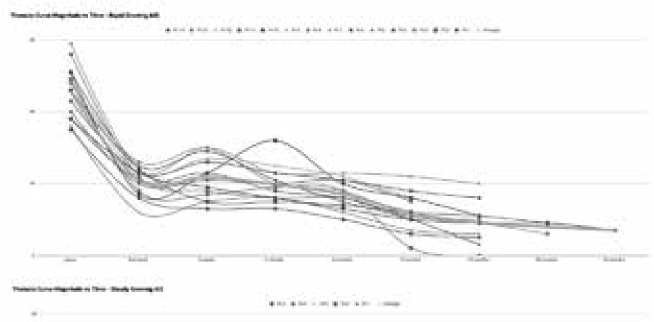
All patients were operated via thoracoscopy. Radiographic measurements were done in pre- and post-operative first-erect, 6-weeks, 3-6-9-12-18-24- and 36-months f/up. Surgical and total f/up correction percentages were calculated. Patients were analyzed as a whole cohort and as two groups; Rapid and Steady Growing. A descriptive analysis was done.

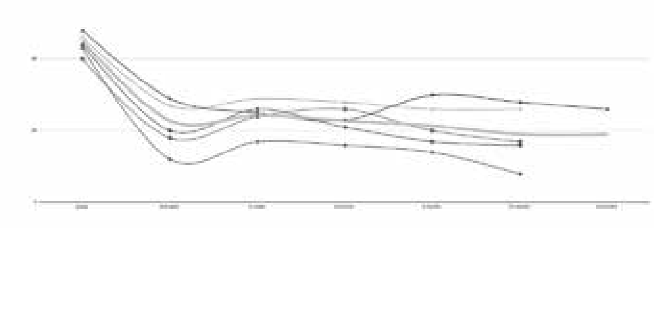
Results

19 Lenke 1 pts were included. Mean age: 12.5±1(11-14) yrs. Mean f/up: 17.6±7.3(12-41) months. UIV was T5 or T6, and LIV was T11-T12 or L1. Rapid Growing mean height gain: 8.1 (5-17)cm. Pre-op mean MT Cobb was 45.4° (35°-59°). Average initial and total correction rates: 53% and 75% (Fig 1a). Mean compensatory TL/L Cobb was 29.9° (12°-42°). Average initial and total spontaneous correction rates: 44% and 64%. Average hump reduction: 12.9° to 5.6°. 2 atelectasis resolved with physical therapy. LIV screw loosened in a patient who grew 17cm. A tether was released due to overcorrection and there are 2 more candidates. Steady Growing mean height gain: 2.6 (1-4)cm. Pre-op mean MT Cobb was 44.2° (40°-48°) Average initial and total correction rates: 53% and 57% (Fig 1b). Mean compensatory TL/L Cobb was 30.2° (22°-40°). Average initial and total spontaneous correction rates: 52% and 62%. Average hump reduction: 11° to 6°. No complications were recorded.

Conclusion

VBT is a promising minimal invasive non-fusion technique enabling spontaneous correction while allowing for growth. It may also safely be performed in steady growing patients. However, longer term follow-up is needed.





36. In The Relationship Between Change in Kyphosis and Change in Lordosis: Which Drives Which?

Renaud Lafage, MS; Tejbir Pannu, MD, MS; Jonathan Charles Elysée, BS; Brandon Carlson, MD, MPH; Frank J. Schwab, MD; Han Jo Kim, MD; Virginie Lafage, PhD

Summary

Curves in the spine exist in fluid harmony. Altering any one part may lead to proportionate changes in another. This study investigated how spinal stiffness in either the thoracic or lumbar spine influenced the relationship between LL and TK. The results demonstrated that "Thoracic Fusions" drove changes in LL while this relationship is affected by TK's natural stiffness in "Lumbar Fusion" pts. Understanding the relative stiffness and curve harmony may play a role in reducing acute changes above the construct.

Hypothesis

Spinal curve stiffness drives the relationship between alignment parameters

Design

Retrospective single center, single surgeon database of ASD pts.

Introduction

Proper sagittal alignment exists in harmony between the spinal curvatures, with thoracic kyphosis and lordosis being proportional related to each other. This study aims to investigate how spinal stiffness from instrumentation influences the normal relationship between lordosis and kyphosis.

Methods

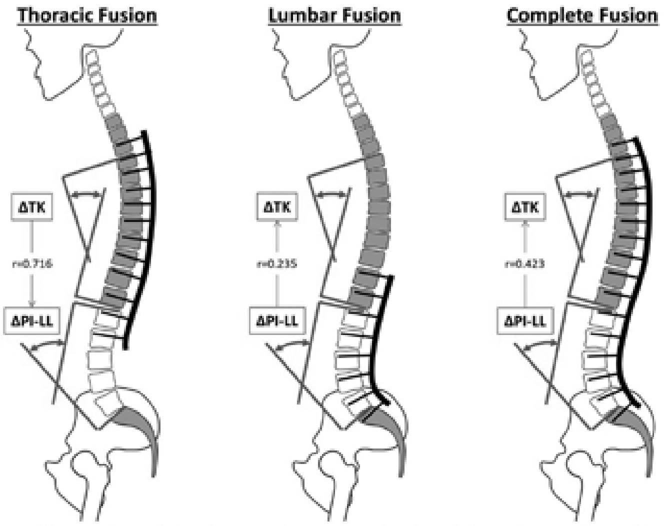
Surgically treated pts with a minimum of 6 months FU were analyzed. Pts were stratified based on post-operative posterior instrumentation as: "Thoracic fusion" = complete fusion of TK and a L1-S1 not complete fused; "Lumbar Fusion" = complete fusion of LL and at least T1-T7 unfused; and "Complete fusion" = complete fusion from sacrum to at least T5. Bi-variate correlations and regression analyses were used to evaluate the relationship between ΔTK and ΔPI-LL. Analyses were repeated on pts with flexible pre-op TKs.

Results

A total of 153 of 167 patients were included (62 yo, 26.7 kg/m2, 78%F). Mean FU was 11.5m±6.8. From pre to post, there were significant changes (all p<0.001) in PT (24.4 vs 19.1), PI-LL (17.1 vs -0.4), T4-T12 (-34.3 vs -41.5), TPA (23.4 vs 14.2), and SVA (70 vs 14). The association between ΔPI-LL and ΔTK for each of the fusion group revealed r-values of 0.716 for "Thoracic Fusion", 0.235 for "Lumbar Fusion", 0.634 for "Lumbar Fusion" with flexible TK, and 0.423 for "Complete Fusion". Interestingly, the ΔPI-LL was equal to 34% and 39% of ΔTK for the first two groups respectively but was only 21% for the "Complete Fusion" group. In this last group, in which ΔTK and ΔPI-LL were not proportionate, patients were more likely to develop PJK (35.9% vs. 11.1%, p=0.048).

Conclusion

The relationship between ΔTK and ΔPI-LL is dependent upon the levels instrumented: "Thoracic Fusion" drives change in LL while this relationship is affected by TK's natural stiffness in "Lumbar Fusion" pts. Understanding the relative stiffness and harmony between curves may play a large role in the reduction of acute changes above the construct.



Coefficient of correlation between change in TK (ΔTK) and change in PI-LL (ΔPI-LL) in function of fused group

37. The Role of the Fractional Lumbosacral Curve in Persistent Coronal Malalignment Following Adult Thoracolumbar Deformity Surgery

Alekos Theologis, MD; Thamrong Lertudomphonwanit, MD; Lawrence G. Lenke, MD; Keith Bridwell, MD; Munish Gupta, MD

Summary
In this cohort of adults who underwent primary, posterior-only operations for thoracolumbar spinal deformity, the majority of preoperative Type C coronal deformities remained coronally undercorrected and malaligned postoperatively. As such an alternative surgical strategy should be considered to more adequately correct lumbosacral fractional curves and maintain and/or restore coronal balance in this groups of patients.

Hypothesis
Coronal imbalance ipsilateral to thoracolumbar scoliosis' apex is more difficult to adequately correct due to undercorrection of lumbosacral fractional curves.

Design
Retrospective cohort.

Introduction
Achieving appropriate coronal alignment is less reliable in adults with coronal malalignment due to trunk shift ipsilateral to degenerated thoracolumbar scoliosis' apex. We compare radiographs/surgical techniques for thoracolumbar deformity with varying severity and direction of coronal imbalance.

Methods
Review of adults who underwent posterior spinal fusions to pelvis (≥5 levels) for thoracolumbar scoliosis. Exclusion: revisions, no coronal deformity, thoracic Cobb>300, and anterior operations. Patients were divided into 3 groups, as proposed by Bao et al.: (1) Type A, CSVL<3cm; (2) Type B, CSVL>3 cm and C7 plumb shifted to scoliosis' concavity; (3) CSVL>3cm and C7 plumb shifted to scoliosis' convexity. Radiographic parameters and surgical techniques were compared.

Results
144 patients (male-6; female-118; avg age 58±10 years; Type A-87; Type B-19; Type C-18). Type C had significantly greater lumbosacral fractional curves. 28% of Type C were treated with fractional curve TLIFs, while all, but one, Type B had TLIFs of the fractional curve. Deformity parameters after surgery were similar, except Type C had persistently greater fractional curves/coronal malalignment. All preop Type B were appropriately corrected postop. For preop Type C, 67% remained Type C and 33% became Type A postop. Compared to those who became Type A, persistently undercorrected and malaligned (Type C) patients had significantly greater preop lumbosacral fractional curves, greater preop coronal Cobb angles, and more commonly involved TLIFs of lumbosacral fractional curves.

Conclusion
In adults who underwent primary, posterior-only operations for thoracolumbar spinal deformity, the majority of Type C coronal deformities remained coronally undercorrected and malaligned postop. For these patients, an alternative surgical strategy should be considered to more adequately correct lumbosacral fractional curves and maintain and/or restore coronal balance.

Preop CSVL Type (Bao Classification)	A (n=87)			B (n=19)	C (n=18)		
Postop CSVL Type (Bao Classification)	A (N=71)	B (N=1)	C (N=15)	A (N=19)	A (N=6)	B (N=0)	C (N=12)
Female	69	1	14	17	4		12
Age (yrs)	57 ± 10	66	58 ± 7.2	65.7 ± 5.0	60 ± 5		54 ± 11
BMI	25.6 ± 3.7	22.1	27.2 ± 5.2	25.9 ± 5.4	26.3 ± 5.1		24.6 ± 4.0
Follow-up (mos)	43.1 ± 15.6	66.8	51.6 ± 21.7*	39.2 ± 19.3	34.0 ± 14.3		42.1 ± 14.9
UIV							
UT (T1-T5)	40	0	11	15	1		5
MT (T6-T9)	5	0	1	3	1		2
LT (T10-L2)	26	1	3	1	4		5
Avg # levels fused/instrumented	13.4 ± 3.7	10	15.2 ± 3.3	15.7 ± 2.5	10.7 ± 3.4		13.0 ± 3.4
Max Cobb (deg)							
Preop	56.4 ± 17.9	57	66.7 ± 13.0*	67.5 ± 19.1	41.7 ± 18.1		51.8 ± 13.7
Latest F/U	23.5 ± 12.7#	49	27.7 ± 15.2	26.5 ± 12.4#	21.5 ± 11.8#		21.7 ± 8.6#
Curve apex							
Left	29	0	3	7	4		4
Right	41	1	11	12	2		8
CSVL (cm)							
Preop	1.53 ± 1.14	1.7	1.69 ± 1.18	6.98 ± 5.82	4.32 ± 0.65		4.81 ± 1.82
Latest F/U	1.71 ± 1.06	6.4	3.71 ± 1.10#*	1.96 ± 2.01#	2.40 ± 1.12#		4.42 ± 1.67*
Fractional curve (deg)							
Preop	22.6 ± 10.0	16.9	25.4 ± 6.5	22.6 ± 11.9	23.2 ± 9.9		32.7 ± 11.5*
Latest F/U	9.1 ± 6.2#	12	14.9 ± 5.5#*	8.3 ± 7.1#	13.1 ± 7.5		15.7 ± 8.4#
C7 SVA (cm)							
Preop	1.7 ± 2.8	1.3	3.7 ± 4.8*	8.6 ± 6.7	5.4 ± 5.0		2.4 ± 4.4
Latest F/U	1.9 ± 2.8	-2.9	2.8 ± 4.1	4.6 ± 5.9#	4.0 ± 5.4		3.1 ± 2.9
PI (deg)							
Preop	50.2 ± 11.8	45	59.7 ± 15.4*	58.4 ± 13.6	52.8 ± 20.4		50.8 ± 19.3
Latest F/U	50.3 ± 11.7	45	59.5 ± 15.5*	58.2 ± 13.5	52.5 ± 20.2		50.9 ± 19.0
PT (deg)							
Preop	20.6 ± 8.5	24	27.4 ± 12.4*	32.0 ± 8.4	25.7 ± 8.3		23.2 ± 12.9
Latest F/U	21.2 ± 9.0	13	21.9 ± 10.8#	26.3 ± 7.9#	24.7 ± 9.3		19.9 ± 12.5
LL (deg)							
Preop	-39.6 ± 18.2	-18	-39.5 ± 17.0	-30.0 ± 26.3	-36.2 ± 19.5		-33.1 ± 19.6
Latest F/U	-43.2 ± 13.5#	-46	-49.3 ± 13.5#	-41.5 ± 15.0#	-39.5 ±15.6		-43.4 ± 11.3#
PI-LL (deg)							
Preop	10.6 ± 15.2	27	20.2 ± 18.1*	28.4 ± 19.5	16.7 ± 12.9		17.7 ± 19.8
Latest F/U	7.0 ± 13.0#	-1	10.1 ± 17.0#	16.6 ± 16.0#	13.0 ± 18.2		7.5 ± 15.7#
TK (deg)							
Preop	28.1 ± 17.2	-4	28.7 ± 18.0	32.8 ± 20.1	28.3 ± 14.9		18.9 ± 11.9
Latest F/U	34.8 ± 12.3#	26	32.0 ± 10.6	31.9 ± 12.4	35.0 ± 15.6		35.6 ± 12.0#
Interbody fusion	28	0	7	18	0		5*
L3-4	4	0	1	9	0		4
L4-5	22	0	6	13	0		4
L5-S1	26	0	6	14	0		5
EBL (cc)	1,300 ± 858	650	1,697 ± 1,119	2,168 ± 594	1,125 ± 733		1,292 ± 1,1174
OR time (mins)	398 ± 82	323	448 ± 95*	555 ± 158	309 ±117		409 ± 77*

* p-value< 0.05 (A vs. C) / # p-value < 0.05 (pre-op vs. post-op)

38. A Radiographic Analysis of Lumbar Fusion Status after Complex Adult Spinal Deformity Surgery: Subanalysis of the Scoli-Risk-1 Database

Takayoshi Shimizu, MD, PhD; Meghan Cerpa, BS, MPH; Eduardo Beauchamp, MD; Leah Yacat Carreon, MD, MS; Christopher Shaffrey, MD; Kenneth Cheung, MD, FRCS; Lawrence G. Lenke, MD

Summary

This radiographic sub-analysis of the Scoli-Risk-1 study demonstrated an overall fusion rate of 69.9% in the lumbar spine after complex adult spinal deformity surgery at 2-yr follow-up. Surprisingly, a relatively high fusion rate of 89.5% was observed at the lumbo-sacral junction. The incidence of rod breakage increased over f/u to 9.8% at 2-yr f/u, while PJK was fairly stable at 4.9% at 2 year f/u.

Hypothesis

At two years after complex adult spinal deformity (ASD) surgery, a significant number of patients will demonstrate radiographic evidence of fusion with minimal instrumentation failure

Design

Sub-analysis from a prospective, multicenter, international cohort

Introduction

Achieving fusion is crucial for maintaining optimal alignment in ASD surgery. Loss of fixation has been shown to result in spinal malalignment and poor clinical outcomes. However, prospective data using large patient populations are lacking on these information

Methods

Postoperative radiographs of 163 patients from the Scoli-Risk-1 database, who underwent complex ASD surgery with fusion to the sacrum, were evaluated by 3 independent spine surgeons at 6-week, 6-month, and 2-yr follow-up. The fusion rate of the lumbar spine segments at 2-yr follow-up was determined by using previously published radiographic grading criteria. We also assessed the incidence of implant failures at each follow-up period

Results

The inter-rater reliabilities for grading the fusion status were overall fair at each level evaluated (Kendall's coefficient, 0.336-0.432). 69.9% (114/163) demonstrated solid fusion of the entire lumbar spine at 2-yr follow-up. The fusion rate of each segment were L1/2: 87.1%, L2/3: 81.5%, L3/4: 83.4%, L4/5: 89.5%, and L5/S1: 89.5%. Pedicle screw (PS) loosening was most frequent implant failure throughout the observation period. No rod breakage was observed at 6-week, increasing to 9.8% at 2-yr. The incidence of postoperative proximal junctional kyphosis (PJK) was 5.5% at 6-week, showing no difference at 2yr postop (Table 1)

Conclusion

In this series of complex ASD surgeries from the Scoli-Risk-1 study, 69.9% showed solid fusion of the entire lumbar spine. The lower lumbar segments (L4/5 and L5/S1) showed a surprisingly high fusion rate at 2-yr f/u likely due to routine anterior column support and graft. The incidence of rod breakage increased as follow-up proceeded to 9.8% at 2-yr f/u, while PJK was observed at a stable incidence of 4.9% at 2-yr f/u

	PS (or hook) loosening	Rod breakage	PJK	P
At 6-week	9.2%	0.0%	5.5%	**<0.001**
6-month	11.6%	4.2%	7.9%	**0.049**
24-month	11.0%	9.8%	4.9%	0.112
P	0.756	**<0.001**	0.474	

Chi-Square test, significance at P < 0.05
PS, pedicle screw; PJK; proximal junctional kyphosis

39. Spinal Deformity Surgery in Patients ≥75 Years Old: How Do the Outcomes Compare with Younger Patients?

Zac Lovato, DO; Andrew Chung, DO; Dennis Crandall, MD; Jan Revella, RN; Michael Chang, MD

Summary

176 elderly patients underwent ASD surgery. Being ≥75 yrs old or having ≥3 comorbidities did not show a significant difference in HRQoL's or complications when compared to a 65-74 age group or a lower comorbidity burden in our elderly study population.

Hypothesis

Patients ≥75 yrs old that undergo adult spinal deformity (ASD) surgery will have worse outcomes and more complications compared to a 65-74 age group.

Design

Retrospective study of a prospectively collected database at one center.

Introduction

Up to 68% of the elderly population has spinal deformity which is a growing concern given that avg lifespan is increasing. ASD surgeries are generally taxing and have significant morbidity. We compared outcomes/complications of ASD surgery between 65-74 and ≥75 yrs old.

Methods

Radiographic parameters and HRQoL outcomes (VAS/ODI) measured at preop, postop, and 2 yrs. Comorbidities included based on Charlson Comorbidity Index and compared to incidence of complications and need for revision surgery.

Results

176 patients (Group 1=130 aged 65-74, Group 2=46 aged ≥75; Subgroup A=0-2 comorbidities, Subgroup B=≥3 comorbidities) with avg f/u of 69.1mo (25-186mo). No demographic differences other than age and BMI (Grp 1 BMI: 27.3, Grp 2 BMI: 23.0, p=0.003) were of significance. Both age groups improved radiographic parameters at all time points. 47.9% of group 1A vs 54.5% in 1B had a complication. 37.8% in group 1A required revision vs 45.5% in 1B. 61.9% of group 2A vs 50.0% in 2B had a complication. 38.1% of group 2A required revision vs 50.0% of 2B. Comparing the different age groups with similar comorbidity burden in regards to complications and need for revision yielded no statistically significant differences (SSD). VAS improvement was similar between the groups at 2 yrs (Grp 1: 2.6, Grp 2: 2.5). Both groups improved ODI by 15.4 at 2 yrs. There were no SSD in HRQoL's between comorbidity subgroups.

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Conclusion

No SSD between outcomes/complications of ASD surgery in patients ≥75 yrs old compared to age 65-74. ≥3 comorbidity burden did not have a significant impact on the complications or need for revision in our elderly ASD surgery population.

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40. Probability of Severe Frailty Development Among Operative and Non-Operative Adult Spinal Deformity Patients: An Actuarial Survivorship Analysis over a 3-Year Period

Peter Passias, MD; Frank Segreto, BS; Cheongeun Oh, PhD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin Smith, MD, PhD; Alan Daniels, MD; Breton G. Line, BS; Han Jo Kim, MD; Juan S. Uribe, MD; Robert K. Eastlack, MD; D. Kojo Hamilton, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Christopher Shaffrey, MD; Christopher Ames, MD; Shay Bess, MD; International Spine Study Group

Summary

Little is known of how frailty, a dynamic measure of physiological age, progresses relative to age or disability status. Operative treatment(Op) of adult spinal deformity(ASD) may play a role in frailty remediation and maintenance. Our analysis found Op patients to have significantly improved frailty at 1Y, 2Y and 3Y followups(f/u) compared to non-operative(Nop) patients and baseline(BL) status. Nop patients, patients with severe SVA(++) deformity at 6W f/u, or Schwab thoracic coronal curvature patients were more likely to develop severe frailty.

Hypothesis

Operative intervention for ASD may reduce frailty progression

Design

Retrospective review of a prospective ASD multicenter database

Introduction

Frailty progression is poorly understood. Operative intervention may play a role in frailty progression among ASD patients.

Methods

ASD patients(coronal scoliosis≥20°, SVA≥5cm, PT≥25°, or thoracic kyphosis≥60°) >18y/o, with BL frailty scores were included. Frailty was scored from 0-1 (not frail: <0.3, frail 0.3-0.5, severe frailty >0.5). Op and Nop patients were propensity matched by BL age, Charlson score(CCI), and frailty. T-tests compared frailty among treatment groups and BL, 1Y, 2Y, and ≥3Y f/u. An actuarial Kaplan-Meier survivorship analysis with Log Rank(Mantel-Cox) test, adjusting for patients lost to follow-up, determined probability of severe frailty development. Multivariate Cox Regressions gauged the effect of sagittal malalignment on severe frailty development.

Results

556 patients were included (278 Op, 278 Nop). Demographics were similar except gender (Table 1). Op exhibited decreased frailty at all f/u intervals compared to BL (BL:0.22 vs Y1:0.17; Y2:0.15; Y3:0.16, all p<0.001). Nop displayed similar frailty from BL to 2Y f/u, and increased frailty at 3Y f/u (0.20 vs 0.23, p=0.014). Compared to Nop, Op had lower frailty at 1Y (0.17 vs 0.22), 2Y (0.15 vs 0.21) and 3Y (0.16 vs 0.23) f/u (all p<0.001). Mean time to severe frailty development was 153.1[151.1-155.1] weeks for Op and 149.1[146.1-152.2] weeks for Nop (p=0.018). Cumulative probability of maintaining non-severe frailty was (Op:98.1%, Nop:95.3%) at 1Y, (Op:96.4%, Nop:91.5%) at 2Y, and (Op:96.4%, Nop:90.6%) at ≥3Y f/u, p=0.018. Schwab thoracic only coronal curve type (HR:7.9[1.1-56.5], p=0.039) and SVA ++ modifier (HR:38.8[4.4-342.6], p<0.001) at 6W f/u predicted shorter time to severe frailty development.

Conclusion

Nop patients were more likely to develop severe frailty, and at a quicker rate. Sagittal malalignment at 6W f/u significantly predicted severe frailty development. Operative treatment appears to play a significant role in frailty remediation and maintenance in ASD patients.

Table 1: Demographic and Surgical Details among Operative and Non-operative Cohorts

Patient Demographic and Surgical Details			
	Operative (Op)	Non-Operative (Nop)	p-value
Age	53.3	54.4	0.126
Gender (F)	77.2%	87.8%	<0.001
BMI	26.1	25.8	0.561
CCI	1.12	1.18	0.614
Frailty	0.22	0.22	0.864
Race	91.8% White	90.6% White	0.747
Anterior Only Approach	0.4%	-	-
Posterior Only Approach	68.1%	-	-
Combined Approach	31.5%	-	-
Staged Procedure prevalence	14.5%	-	-
Osteotomy prevalence	65.5%	-	-
Mean Operative time	363.9 min	-	-
Mean Estimated Blood Loss	1442.9ccs	-	-
Mean Length of Stay	7.24	-	-
Mean Anterior Levels fused	5.3	-	-
Mean Posterior Levels fused	10.6	-	-

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41. Frailty Phenotype Correlates with EQ5D and ODI Scores in Patients with Spinal Disorders

Shane Burch, MD, MS, FRCS(C); Sigurd H. Berven, MD

Summary

Frailty is a clinical syndrome that characterizes the risk or vulnerability of a patient to an adverse health outcome. There are two wide-spread approaches to measure frailty: the phenotypic model (PF) and the frailty index (FI). The FP model is characterized by unintentional weight loss, exhaustion, weakness, slow walking and low physical activity on a 5 point scale. FP correlates well with EQ5d and ODI scores indicating it may be an independent predictor of outcomes.

Hypothesis

Frailty phenotype is an independent predictor of outcomes.

Design

A retrospective review of a prospective cohort study

Introduction

HRQOL scores determine the effect and value of surgery. However, some patients have limited improvement. The frailty phenotype (FP) characterized by unintentional weight loss, exhaustion, weakness, slow walking and low physical activity measured on

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a 5 point scale, offers a method to stratify patients into low (robust), moderate (pre-frail) or high risk (frail). The purpose of the study is to determine the pre-operative ODI and EQ5D scores for robust, pre-frail and frail patients.

Methods

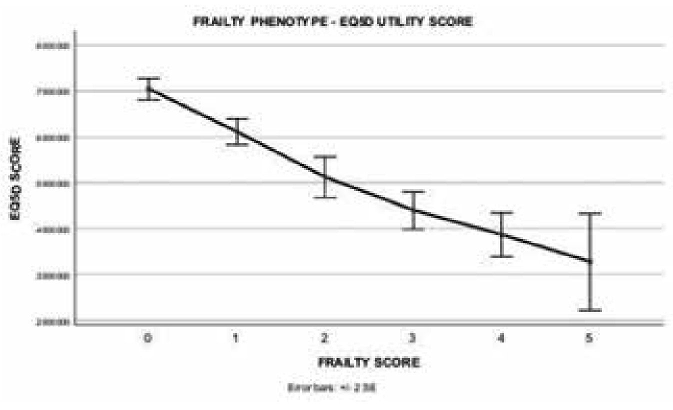
Retrospective review of a consecutive prospective pre-operative cohort of patients (n=737) assessed from 2014-2017. Using the scoring method of Woods et al 2005, robust, pre-frail and frail patients were identified. Mean EQ5D, SF 36 and ODI scores were compared between robust, pre-frail and frail groups. Statistical methods included ANOVA with post hoc analysis and Pearson bivariate correlation.

Results

Robust (n= 289), pre-frail (n= 270) and frail (n=178) patients were identified. Higher scores were seen for robust patients (EQ5D =0.704, ODI = 31) and pre-frail patients (EQ5D =0.511, ODI = 53) than frail patients (EQ5D =0.386, ODI = 60); p=<0.001. The Pearson correlation coefficient for FP and EQ5D = -.511 and ODI =.471; p=<.001.

Conclusion

The frailty phenotype correlates and stratifies patients HRQOL scores at baseline. Frail patients have a remarkably low HRQOL scores indicating the effect the FP domains have on a patient's health status compared to robust patients. This suggests that frail patients with a lower HRQOL score may not improve as much as a robust patient with a lower HRQOL score and it may be difficult to demonstrate cost effectiveness or value in frail patients vs robust patients.



42. Effects of Restoring Individualized Sagittal Shape and Alignment on Mechanical Complications and Patient-Reported Outcomes in Elderly Patients Fused To Pelvis

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Summary

120 patients of ≥60 years-of-age who were fused from lower thoracic to sacroiliac spine, experienced lower mechanical complication rates and had sustainable improvement in patient-reported outcomes (PROMs) in ≥2 year follow-up, when their sagittal plane restoration was performed according to the individualized sagittal plane shape and alignment.

Hypothesis

Restoration of the sagittal plane to individualized ideals results in less mechanical complications and better outcome.

Design

Retrospective analysis of a prospectively collected data of adult spinal deformity (ASD) pts.

Introduction

Sagittal plane has been associated with PROMs and mechanical complications in ASD patients. The aim was to compare mechanical complication rates and PROMs of elderly patients fused from lower thoracic to sacroiliac spine that reached different individualized sagittal shape and alignment.

Methods

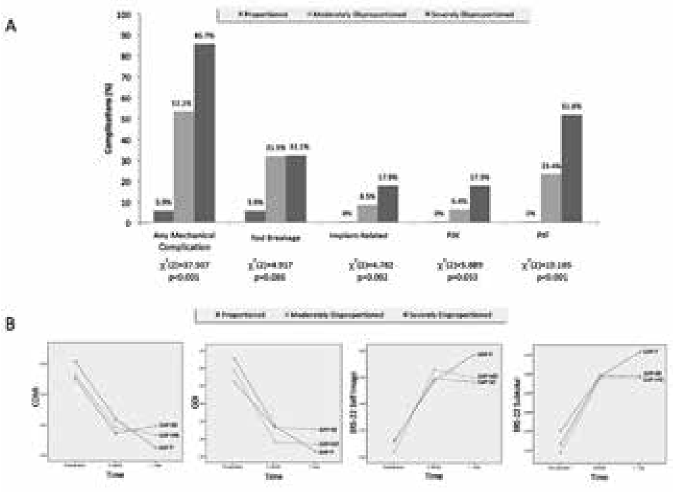
Inclusion criteria: ≥60yrs, ≥2y f/up, UIV to be between T8-L1, and LIV to be S1-S2 or ilium. Mechanical complications: PJK/PJF, rod breakage and implant-related complications. The Global Alignment and Proportion (GAP) score was used to postoperatively divide pts into 3 groups: Proportioned (GAP-P), Moderately Disproportioned (GAP-MD) and Severely Disproportioned (GAP-SD). Mechanical complication rates were compared using Chi-squared tests. Pearson's partial correlation and Two-Way Mixed ANCOVA was performed to determine the relationship between the change in the sagittal plane (assessed by pre- and post-op GAP score) and change in PROMs (pre-op, 6m and 1 yr).

Results

120 pts (100F, 20M) were included. Mean age:69.6±5.7 yrs. Mean f/up:30.8±5.7(24-62) months. Mechanical complication rates were 5.9% in GAP-P, 53.2% in GAP-MD and 85.7% in GAP–SD groups. Details are given in fig 1a. All groups had significant improvement in PROMs at 6 months regardless of the amount of correction in the sagittal plane (p>0.05), while PROMs at 1 year was associated with the GAP Score (r=0.332, p<0.01 for COMI, r=0.268, p<0.05 for ODI and r=-0.245, p<0.05 for SRS22-subtotal). The improvement in PROMs was significantly related to GAP categories (Fig 1b).

Conclusion

PROMs of all elderly patients fused to sacroiliac spine were improved in early follow-up regardless of their sagittal plane restoration. However; only GAP-P patients reported sustainable improvement, while GAP-MD and GAP–SD were stable or worsened. Mechanical complication rates were lower when sagittal plane was restored to the individualized ideal.



43. Ability of the Global Alignment and Proportion Score to Predict Mechanical Failure in ASD: Validation in 149 patients with Two-Years Follow-Up.

Tanvir Bari, MD; Soren Ohrt-Nissen, MD, PhD; Benny Dahl, MD, PhD; Martin Gehrchen, MD, PhD

Summary
In a study of patients with Adult Spinal Deformity (ASD) we found no association between Global Alignment and Proportion (GAP) score and the risk for revision surgery. The current cohort was different from the original study and based on retrospective data. We hypothesize that the predictive ability of the GAP score may be limited by surgical factors.

Hypothesis
The GAP-score can predict revision surgery due to mechanical failure.

Design
Retrospective longitudinal study

Introduction
Mechanical failure following surgery for ASD remains a frequent indication for revision. Recently, the GAP score was developed for predicting revision surgery due to mechanical failure based on overall sagittal and spinopelvic balance. The current study aimed to validate these findings.

Methods
All patients with ASD undergoing surgery with instrumentation of ≥4 levels over a three-year period with at least 2 years of follow-up were included. Revision surgery was defined as revision due to mechanical failure. Postoperative GAP score was calculated and further subcategorized into 3 groups according to the original score.

Results
A total of 149 patients were included. Mean age was 57.4 (±15.9), 105 were female (70.5%) and a mean number of 12 levels were instrumented (±3.5). Three-column osteotomy (3CO) was performed in 86 (58%) patients and 88 (59%) patients had been instrumented prior to the index procedure. A total of 74 (50%) patients had a mechanical failure and 52 (35%) underwent revision surgery. Mean postoperative GAP-score was 4.8 (range 0-12). Area under the curve (AUC) based on receiver operating characteristic plots showed no association between GAP score and revision (AUC = 0.49, CI = 0.39-0.59). Cochrane-Armitage test was without significant trend (chi-square = 1.16, p = 0.28) for the 3 categories. Multiple logistic regression showed no significant difference between GAP categories regarding risk of revision.

Conclusion
In the present cohort of high-risk patients, we found no association between GAP score and revision surgery due to implant failure. Compared to the original study, the current cohort consisted of patients with severe deformities and a higher rate of 3CO as well as rate of previous surgery, postoperative mechanical failure and revision surgery. Hence, the two populations are not fully comparable. We hypothesize that the predictive ability of the GAP score may be limited by surgical factors such as previous instrumentation and/or extent of osteotomies.

44. Comparison of a Lumbar GAP Score to PI-LL Mismatch to Predict Adjacent Segment Disease in the Degenerative Lumbar Spine

Dominique A. Rothenfluh, MD, PhD; Étienne Bourassa-Moreau, MD, FRCS(C), MSc; Ahmet Alanay, MD; Caglar Yilgor, MD

Summary
A lumbar GAP score (L-GAP), relative lumbar lordosis (RLL) and PI-LL are equally accurate in predicting revision surgery for adjacent segment disease after short lumbar fusions with no significant differences between their corresponding ROC areas. The risk is increased with L-GAP above 3 and RLL higher than -20º.

Hypothesis
Lumbar GAP score is equally accurate as PI-LL for prediction of revision surgery for adjacent segment disease.

Design
Retrospective case-control study

Introduction
A cut-off value of the difference between pelvic incidence and lumbar lordosis (PI-LL) of 10º has been suggested to increase the risk of revision surgery for adjacent segment disease (ASD) after short lumbar fusions. The concept of PI-LL as a measure of lumbo-sacral malalignment has come under scrutiny for sagittal deformities. The Global Alignment and Proportion (GAP) score has been shown to predict mechanical failure for long instrumentations more accurately than PI-LL combined with pelvic tilt (PT) and the C7 sagittal vertical axis (SVA). In the present study, we want to test whether a lumbar GAP score is accurate in predicting revision surgery and compare it to PI-LL.

Methods
Spinopelvic parameters (SPP) were measured and analysed in 84 patients: 45 with revision surgery for ASD and 39 controls with 5 year follow up. SPPs and GAP score without relative spinopelvic alignment (RSA) (L-GAP) were analysed using logistic regression. Tests of equality of ROC area under curve (AUC) were

performed with adjusted significance levels for multiple tests via Sidak's correction.

Results

The L-GAP score behaves similarly to PI-LL (ROC AUC 0.66 vs. 0.72, p=0.25). The relative lumbar lordosis (RLL) as a pelvic incidence-adjusted single parameter performs the same as L-GAP (RLL ROC AUC 0.67, p=0.53). Adjusting for pelvic incidence, L-GAP, PI-LL and RLL perform better in patients with low pelvic incidence, i.e. <1 standard deviation below the mean (<51º, AUC 0.74, 0.80, 0.80 respectively). L-GAP provides a predictive model at a cut-off value of >=3 (sens 0.44, spec 0.74) and RLL with a cut-off of -20.5º above which there is a higher risk (sens 0.44, spec 0.82 vs. PI-LL sens 0.71 spec. 0.81).

Conclusion

Both L-GAP and RLL accurately predict the risk for revision surgery for ASD similar to PI-LL although their sensitivity is lower in the given patient population.

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45. Results From an External Validation of the Global Alignment and Proportion Score (GAP): Can it Predict Proximal Junctional Kyphosis?

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Summary

The GAP score is a recently described radiographic assessment methodology reported to help predict, and potentially prevent, mechanical failures and PJK following ASD surgery. We applied the GAP methodology to our multicenter ASD database and found poor associations between GAP score and PJK at 6wk and 2yr follow up. The etiology of PJK following ASD surgery is likely multifactorial. Further research is needed to improve the predictive capacity GAP score integrating other variable beyond radiographic parameters and age.

Hypothesis

GAP scores correlate with PJK and revision surgery for PJK in ASD.

Design

Retrospective Review

Introduction

GAP score has been recently described as a novel patient-tailored tool that can predict mechanical failure, including PJK. This score is calculated based on morphological parameters and evaluates the harmony and proportionality of spinal alignment. While the application of this is promising, an external validation has not yet been performed.

Methods

Adult Spinal Deformity (ASD) pts undergoing >5 level fusion with LIV S1/Ilium were categorized based on the presence of PJK (Glattes criteria) at 2yrs or PJF (PJK revised w/i the 2yrs fu). The GAP score (Yilgor et al) was evaluated pre and post-operatively at 6wks & 2yrs and compared between groups (Non-PJK, PJK, PJF). GAP scores were categorized as proportional (GAP-P; scores 0-2), moderate disproportional (GAP-D; scores 3-6) or severe disproportional (GAP-SD; scores>7-13).

Results

350 out of 481 eligible (72%) pts were included (63 yo; 80%F). Pre-operatively the mean GAP score was 8.54±3.96, with 10.6%, 19.7%, and 69.7% of the pts categorized in GAP-P, GAP-D, and GAP-SD respectively. The GAP components revealed that 71.7% of the pts had moderate/severe retroversion, 56.7% hypolordosis, 56.7% severe truncal malalignment, and 64% were older than 60yo. (Table 1) At 6wks post-op, the GAP significantly decreased to 4.90±3.59 with 28.3%, 41.9%, and 29.7% of the pts categorized in GAP-P, GAP-D, and GAP-SD. At 2-yr fu the GAP was 5.53±3.7 with 23.5%, 34.7% and 39.1% in GAP-P, D and SD respectively. There was no significant difference in GAP score between non-PJK, PJK, and PJF pts at 6 wks (p=0.52) or at 2 yrs (p=0.09), and no difference in terms of GAP categories (p=0.73 & 0.14). Similar results were obtained when including pts who presented w/o PJK/PJF at 6wks and when combining PJK and PJF (all p>0.1).

Conclusion

The GAP score was not associated with PJK at 6wks or at 2yr fu during our validation testing on ASD pts. Other factors outside of alignment parameters likely play significant roles in PJK development that the GAP score does not take into account.

	Score	GAP-P	GAP-MD	GAP-SD	p
Pre-op	8.54 ± 3.95	37 (10.6%	69 (19.7%)	244 (69.1%)	<0.001
6wk Post-op	4.89 ± 3.59	100 (28.3%)	148 (41.9%)	105 (29.7%)	
no PJK (N=171)	4.69 ± 3.59	51 (29.8%)	71 (41.5%)	49 (28.7%)	
PJK (N=164)	5.12 ± 3.66	46 (28%)	67 (40.9%)	51 (31.1%)	*n.s*
PJF (N=18)	5.28 ± 3.21	3 (16.7%)	10 (55.6%)	5 (27.8%)	
No PJK (N=156)	4.77 ± 3.56	44 (28.2%)	67 (42.9%)	45 (28.8%)	*n.s*
PJK & PJF (N=71)	5.30 ± 3.76	19 (26.8%)	27 (38.0%)	25 (35.2%)	

GAP Score in relation to PJK at pre-op and 6wk post-op timepoints

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46. Preliminary Review of an ISSG AO Multi-Domain Spinal Deformity Complication Classification System

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Summary

Determining the impact of complications is difficult with the current major/minor classification. A system that accurately reflects the intervention severity, resolution of complication, without bias is needed. This study finds the rate of accurate reporting to vary based upon the information gathered. The more granular the data, and the more complex the complication the more difficult it is to capture accurately.

Hypothesis
Simple categories for the assessment of complications will improve our ability to classify and quantify the impact of complications.

Design
Case based survey for the identification and classification of complications

Introduction
The current classification system for post-op complications (minor or major) lacks granularity to predict outcome metrics and impact.

Methods
10 randomized cases were sent to participants, who were asked complete a standardized complications data collection form. There were 34 events: 25 with only 1 complication and 9 with ≥2 complications. 20 had neurological events. Intervention severity was: 5 no intervention, 13 mild intervention, 4 moderate intervention, and 4 severe intervention. Complete resolution in 18, partial resolution in 5, no resolution in 2 and one death.

Results
17 people filled out all questionnaires. Overall accuracy in capturing high level categories is 87.4% (i.e. neurologic, gastrointestinal, cardiac etc.) and 75.7% with more granular data (i.e. motor deficit, ileus, MI etc). Break down by type of complication demonstrated similar level of accuracy for medical and surgical complications (87.6% vs 87.1% for high level, 77.4% vs 74.3% for detail). Deeper analysis revealed that highest accurate rate is for CNS, wound and radiographic (> 96%), and lowest rate is for pulmonary, musculoskeletal, renal/implant. By subtype, highest accurate rate is for CVA, gastrointestinal and radiographic (> 94%), and lowest accurate rate is for renal (44.8%), pulmonary (54.5%) and cardiac (55%). Overall event accuracy (combination of complications) is 57.1%. Reporting on neurologic impairment per event was accurate for 79.1%. The intervention severity is 79.6% accurate, with the highest rate for severe intervention (98.6%). Resolution was accurately reported for 70.3% of the events.

Conclusion
Accurate reporting and gathering of complications is difficult to standardize. In this study, complex complications were categorized accurately 87%, neuro deficits accurately 79%, intervention accuracy of 80% and resolution accuracy of 70%. Surgeons need to be actively involved in complication reporting to enhance accuracy.

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47. Impact of Serious Adverse Events on Health-Related Quality of Life Measures Following Surgery for Adult Symptomatic Lumbar Scoliosis

Justin Smith, MD, PhD; Christopher Shaffrey, MD; Michael P. Kelly, MD, MS; Elizabeth Yanik, PhD, MS; Jon D. Lurie, MD; Charles Edwards, MD; Steven Glassman, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; Jacob Buchowski, MD, MS; Leah Yacat Carreon, MD, MS; Charles Crawford III, MD; Thomas Errico, MD; Stephen Lewis, MD, FRCS(C); Tyler Koski, MD; Stefan Parent, MD, PhD; Han Jo Kim, MD; Shay Bess, MD; Frank J. Schwab, MD; Keith Bridwell, MD; Christine Baldus, RN, MS

Summary
Operative treatment for adult symptomatic lumbar scoliosis (ASLS) can significantly improve health-related quality of life (HRQL), but the incidence of serious adverse events (SAEs) remains high. How these SAEs may impact HRQL outcomes remains unclear. This study demonstrates that patients affected by SAEs have significant negative impact on mean HRQL measures at 2- and 4-year follow-up compared with those not affected by SAEs. Regardless of SAE occurrence, operatively treated patients experienced significantly greater improvement in HRQL than nonoperative patients.

Hypothesis
SAEs associated with surgery for ASLS will negatively impact HRQL at 2- and 4-yr follow-up.

Design
Retrospective review of prospective multicenter cohort

Introduction
Surgery for ASLS can improve HRQL but has high rates of SAEs. The impact of SAEs on HRQL has not been well defined.

Methods
The ASLS study is a prospective multicenter study to assess operative versus nonoperative treatment for ASLS, with randomized and observational arms. Patients recruited were 40-80 yrs old with ASLS, defined as a lumbar coronal Cobb ≥30 degrees and ODI ≥20 or SRS-22 ≤4.0 in pain, function and/or self-image domains. SRS-22 and ODI scores were compared between operative patients with and without a related SAE and nonoperative patients using an as-treated analysis combining randomized and observational cohorts. Comparisons were adjusted for baseline demographics, HRQL scores and radiographic measures.

Results
286 patients were enrolled, and 2- and 4-yr follow-up rates were 90% and 81%, respectively. At 2 yrs the as-treated cohorts included 173 operative and 85 nonoperative patients and at 4 yrs included 129 operative and 78 nonoperative patients. Of 130 total related SAEs, the most common were implant failure/pseudarthrosis (n=26), pulmonary (n=19), neurological deficits (n=17), and proximal junctional failure (n=12). At 2 yrs patients with an SAE improved significantly less than those without an SAE based on SRS-22 (0.52 vs 0.79, p=0.004) and ODI (-11.59 vs -17.34, p=0.021). This finding was maintained at 4-yr follow-up for both SRS-22 (0.51 vs 0.86, p=0.001) and ODI (-10.73 vs -16.69, p=0.012; Figure). Despite this impact, the SAE and no SAE operative groups had SRS-22 and ODI improvements that were greater than those of nonoperative patients (p<0.001).

Conclusion
Operative treatment for ASLS can improve HRQL but has high rates of SAEs. Patients affected by SAEs had significantly less improvement of HRQL measures at 2- and 4-yr follow-up. Regardless of SAE occurrence, operatively treated patients had significantly greater improvement in HRQL than those treated nonoperatively.

Effect of Related Serious Adverse Events (SAEs) on Patient Outcomes Among Operative Patients in the Combined Randomized and Observational Cohorts As Treated

	2-Year				4-Year			
	Average change from baseline (SE)		Difference in Average Change (95% CI)	P value	Average change from baseline (SE)		Difference in Average Change (95% CI)	P value
	SAE	No SAE			SAE	No SAE		
SRS-22	0.52 (0.08)	0.79 (0.06)	-0.27 (-0.45, -0.09)	0.004	0.51 (0.08)	0.86 (0.07)	-0.36 (-0.57, -0.14)	0.001
ODI	-11.59 (2.07)	-17.34 (1.35)	5.76 (0.87, 10.64)	0.021	-10.73 (1.91)	-16.69 (1.39)	5.97 (1.30, 10.63)	0.012

ASLS=adult symptomatic lumbar scoliosis; R/T=related to; SE=standard error; SAE=serious adverse event; 95% CI=95% confidence interval; ODI=Oswestry Disability Index; SRS=Scoliosis Research Society

48. Topical Vancomycin Eliminates Staphylococcus epidermidis in Experimental Chronic Spinal Implant-Associated Infection†

Chenghao Zhang, PhD, MBBS, MS; Todd Milbrandt, MD; A. Noelle Larson, MD; Andre van Wijnen, PhD; Thomas Boyce, MD; Robin Patel, MD

Summary

Topical vancomycin powder eliminated implant-associated methicillin-resistant S. epidermidis (MRSE) spine infection in an experimental rat model. This work supports the use of topical antibiotics for treatment of biofilms and chronic implant-associated MRSE spine infection.

Hypothesis

Topical vancomycin powder is an effective treatment for established S. epidermidis biofilms using an experimental rat model of chronic implant-associated spine infection.

Design

Experimental rat model of chronic spine infection.

Introduction

Surgical spinal infections can have costly and devastating effects. They can be hard to treat; surgical debridement and resection are often necessary. Vancomycin powder has been used intraoperatively to prevent surgical spinal infections. We hypothesized that vancomycin powder would be an effective treatment for established S. epidermidis biofilms in vivo.

Methods

An infected spinal instrumentation model was developed in female ~250 gram Sprague Dawley rats. Rats were randomized to either no treatment or vancomycin powder. Biofilms were grown on 1.1 mm x 14 mm threaded stainless steel Kirschner wires (K-wire) in 1 ml tryptic soy broth containing 10^5 colony forming units (cfu) of S. epidermidis ATCC-35984 for 18 h at 37°C. Biofilm density on two K-wires were quantitated pre-implantation. A K-wire was implanted into the right side of L4 and L5, secured with a wire fastener and sprinkled with 1.4 mg vancomycin powder. After 8 weeks, the K-wire as well as surrounding bone tissue, soft tissue and wire fasteners were collected. Quantitative cultures were performed and mean log10 cfu/wire and log10 cfu/gram of tissue were reported. All cultures from the vancomycin-treated rats were screened for vancomycin resistance.

Results

The average biofilm density on the K-wire was 5.62 (SD ± 0.44) log10 cfu/wire at implantation. After 8 weeks, there was a significant reduction in bacterial load in rats treated with vancomycin compared to no treatment (Figure, p<0.05). All control rats had positive cultures from all specimens tested, whereas 15 of 16 vancomycin-treated rats had no detectable bacteria in any culture. There was no development of vancomycin resistance.

Conclusion

Topical application of vancomycin powder eradicated MRSE in an experimental rat model of implant-associated spine infection.

49. A Novel Axial MRI Classification of Spinal Cord Shape and CSF Presence at the Curve Apex to Assess Risk of Intraoperative Neuromonitoring Data Loss With Thoracic Spinal Deformity Correction†

J. Alex Sielatycki, MD; Meghan Cerpa, BS, MPH; Martin Pham, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary

A simple MRI-based classification system describing the axial spinal cord shape and surrounding CSF at the thoracic apex is able to identify patients at risk of losing neuromonitoring data during spinal deformity correction. Remarkably, patients with Type 3 spinal cords (spinal cord deformed against the apical concave pedicle) have 28 times greater odds of losing data during surgery vs. Type 1 (Normal cord and CSF) and Type 2 (Normal cord but absent CSF against apical concave pedicle).

Hypothesis

The architecture of the spinal cord and amount of CSF at the thoracic apex can identify patients at risk for intraoperative loss of neuromonitoring data during spinal deformity correction.

Design

Review of a consecutive series of thoracic deformity patients undergoing surgical correction at a single academic center.

Introduction

Here we propose a classification system to identify spinal cords at risk for data loss with thoracic deformity correction based on the preop axial MRI images at the curve apex.

Methods

We reviewed 128 consecutive patients undergoing surgical correction of a thoracic deformity with pedicle screw/rod constructs. On preop MRI axial imaging at the apical concavity, 3 types of spinal cord/CSF architecture were defined. Type 1: circular cord with visible CSF between the cord and the apical concave pedicle. Type 2: circular cord but no visible CSF between it and the concave pedicle. Type 3: cord deformed against the apical concave pedicle, with no intervening CSF (Figure 1).

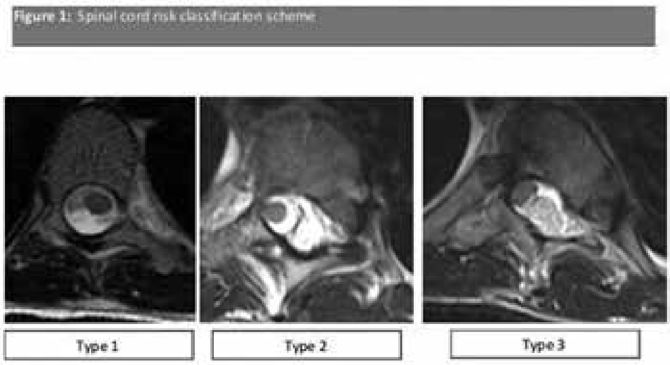
Results

Of the 128 pts: 81(63%) had Type 1; 32 (25%) Type 2; and 12 (11.7%) Type 3 spinal cords. Lower extremity trans-cranial motor-evoked potentials (TcMEPs) and/or somatosensory evoked potentials (SSEPs) were lost intraoperatively in 21 (16%) cases, with full recovery of data in 20 of those. On regression analysis, a Type 1 spinal cord was protective against intra-operative data loss (Odds ratio = 0.17, p=0.0003). A Type 2 spinal cord had no association with data loss (OR = 0.66, p=0.49). Type 3 spinal cord had significantly higher odds of intraoperative data loss (OR = 28.3, p<0.0001). Performing a vertebral column resection (VCR) was not itself associated with loss of spinal cord data (17 cases, 94% with Type 2 or 3 spinal cords).

Podium Presentation Abstracts

Conclusion

This MRI-based spinal cord risk classification scheme identifies patients at risk of losing monitoring data during surgery. Patients with the spinal cord deformed against the apical concave pedicle (Type 3) have 28 times greater odds of losing monitoring data during surgery vs. normal cord/CSF morphology (Type 1 and Type 2).



50. NF-κB Inhibitor Reduces the Inflammatory Response and Improves Bone Formation in rhBMP-2-Mediated Spine Fusion†

Juliane Glaeser, PhD; Phillip Behrens, MD; Khosrowdad Salehi, BS; Linda Kanim, MA; Dmitriy Sheyn, PhD; Zachary NaPier, MD; Jason Cuellar, MD, PhD; Hyun Bae, MD

Summary

Loading of absorbable collagen sponges (ACS) with recombinant human bone morphogenic protein-2 (rhBMP-2) has been successfully used to enhance bone formation and induce spinal fusion. However, there is also an increase in soft-tissue edema and inflammation. NEMO binding domain peptide (NBD) stimulates bone formation, reduces the inflammatory response, diminishes nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) binding, and blocks transcription of NF-κB-regulated cytokines in response to high-dose rhBMP-2 in rats.

Hypothesis

NBD reduces rhBMP-2-induced soft-tissue inflammation and stimulates spinal fusion

Design

Prospective, randomized, in vivo study

Introduction

ACS with rhBMP-2 has been shown to enhance bone formation and induce spinal fusion. However, side effects, such as soft-tissue edema and inflammation, have been reported. NBD inhibits activation of NF-κB, a central regulator of immune response.

Methods

To evaluate inflammation, ACS with either high dose rhBMP-2, rhBMP-2+NBD, NBD only or buffer only were implanted into intramuscular fusion beds of 32 rats. To analyze new bone formation in the presence of NBD, ACS was loaded with rhBMP-2 or rhBMP=2+NBD and implanted during posterolateral intertransverse lumbar fusion in 16 rats and analyzed by manual palpation, μCT and bone histology. Edema formation at the implant sites was assessed using MRI T2-weighted relaxation time (T2-RT). Cellular activity was measured by histological analysis of the implant-surrounding zones. NF-κB binding and gene expression of inflammatory markers, interleukin(IL)1β, IL6, IL18, chemokine ligand(CCL)2 and CCL3 were analyzed in the implants.

Results

T2-RT values were increased in the BMP-2 group compared to BMP-2+NBD, NBD and ACS groups. No difference was detected between BMP-2+NBD versus NBD and ACS controls. Histological analysisof the implant-surrounding zones showed an increase in cellular activity in the BMP-2 group compared to BMP-2+NBD and controls. Presence of rhBMP-2 increased relative NF-κB binding and gene expression of inflammatory markers, IL1β, IL6, IL18, CCL2 and CCL3 compared to controls. In the BMP-2+NBD group, cytokine expression was blocked. No differences were found between BMP-2+NBD and control groups. BMP-2+NBD resulted in a higher bone volume and reduced trabecular spacing compared to BMP-2, a higher number of levels fused, and similar structural properties of the bone tissue.

Conclusion

NEMO binding domain peptide (NBD) stimulates bone formation, reduces soft-tissue edema formation, reduces recruitment of inflammatory cells, diminishes NF-κB binding, and blocks transcription of NF-κB-regulated cytokines in response to rhBMP-2 in rats.

51. POC5 and Cilia Anomalies in Adolescent Idiopathic Scoliosis†

Amani Hassan, PhD; Stefan Parent, MD, PhD; Sirinart Molidperee; Soraya Barchi, BS; Kessen Patten, PhD; Florina Moldovan, MD, PhD

Summary

We investigated the role of Centriolar protein POC5 in human cells and zebrafish model of scoliosis. We found that Genetic mutation of POC5 gene (c. C1286T; p. A429V) causes disruption of POC5 with several ciliary proteins, contributes to the primary cilia anomalies, and affects photoreceptor structural integrity of the outer segment. We suggest a visuo-spatial impairment and phenotypic overlap between the AIS, ciliopathies and other syndromes developing spinal abnormalities such as progressive curving of the spine deformities.

Hypothesis

Our hypothesis is that a panel of genes can induce AIS by producing defective proteins of the primary cilia and centrosome

Design

The potential pathogenic effect of mutated POC5 was investigated in vitro (cellular model, and human cells) and in vivo (in a zebrafish animal model).

Introduction

Recently, several genes were suspected to contribute to AIS. Our group identified gene variants of POC5 centriolar protein in French and French-Canadian families with multiple members affected with AIS. We sought to expand on this study and to investigate for the role of POC5 gene and mutated protein.

Methods
We examined subcellular localization of POC5 with respect to cilia in cells overexpressing wild type (wt) or POC5 variants (C1286T, A429V) and in osteoblasts from scoliotic patients carrying POC5 variants and normal control cells. We also created a loss-of-function model in zebrafish. The role of POC5 was investigated by: 1) mass spectroscopy analysis and co-immunoprecipitation 2) immunolocalization of POC5 at the cellular level; 3) histology and immunohistochemistry performed on tissues from wt (control) and scoliotic (poc5 mut) zebrafish.

Results
Several ciliary proteins were identified to be interacting partners of wt POC5 but not mut POC5. At the cellular level, co-localisation of wt POC5 and mut POC5 protein with alpha acetylated tubulin, confirmed the consequence of the mutation on subcellular location with respect to cilium structure, length and staining intensity of cilia. We showed that loss of POC5 connection with acetylated-α-tubulin impaired cell-cycle progression and induced ciliary retraction in osteoblasts from scoliotic patients carrying POC5 variant (c. C1286T; p. A429V). Finally, using different markers for retinal layers such as Zinc Finger protein 1 and 3, neurofilament-associated antigen 3A10 and acetylated tubulin, we found anomalies in photoreceptor layer in the mutpoc5 zebrafish consisting in reduced staining intensity, cell number, layer thickness and cellular organization.

Conclusion
This study strengthens the role of POC5 gene in AIS pathogenesis and opens new avenues for the understanding the primary causes of AIS at the molecular and physiological levels.

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52. Increased Radiation But No Benefits In Pedicle Screw Accuracy Using Intraoperative CT-Based Navigation Compared To Freehand Technique In Idiopathic Scoliosis Surgery*

Wiktor Urbanski, MD, PhD

Summary
In 49 patients who underwent surgery for moderate idiopathic scoliosis (IS), we analysed accuracy of pedicle screws (PS) placement and radiation received by patients. We compared two methods of PS introduction; intraoperative 3D-image based navigation and freehand technique. We found no differences in accuracy between freehand and navigated groups in proportion of properly positioned screws, but the patients experienced greater exposure to radiation. Hence, cautious selection of method is essential to balance surgical safety and adverse effects of increased radiation.

Hypothesis
To compare accuracy of two methods of PS placement; intraoperative 3D image based navigation vs freehand technique in patients with IS, and to evaluate the radiation received by patients in both methods

Design
clinical study level III

Introduction
Pedicle screws (PS) are crucial in surgical treatment of spinal deformities, but inappropriately placed may result in complications. Navigation systems based on intraoperative 3D imaging were developed to limit PS misplacements. However, there is a lack of data confirming superiority of navigation above other techniques and there are concerns regarding increased radiation required during procedure.

Methods
835 PSs inserted by two surgeons in 49 patients who underwent posterior spinal fusion with all PS constructs for idiopathic scoliosis (IS) were included into the study. Study design involved alternating the use of the freehand technique and o-arm based navigation to position PSs in consecutive patients resulting in two groups; 451 PSs navigated and 384 freehand. Two observers not involved in the treatment evaluated the position of the screws. The pedicle breach was assessed on CT according to grading system: grade 0 no pedicle wall violation, grade 1 perforation ≤2mm, grade 2 - 2-4mm, grade 3 perforation of >4 mm. Grades 0 and 1 were considered as a properly positioned, grades 2 and 3 represented malposition. The radiation doses from o-arm and c-arm used throughout the procedure were collected.

Results
We found no differences in accuracy between the freehand and navigated PSs - 96.8% freehand and 95.8% in the navigation group of properly positioned (p=0.518). Grade 3 PSs were observed only in the freehand group and were all located in the upper thoracic spine. Patients undergoing navigated PS placement received a greater mean radiation dose than those whose screws were placed freehand (1070.5mGycm vs 390.5mGycm, p<0.001).

Conclusion
We did not observe benefits of PS placement with CT-based navigation in patients with moderate IS undergoing primary surgery, but the patients experienced significantly greater exposure to radiation.

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53. The Use of Tranexamic Acid in Adult Spinal Deformity: Is There an Optimal Dosing Strategy?*

Tina Raman, MD; Peter Zhou, BS; Dennis Vasquez-Montes, MS; John Moon, BS; Aaron Buckland, MBBS, FRACS; Thomas Errico, MD

Summary
Adult spinal deformity surgery can entail complex realignment procedures, and significant blood loss. We looked at effects of tranexamic acid dosing in 230 patients, and found that a loading dose of 50 mg/kg followed by 5 mg/kg/hr infusion demonstrated significantly less EBL and percent blood volume (BV) lost. Regimens of 20 mg/kg followed by 2 mg/kg/hr, and 10 mg/kg followed by 1 mg/kg/hr, were associated with greater EBL, percent BV lost, and need for RBC transfusion than higher dose regimens.

Hypothesis
There is no effect of different loading and infusion dosage regimens of TXA on estimated blood loss (EBL), percent blood volume (BV) lost, red blood cell (RBC) transfusion, or rate of TXA related complications.

Design
Retrospective review of prospectively collected database.

Introduction
It is well known that ASD surgery may be associated with extensive blood loss and subsequent risks of end organ ischemia and mortality. We sought to compare the effects of different dosing regimens of TXA on EBL, percent blood volume (BV) lost, RBC transfusion, and TXA related complication

Methods
We assessed a single center multi-surgeon database of 230 patients who received TXA at the time of ASD surgery. Dosing regimens assessed will be abbreviated by loading dose in mg/kg followed by infusion rate in mg/kg/hr: 10/1 (n=128), 20/2 (n=40), 50/5 (n=15), 30/10 (n=15), and 40/1 (n=14). EBL, percent BV lost, RBC transfusions, and perioperative hemoglobin levels were assessed.

Results
230 patients (Age: 52 ± 19y; 172 F, 58 M; BMI: 26 ± 6, ASA: 2.3 ± 0.6, Levels fused: 11.7 ± 3.9) were included in the analysis. There was no significant difference in characteristics between patients in each dosing regimen group (p>0.05). 50/5 (23.3 ± 11.5%) and 40/1 (32.9 ± 19.1%) were associated with a significantly lower percent BV lost than 20/2 (58.9 ± 32.2%) (p<0.001). 50/5 was associated with significantly lower EBL (1093 ± 612 mL) compared with 20/2 (2531 ± 1332 mL) (p=0.005), but was not significantly different from 30/10 and 40/1. By multivariate regression, 10/1 was associated with an additional 10.7% BV lost (p=0.038) and 678 additional mL of EBL (p=0.035), and 20/2 was associated with an additional 26.2% of BV lost (p<0.0001), 1058 additional mL of EBL (p=0.004), and an additional 1.8 ± 0.6 U of RBCs transfused intraoperatively (p=0.003) compared with the higher dose regimens. There were no significant differences in rate of any complications between the different regimens of TXA.

Conclusion
Dosing regimens of 10 mg/kg and infusion rate of 1 mg/kg/hr, and 20 mg/kg and infusion rate of 2 mg/kg/hr were associated with greater EBL and percent BV lost compared with higher dose regimens of TXA.

54. Unfulfilled Expectations after Surgery for Adult Lumbar Scoliosis Compared to Other Degenerative Conditions*

Carol Mancuso, MD; Roland Duculan, MD; Frank Cammisa Jr, MD; Andrew Sama, MD; Alexander Hughes, MD; Federico Girardi, MD

Summary
Adult lumbar scoliosis patients requiring surgery at more levels are more likely to have unfulfilled expectations 2 years postop compared to age-matched patients with other degenerative conditions also having surgery at more levels. Possible explanations include more unrealistic expectations with more extensive scoliosis, greater likelihood of emergence of new postop symptoms from adjacent levels, and progression of the underlying disease process. Our findings support tailored preop education and counseling about likely outcomes for scoliosis patients.

Hypothesis
Fulfillment of expectations varies based on diagnosis and number of levels.

Design
Sub-analysis, 2-year cohort study

Introduction
We compared the proportion of expectations fulfilled based on vertebrae involved between adult scoliosis patients versus age-matched controls having surgery for other degenerative conditions.

Methods
Before surgery patients completed the valid 20-item HSS Lumbar Spine Surgery Expectations Survey asking how much improvement they expected for symptoms, function, and mental well-being. Scores range from 0 (least) to 100 (most) expectations. Two-years after surgery patients were asked how much improvement was actually received for each item; fulfillment is defined as a proportion (i.e. received improvement divided by expected improvement) and ranges from 0 (none fulfilled) to 1 (completely fulfilled). 42 patients with scoliosis were age-matched to 134 patients with other degenerative conditions (stenosis, spondylolisthesis, disc disease).

Results
Patients with scoliosis (mean lumbar Cobb angle 27; range 6-68) vs degenerative conditions did not differ by mean age (66 vs 64), or Expectation Survey score (72 vs 70)(p>.05), but were more likely to have surgery on ≥3 levels (64% vs 43%, p=.03). When stratified by number of levels (<3 or ≥3) scoliosis patients differed in proportion of expectations fulfilled (.81 vs .45, p=.01; OR 5.5, CI 1.7-18.2, p=.005), but patients with other conditions when stratified by number of levels (<3 or ≥3) did not differ in proportion of expectations fulfilled (.71 vs .62, p=.16; OR 1.5, CI .9-2.8, p=.15). The proportion was less for the 10 scoliosis patients whose surgery extended to the thoracic spine (.49 vs .63). Among all scoliosis patients the expectations more likely to be unfilled were improve balance, exercise, mobility, emotional well-being, stop condition from worsening, and remove the control the spine has on my life (p<.05) for all comparisons.

Conclusion
Adult lumbar scoliosis patients requiring surgery at more levels are more likely to have unfulfilled expectations 2 years postop compared to age-matched patients with other degenerative conditions also having surgery at more levels.

55. A High Degree of Variability Exists in How "Safety and Efficacy" is Defined and Reported in Growing Rod Surgery for Early-Onset Scoliosis: A Systematic Review*

Pooria Hosseini, MD; Areian Eghbali; Jeff Pawelek, BS; Karen Heskett, MSI; Gregory Mundis, MD; Behrooz Akbarnia, MD

Summary
Established criteria for reporting safety and efficacy have not yet been defined in growing rod surgery for early-onset scoliosis. A systematic literature review revealed a high degree of variability in how authors stratified complications and patient outcomes as a means to define safety and efficacy for this challenging patient population.

Hypothesis
There is no consensus on the minimum requirements for reporting safety and efficacy in growing rod surgery for EOS.

Design
Systematic literature review.

Introduction
Several publications have reported the safety and efficacy of traditional growing rods (TGR) and magnetically controlled growing rods (MCGR) for the treatment of early-onset scoliosis (EOS). Radiographic parameters are used to measure efficacy, while incidence and type of complications are used to assess safety. A systematic review of peer-reviewed articles was performed to identify whether consensus exists in how safety and efficacy are reported.

Methods
Four databases were searched to identify all qualified peer-reviewed articles on TGR and MCGR. Key word searches are in Table 1. All peer-reviewed articles in English that reported any data related to safety or efficacy were included. Articles that met the inclusion criteria were scored by modified Downs and Black scoring system for non-randomized studies.

Results
111 unique citations were identified including: PubMed 50, Embase 68 (21 duplicates), Web of Science 29 (15 duplicates), and CINAHL 15 (all duplicates). 56/111 citations were excluded during abstract review and 16 were excluded during full manuscript review. The remaining 39 articles included 23 TGR (2007-2016) and 16 MCGR papers (2012-2016). The overall score of TGR papers was 63.9 vs. 64.0 for MCGR papers, p>0.05. Efficacy measures were not consistently reported among the publications. The only consistently reported efficacy parameter the in majority (>90%) of papers was curve size. Complication reporting was highly variable.

Conclusion
Curve size was the only consistent parameter to report efficacy in TGR and MCGR publications. Complications were not consistently reported, thus assessing safety of either treatment was infeasible. Establishing standardized safety and efficacy parameters for growing rod surgery would improve the quality of future studies and allow meaningful comparisons of different treatment modalities possible.

Table 1.

Key word search: adverse effects, complications, risk, treatment outcome, safety, efficacy, effectiveness, magnetically controlled growing rod, MCGR, traditional growing rod, conventional growing rod, TGR, CGR, growing spinal implant, growing rod implant, growing rod surgery, magnetic expansion control rod, magnetic driven growing rod, MAGEC, and early onset scoliosis.			
Modified Downs and Black Scoring			
	TGR	**MCGR**	**P**
Reporting Score (%)	86.4 ± 13.5 (50-100)	85.1 ± 12.2 (62.5 – 100)	> 0.05
External Validity (%)	75.5 ± 17.9 (33-100)	75.4 ± 14.7 (67 - 100)	> 0.05
Internal Validity (%)	39.2 ± 8.0 (22-55)	41.2 ± 4.9 (33-44)	> 0.05
Overall Score (%)	63.9 ± 6.9 (50-75)	64.0 ± 6.3 (50-75)	> 0.05
Demographics			
	TGR	**MCGR**	**P**
Sample size	45.0 ± 62.2 (5-327)	15.1 ± 9.4 (1-34)	< 0.05
Mean age (years)	6.5 ± 0.8 (5.1-8.7)	8.0 ± 1.7 (4.5-12)	< 0.05
Follow up (years)	4.6 ± 1.3 (2.3-7.2)	1.8 ± 0.6 (0.2-2.5)	< 0.05
Country (most publications)	USA (12/23, 52%)	UK (6/16, 37.5%)	
Control group	4/23 (17.3%)	2/16 (12.5%)	
Study design (Most popular)	Retrospective 21/23 (91%)	Retrospective 8/16 (50%)	
Level of evidence (Most popular)	Level III 17/23 (74%)	Level III 9/16 (56%)	
Efficacy measures			
	TGR	**MCGR**	**P**
T1-T12 height (Number of papers reported)	3/23 (13%)	9/16 (56%)	> 0.05
T1-S1 height (Number of papers reported	10/23 (43%)	11/16 (69%)	< 0.05
Curve Size (Number of papers reported)	21/23 (91%)	15/16 (94%)	< 0.05
Kyphosis (Number of papers reported)	10/23 (43%)	8/16 (50%)	< 0.05

56. A Prospective, Multicenter Analysis of the Efficacy of Anterior Vertebral Body Tethering (AVBT) in the Treatment of Idiopathic Scoliosisis*

Firoz Miyanji, MD, FRCS(C); Jeff Pawelek, BS; Luigi Nasto, MD, PhD; Stefan Parent, MD, PhD

Summary
Spinal fusion remains the gold standard surgical treatment for progressive IS, however concerns about the long-term effect of spinal fusion have led to the development of growth-modulation techniques.We present minimum 2-year results in a prospective cohort of 28 consecutive patients treated with AVBT at 2 independent centers and found the technique effective in preventing curve progression and obtaining curve correction with most curves reaching a clinical success of ≤30°.

Hypothesis
Anterior vertebral body tethering (AVBT) is limited in effectively preventing curve progression and maintaining curve correction to ≤30° at 2 yr f/u.

Design
Prospective observational cohort

Introduction
AVBT has sparked interest as a possible alternative in the management of progressive idiopathic scoliosis (IS).To date limited available data exists regarding the efficacy and complication rate with AVBT.The aim of our study was to evaluate the clinical,

radiographic and perioperative outcomes and complication rates to determine the efficacy of AVBT in skeletally immature IS patients.

Methods
A retrospective review of all consecutive patients treated with AVBT at 2 centers with minimum 2 year f/u was conducted using a prospective multicenter database.Clinical success was set a priori as major coronal curve size ≤30° at most recent f/u.

Results
28 patients with 33 procedures were analyzed. Mean age at surgery was 12.7 (9.7-16.8) years with majority female (89%) and mean f/u of 28 (24-40) months. Mean pre-op major curve of 54°(35°-81°) degrees improved to mean 34°(5°-63°) at first erect x-ray with further correction to a mean 29°(4-46°) at 2 yr f/u(46%, p<0.01). Significant spontaneous curve correction was also observed in the un-instrumented curves on average by 28% (p<0.01) at 2 year f/u. Average number of instrumented levels was 6.2(5-8) with a mean OR time of 214(138-505) min.Average EBL was 253(50-650) cc with no patient requiring allogeneic blood.Length of hospital stay was mean 5.0(3.0-8.0) days.Clinical success was noted in 57% of patients at most recent f/u.There were 10 complications in 28 patients (36%) with 2 (7%) requiring conversion to fusion due to curve progression and 3 (11%) requiring revision due to adding on,overcorrection and tether breakage.

Conclusion
AVBT is effective in obtaining clinical success in skeletally immature IS patients with minimum 2 yr f/u.Although a reoperation rate of 18% demonstrates further need to refine indications and technique,the 2 yr major curve correction results are promising. Longer-term follow-up is needed to determine the true clinical benefits of this technique.

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57. 10-Year Natural History of the Uninstrumented Compensatory Curve in Selectively Fused AIS*

Burt Yaszay, MD; Madeline Cross, MPH; Carrie E. Bartley, MA; Tracey P. Bastrom, MA; Suken Shah, MD; Baron Lonner, MD; Patrick Cahill, MD; Amer F. Samdani, MD; Vidyadhar Upasani, MD; Peter Newton, MD

Summary
The current study found that at 10 years post-op, the compensatory curve's spontaneous correction was maintained in both primary thoracic and primary thoracolumabar curves, with some improvement of coronal balance seen in the thoracolumbar curves.

Hypothesis
In selectively fused adolescent idiopathic scoliosis (AIS) curves, coronal and sagittal plane correction will be maintained 10 years after surgery.

Design
Retrospective review of prospectively collected data.

Introduction
The purpose of this study was to analyze the 10 year natural history of uninstrumented compensatory curves in patients with selectively fused thoracic and thoracolumbar curves.

Methods
AIS patients with a Lenke C lumbar modifier who were fused selectively were included. For primary thoracic (TH) curves, a lowest instrumented vertebra (LIV) of L1 or cephalad was required. For primary thoracolumbar/lumbar (TL/L) curves, an upper instrumented vertebra (UIV) of T9 or caudal was required. All patients with pre-operative, first post-op (FE), mid-range (2-5 year) post-op, and 10 year post-op visits were included in the analysis. Repeated measures were utilized to analyze outcomes over the 10 year post-operative period.

Results
Fifty-one patients met inclusion—21 had a main TH curve (48% posterior fusions, mean age 14+2yrs); 30 had a main TL/L/lumbar curve (10% posterior fusions, mean age 15+1yrs). In the instrumented curves, there was a slight loss of correction (~4°) from FE to mid-range f/u in the main TH group (p=0.004, Table); no changes were observed in the TL/L group (p=0.9). Both groups maintained the spontaneous correction of the uninstrumented curves over time, with improvements seen from FE to 10yrs (p≤0.02). Approximately 10% of patients in each group had progression (>5°) of the main curve at 10yrs post-op. Post-op, there were no significant changes in coronal balance; however from PRE to 10yrs, the TL/L group showed significant improvement (p=0.04). In both groups, kyphosis was maintained throughout the post-op period and lordosis was initially reduced at FE, but regained similar PRE values by mid-term f/u. Neither group demonstrated significant changes in SRS scores over time (p>0.1).

Conclusion
In selectively fused thoracic and thoracolumbar curves, the uninstrumented curve adjusted to match the Cobb of the fused segments resulting in a balanced spine at 10 year post-op. Only 10% of patients demonstrated any significant progression during this time.

Table: Average radiographic values for both groups at pre-op and post-operative time points

Primary Thoracic Curves	Pre	FE	Mid	10yr
Primary Cobb (°)	52	23	27	25
Primary Cobb % correction		55%	48%	51%
Compensatory Cobb (°)	44	30	26	25
Compensatory Cobb % correction		32%	40%	43%
Coronal C7 to CSVL (cm)	-2.1	-2.0	-1.2	-1.3
Lateral T5-T12 (°)	22	24	28	27
Estimated 3D T5-T12 (°)	7	25	26	26
Lordosis (Top of 12 - Top of Sacrum) (°)	66	55	65	68
Primary Thoracolumbar/lumbar curves	**Pre**	**FE**	**Mid**	**10yr**
Primary Cobb (°)	45	16	16	17
Primary Cobb % correction		64%	64%	60%
Compensatory Cobb (°)	25	20	18	16
Compensatory Cobb % correction		21%	30%	34%
Coronal C7 to CSVL (cm)	-1.7	-1.2	-0.4	-0.3
Lateral T5-T12 (°)	30	29	30.	31
Estimated 3D T5-T12 (°)	29	31	33	34
Lordosis (Top of 12 - Top of Sacrum) (°)	59	50	58	61

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58. Can TGR Change the Natural History of Pulmonary Functions in EOS? Is Radiological Straightness Correlated with Normal Lung Development?*

Ebru Celebioglu, MD; Alper Yataganbaba, MD; Asli Oncel, MD; Ceren Degirmenci, MD; Senol Bekmez, MD; Fatih Tekin, MD; Gokhan Demirkiran, MD; Elmas Ebru Yalcin, MD; Ahmet Demir, MD; Muharrem Yazici, MD

Summary

Even though traditional growing rod (TGR) graduates score lower in exercise tolerance and spirometry compared to age-matched controls, their pulmonary functions are similar to those of instrumented adolescent idiopathic scoliosis (AIS) patients.

Hypothesis

TGR negates the detrimental effects of early-onset scoliosis (EOS) on pulmonary development.

Design

Cross-sectional comparative study.

Introduction

Despite a long and tedious process, TGR is able to control EOS deformities. There are no studies evaluating pulmonary functions with sophisticated tests and comparing them to healthy adolescents and postoperative AIS patients. In this study, we aimed to compare exercise tolerance and oxygen consumption capacity of otherwise healthy TGR graduates with those of age-matched controls and post-surgical AIS patients.

Methods

Group 1 consisted of 8 TGR graduates without neurologic or systemic comorbidities; group 2 of 9 similarly aged thoracic AIS patients at least 1 year out from instrumentation, and group 3 of 10 individuals without musculoskeletal disorders. Other than radiological studies, subjects underwent cardiopulmonary exercise testing (CPET) and spirometry.

Results

There were no statistically significant differences regarding height, weight and residual deformity between TGR and AIS patients. Pulmonary data is summarized in Table. None of the studied parameters were different between AIS and GR patients; however, both groups' results were significantly different from healthy controls.

Conclusion

AIS and TGR patients have reduced pulmonary reserve compared to healthy counterparts. Final pulmonary reserve of TGR patients is similar to AIS patients. Despite a long and tedious process often wrought with complications, the TGR can help EOS patients, who would otherwise be doomed to serious pulmonary insufficiency, achieve pulmonary capacities compatible with a healthy life. From a pulmonary perspective, TGR transforms EOS into AIS.

	Control	GR	AIS	p overall	p GR/C	p AIS/C	p GR/AIS
Weight	63.1	49.12	49	0.001	0.005	0.003	1.000
Height	173.60	153.12	155.11	0,000	0.000	0.002	1.000
Cobb	NA	43.87	23.3	0.000	–	–	0.603
$VO2_{MAX}$	30.91 (29.3-33.6)	22.2 (17.5-29.5)	23.7 (19.8-26.9)	0.016	0.033	0.055	1.000
$VO2_{LT}$	12.8 (10.1-16.2)	14.0 (11.7-14.9)	14.8 (13.7-16.1)	0.418	-	-	-
BRI_{MAX}	0.39 (0.34-0.45)	0.44 (0.39-0.48)	0.44 (0.37-0.50)	0.284	-	-	-
BRI_{LT}	0.14 (0.10-0.16)	0.25 (0.21-0.28)	0.25 (0.17-0.31)	0.002	0.001	0.002	0.916
FEV1%	100.8 (96-108.5)	69.3 (58.75-78.75)	84.8 (73.5-93.25)	0.001	0.001	0.178	0.296
FVC%	97 (93.75-106.75)	68.6 (62-78)	86.5 (72-93.5)	0.002	0.001	0.306	0.179
FEV1/FVC %	89.9 (86.1-92.8)	93.3 (86.3-94.9)	90.8 (87.3-96.8)	0.605	-	-	-

BRI: Breathing Reserve Index FEV1: Forced Expiratory Volume in One Second FVC: Forced Vital Capacity LT: Lactate Threshold MAX: maximum GR: Growing Rod AIS: adolescent idiopathic Scoliosis

59. Distal Fusion Level Determines the Prevalence of Back Pain and Risk of Cesarean Section in Pregnant Women Who Have Had Scoliosis Surgery*

Suken Shah, MD; Pawel Grabala, MD

Summary

Women who underwent scoliosis surgery, became pregnant and delivered (SPG) were compared to healthy women, without AIS who became pregnant and parous (HPG). SPG women more commonly had back pain during pregnancy (48% vs 34%, $p<0.05$) and underwent Cesarean section (CS) (64% vs 33%, $p<0.05$). Most (55%) of the SPG women who had a CS were fused to L4. As the lowest instrumented vertebra (LIV) moved caudal (L1, L2, L3, L4), the frequency of CS increased ($p<0.05$, $R=0.8$).

Hypothesis

AIS treatment with PSF will not increase back pain or Cesarean section rate in scoliosis patients who become pregnant

Design

Retrospective controlled cohort study of patients who underwent scoliosis surgery from 1998-2015

Introduction

Female patients and their families frequently ask about long-term outcomes after scoliosis surgery (SS) and a major focus is pregnancy and childbirth. We are not equipped to these questions due to insufficient, anecdotal evidence.

Methods

Women with the following inclusion criteria were recruited from four centers after IRB approval: age 16 – 40 years, females who had surgical management of AIS and became pregnant (SPG); and, healthy women, without AIS, who became pregnant and parous, selected at random (HPG). Exclusion criteria were the following: AIS patients with subsequent abdominal surgeries or procedures unrelated to AIS, nonoperative AIS patients, and any patients with other spinal disorders or systemic disease.

Results

179 patients were enrolled: SPG – 97 and HPG – 82. Average age at the time of scoliosis surgery (SS) was 16 years. Mean time of delivery after SS was 5 years (range 2-12, SD=2.8). The mean preoperative major curve was 65° (SD=12), and at final

follow-up (FFU) was 17° (SD=8), mean preoperative thoracic kyphosis (T5-T12) was 26° (SD=11.2), and 24.5° (SD=8.5) at FFU. Screw density was 1.6 (SD 0.2). Back pain (BP) during pregnancy was observed in 48% of SPG and 34% of HPG ($p>0.05$). Average gestation was 39 weeks in SPG and HPG. Cesarean section (CS) was performed in 64% of childbirths in SPG and 33% in HPG ($p<0.05$). In SPG, as the LIV moved caudal (L1 to L4), the frequency of CS increased ($p<0.05$, $R=0.8$) and most CS (55%) were performed in patients with a LIV of L4. BP at FFU (minimum 2 years) after childbirth was not significantly different among these women (43% of SPG and 42% of HPG).

Conclusion
Women who have had scoliosis surgery more commonly have back pain during pregnancy and deliver by CS compared to controls and the prevalence of both increases with more distal fusion level. Fortunately, after delivery, the rates of back pain are equal to women without AIS.

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60. Health-Related Quality of Life in Patients with AIS at Average 45 Years After Instrumented Fusion Compared to the Age Matched US Population.*

Sarah T. Lander, MD; Caroline Thirukumaran, PhD, MBBS, MS; Krista Noble, BS; Ahmed Saleh, MD; Addisu Mesfin, MD; Paul Rubery, MD; James Sanders, MD

Summary
In long-term follow up of AIS patients undergoing PSIF with Harrington instrumentation, patients had PROMIS-29 scores equivalent to and EQ-5D scores better than US general population age matched norms for all domains. There were significant associations with patient factors but not with LIV.

Hypothesis
Long term follow-up of patients with surgically treated AIS will have no difference in health-related quality of life (HRQoL) when evaluating LIV or patient factors compared to a similar US population.

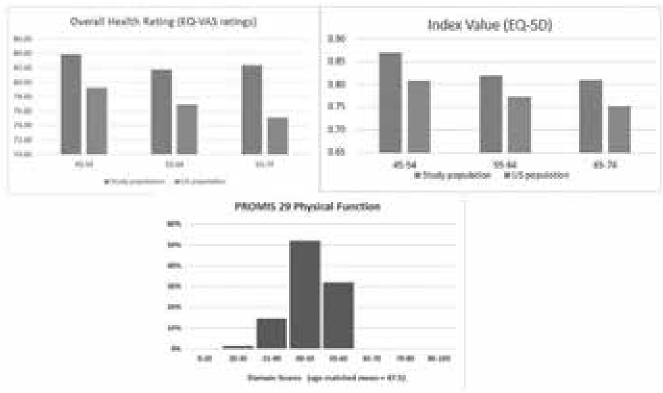
Design
Long term follow up

Introduction
There is uncertainty in how AIS PSIF effects patients' long-term HRQoL. We sought to compare a long-term follow-up cohort to their age matched peers.

Methods
We searched and identified AIS patients treated with Harrington instrumentation and fusion by Louis A. Goldstein from 1961-77. We compared EQ-5D and PROMIS-29 to US age matched norms and used multivariate analysis to examine associations to LIV and other patient social and comorbid factors. There were 7 continuous PROMIS and 5 EQ-5D categorical domains and 2 continuous scales.

Results
Of 314 patients, we identified 91 living, 6 deceased. 76 completed the instruments with follow-up 38-54yrs and current ages 51-70yrs. PROMIS-29 scores were not different and EQ-5D scores were superior to US age based means with no difference by LIV ($P<0.001$). In multivariate analysis, comorbidities, alcohol consumption, marital, and occupational factors had a significant effect on HRQoL ($p<0.001$). Comorbidities were associated with lower mobility, physical function, and overall scores.

Conclusion
Patients have long lasting normal measured HRQoL following Harrington instrumentation and fusion comparing their PROMIS-29 and EQ-5D to the age matched US population regardless of LIV. But, comorbidities, alcohol consumption, marital, and occupational factors have a significant effect on HRQoL.



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61. Liposomal Bupivacaine Reduces Narcotic Consumption in Adult Deformity Surgery

Michael Chang, MD; Andrew Chung, DO; Jan Revella, RN; Dennis Crandall, MD; Yu-Hui H. Chang, PhD, MPH

Summary
90 adults undergoing surgery for scoliosis or kyphosis were given peri-incisional liposomal bupivacaine and compared with a control group of 69 patients receiving only standard bupivacaine. The liposomal bupivacaine group consumed 18% less narcotics during their hospitalization without significant differences in outcomes or complications. This may represent a reasonable treatment strategy to combat the "opioid epidemic".

Hypothesis
Liposomal bupivacaine may reduce post-op narcotic use and length of stay in spinal deformity patients.

Design
Prospective, single-surgeon comparative cohort study

Introduction
Increasing public awareness of the dangers of narcotics use has prompted recent government legislation aimed at curtailing the "opioid crisis". These new regulations place greater restrictions on physicians with some laws penalizing surgeons for excessive utilization of narcotics. Liposomal bupivacaine offers a potential alternative to heavy narcotics use post-operatively, but has demonstrated limited benefit in the literature to date.

Methods
159 adults undergoing elective spinal fusion (mean age 54.2) for scoliosis or kyphosis by a single surgeon (MSC) received either

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peri-incisional combined liposomal and standard bupivacaine (n = 90, group L) or standard bupivacaine only (n = 69, group C). There were no significant baseline demographic differences between the two groups. Post-op pain scores (VAS), opioid use, length of stay, functional outcome and peri-operative complications were recorded. IV and oral narcotic consumption from all sources were standardized to morphine-equivalent units (MEU). This study was independent of industry.

Results
Patients receiving liposomal bupivacaine consumed 18.0% less MEUs compared with controls (259 vs 316 mg) over their hospitalization. The liposomal group also weaned off IV narcotics significantly faster, with 52.6% less IV use by post-op day 3 compared with controls (12.0 vs 25.4 mg, P=0.03). This reduction in narcotic use did not significantly impact length of stay (L: 4.7 vs C: 4.8), as our protocol requirement of bowel movements before discharge ended up being the limiting factor. There were also no significant differences in post-op complication rates for ileus (L: 7[7.8%] vs C: 3[4.3%]) and superficial wound infection (L:1[1.1%] vs C: 0) as well as overall. Functional outcome scores were also no different by 6 weeks post-op.

Conclusion
Liposomal bupivacaine substantially reduces opioid requirements after adult spinal deformity surgery with no noticeable complications. However, the reduction in opioid use did not translate into quicker return of bowel function.

62. The Effect of Balanced Preemptive Analgesia on Postoperative Pain in Spine Surgery": A Double Blinded Prospective Randomized Study

Ajoy Prasad Shetty, MS, DNB; Dilip Chand S, MBBS, MS; Rishi Kanna, MBBS, MS; S. Rajasekaran, PhD

Summary
A randomized double blinded clinical trial was done in 100 patients to analyze the effect of preemptive analgesia. Preoperative administration of a combination of paracetamol (P), ketorolac (K) and pregabalin (PR) aimed to block nociceptive, inflammatory and neuronal stimuli effectively reduced the postoperative pain in spine surgeries. Total opioid consumption was also significantly reduced with no complications. All these led to reduced duration of hospital stay, better functional scores and satisfaction of patients in those who received preemptive analgesia.

Hypothesis
A combination of paracetamol (P), ketorolac (K) and pregabalin (PR) administered preemptively would be able to manage postoperative pain effectively.

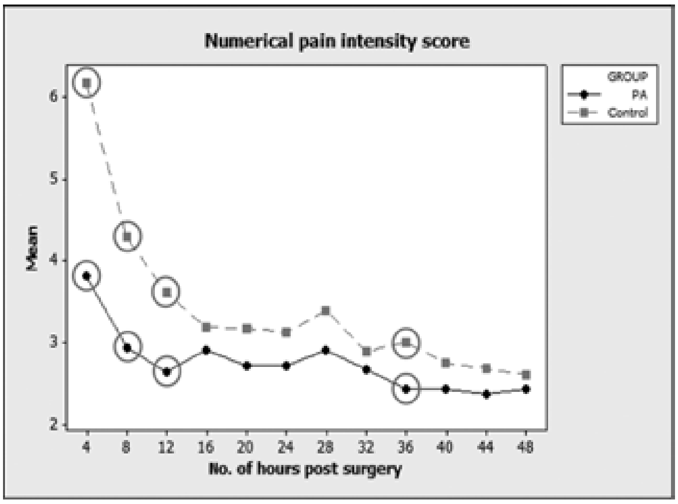
Design
Prospective double blinded randomized clinical trial

Introduction
Spine surgeries are known to cause moderate to severe acute postoperative pain. Inadequate management results in higher morbidity and chronic pain due to central sensitization. The role of preemptive analgesia has gained importance recently.

Methods
100 patients requiring lumbar fusion procedures were randomized into Preemptive analgesia (PA) and control (C) groups. The PA group received P, K and PR preemptively. Both underwent identical anesthetic and postoperative pain management protocol. Demographic and surgical data, four hourly pain levels- Numeric Pain Rating scale (NRS), Ramsay sedation scale (RSS), opioids consumption (TOC) through patient controlled analgesia (PCA), functional levels-Oswestry Disability Index (ODI), North American Spine Society Satisfaction (NASS) scale, hospital stay, and complications were recorded

Results
The average NRS score within the first 48 hour period in PA group (2.7±0.79) was significantly less than the C group (3.4±0.98). Ambulatory NRS scores were also significantly low in PA group. The PA group had significantly low TOC (3.02±2.29 mg) in comparison to the C group (4.94±3.08 mg). The duration of hospital stay were 4.17±1.02 and 4.84± 1.62 days in the PA and C groups (p=0.017). PA group (97.90 %) were extremely satisfactory compared to C group (72%, p=0.002) according to NASS scale

Conclusion
Postoperative pain is unique, as it is a combination of nociceptive, inflammatory and neuronal stimuli. Our strategy of preoperative administration of balanced analgesia with this combination of P, K and PR, helped in blocking all these stimuli and thus resulted in less pain intensity, allowed better ambulation tolerance, improved functional outcomes and had reduced the requirement of opioids and duration of hospital stay with no additional complications



63. Prophylactic Alvimopan to Prevent Ileus in Adult Spinal Deformity Surgery: A Double-Blind, Placebo-Controlled, Randomized Feasibility Trial

Eric Feuchtbaum, MD; David Bumpass, MD; Lukas P. Zebala, MD; Robert Owen, MD; Michael P. Kelly, MD, MS

Summary
A double-blind, placebo-controlled, randomized feasibility trial was conducted to estimate the effect of alvimopan on postoper-

ative ileus after ASD surgery. Time to bowel movement, tolerance of oral nutrition, and discharge were not different between groups. These results do not support a larger scale randomized clinical efficacy trial.

Hypothesis
Prophylactic alvimopan following ASD surgery will result in shorter time to first bowel movement.

Design
Double-blind, placebo-controlled, randomized feasibility trial

Introduction
Ileus following ASD surgery is a cause of increased length of stay, pain, and increased costs. Opioid consumption before and after surgery may contribute to the risk of postoperative ileus. Alvimopan is a mu-receptor antagonist shown to reduce ileus after intra-abdominal surgery. No data exist to support the use of alvimopan as a prophylactic measure against ileus after ASD surgery. This study was designed to assess feasibility of a larger randomized trial and to estimate effect size for a larger sample size estimation.

Methods
Inclusion criteria were adult patients undergoing surgery of minimum 5 levels or fusion to the sacrum and ileum. Block randomization placed patients into one of two groups: 12mg of alvimopan twice daily or placebo. Primary outcome measures were time to first bowel movement, time to solid oral nutrition, and length of stay. T-test compared outcome measures.

Results
31 patients were enrolled; 5 withdrew prior to beginning the trial. Randomization was successful with equal distribution of baseline data. Time to first bowel movement (Alvimopan 51 hours (19.1) vs Placebo 57.3 (24.4), p=0.48); time to solid oral nutrition (72.8 hrs (23.6) vs 75.2 (17.0), p=0.78); and time to discharge (117 hrs (30.1) vs 122 (48.3), p=0.741) were not different between groups. 5 SAE occurred, all deemed unrelated to study medications.

Conclusion
Times to first bowel movement, oral nutrition, and discharge were not different between patients receiving alvimopan versus placebo to reduce postoperative ileus after ASD surgery. No SAE related to study medications occurred. The results of this feasibility study do not support a larger scale randomized clinical trial of alvimopan as a prophylactic measure.

Table 1: Demographics

	Treatment	Mean	Standard Dev.	Sig.
Age	Placebo	54.69	13.65	0.38
	Alvimopan	49.23	17.49	
Weight (kg)	Placebo	81.73	17.48	0.087
	Alvimopan	80.74	13.42	
Height (cm)	Placebo	1.69	0.09	0.68
	Alvimopan	1.68	0.07	
Operative time (min)	Placebo	343.5	107.7	0.99
	Alvimopan	344	92.14	
Levels fused	Placebo	6.3	3.77	0.88
	Alvimopan	6.53	4.37	
Estimated blood loss (ml)	Placebo	776.92	544.91	0.54
	Alvimopan	673.07	335.02	
Length of stay (days)	Placebo	4.92	1.26	0.72
	Alvimopan	5.15	1.99	

Table 2: Primary Outcomes

	Treatment	Mean	Standard Dev.	Sig.
Time to flatus (hrs.)	Placebo	34	16.66	0.25
	Alvimopan	43.22	23.06	
Time to bowel movement (hrs.)	Placebo	51.05	19.17	0.48
	Alvimopan	57.34	24.46	
Time to regular diet (hrs.)	Placebo	72.86	23.64	0.76
	Alvimopan	75.2	17.06	
Time to hospital discharge (hrs.)	Placebo	117.18	30.17	0.74
	Alvimopan	122.47	48.39	

64. The Safety and Efficacy of Intraoperative Acute Normovolaemic Haemodilution (ANH) in Complex Spine Surgery at An SRS GOP Site in Ghana: A Prospective Study

Irene Wulff, MD; Audrey Oteng-Yeboah, MD; Henry Ofori Duah, RN; Henry Osei Tutu, BS; Kwadwo Poku Yankey, MD; Oheneba Boachie-Adjei, MD; FOCOS Spine Research Group; Harry Akoto, MD

Summary
Complex spine surgeries are associated with significant blood loss, requiring blood transfusion. Allogenic blood transfusion is related to surgical time and blood loss. However, in underserved regions,with limited blood product supply, an alternative blood conservation methods such as ANH may reduce/obviate this transfusion demand.

Hypothesis
ANH can safely be applied and will reduce allogenic transfusion in complex spine surgery.

Design
Prospective cohort study

Introduction
ANH has been reported to be a safe and effective method for blood conservation in spine surgery. However its safety and efficacy to reduce /obviate allogeneic transfusion in complex deformity suregry in underserved regions is unclear. The study sought to assess the safety and efficacy of ANH as a blood conservation method in complex spine surgeries.

Methods

76 complex spine pts aged ≥8 with pre op Hb ≥ 12 treated at an SRS GOP site in Ghana were randomly assigned to two groups. 45 ANH (Grp 1) pts were compared to 31 non-ANH (Grp 2) pts. They were matched with respect to age, wgt., preop hemoglobin levels, OR time and fusion levels. Data was analysed for EBL, transfusion, post op Haemoglobin (Hb) and complications. Statistical analysis with odds ratio and independent T- test was utilized for the comparative variables.

Results

There were 76 pts: 26M/19F in Grp 1 vs 13M/18F Grp 2 with an average age of 15yrs in both grps. Avg pre op BMI was 19.46kg/m2 (Grp 1) vs 19.64 kg/m2 (Grp 2). Fusion levels and surgery duration were similar in both Grps. Avg EBL: 1583ml (Grp 1) vs 1623ml (Grp 2) (p=0.82). %Volume of Blood loss avg 58.3% (Grp 1) vs 57.89% (Grp 2) ,p=0.95. Allogenic blood transfusion was 32/45pts (71%) in Grp 1 vs 25/31pts (80.65%) in Grp 2. The volume of allogenic blood transfusion was not significantly higher in Grp 2 (861ml) vs Grp 1 (743ml) (P=0.43). FFPs,Whole Blood and Packed cells transfusions were similar in both groups.Cell saver blood transfusion avg 540ml (Grp 1) vs 560ml (Grp 2) (p=0.76). There was no significant difference in the Hb of the two grps at POD 0 (9.4 mg/L Grp 1 vs 9.6mg/L,p=0.34) and POD 1 (10.15mg/ml vs 10.38mg/ml; p=0.45). Allogenic transfusion relative risk was similar in both groups.

Conclusion

This review showed that ANH can be safely performed in complex spine surgery in underserved regions. Although, the ANH group had lower proportion of allogenic blood use, the volume of allogenic blood transfusion was not significantly lower.

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65. Blood Loss Estimates and Risk Factors for Excessive Blood Loss in AIS Surgery: Have We Been Fooling Ourselves?

Baron Lonner, MD; Yuan Ren, PhD; Nicholas Fletcher, MD; Paul D. Sponseller, MD; Peter Newton, MD

Summary

Assessment of Blood loss (BL) and associated risk factors must rely on accurate estimates. Various means for determining EBL in AIS have been utilized ranging from visual to mathematical estimates based on a multiple of cell saver (CS). Volume of CS transfused correlates with EBL and may act as a surrogate measure; however, this relationship varies widely amongst institutions. The mean for all centers suggests EBL is ~ double the CS returned. Risk factors are similar for EBL and CS.

Hypothesis

Blood loss (BL) as measured by standard estimated means (EBL) is inaccurate and does not parallel cell saver (CS) returned as an objective surrogate measure of intra-operative BL; therefore, risk factors for blood loss will differ depending on which measure is used.

Design

Retrospective review of a prospective AIS registry

Introduction

Assessment of BL and its associated risk factors must rely on accurate estimates of BL and form the basis of surgeon dashboards that drive improvements in surgical strategies. Various means for determining EBL in AIS surgery have been utilized ranging from visual to mathematical estimates based on a multiple of CS concentrated or returned. Our objective is to study the relationship of EBL to the objective CS measure and to assess risk factors for excessive BL.

Methods

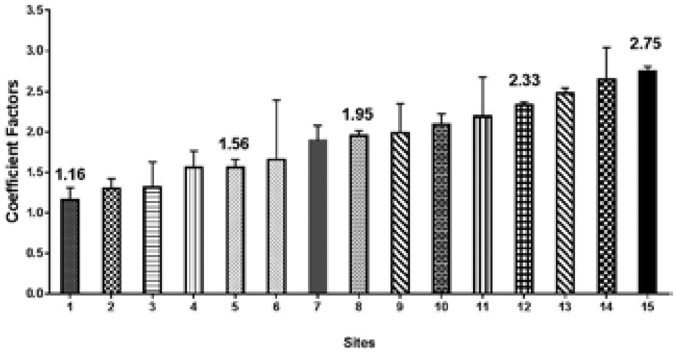
3583 consecutive patients from a multicenter operative AIS database registry were included. The relationship between EBL and CS transfused were evaluated by linear regression. Risk factors for excessive blood loss greater than 1.5 times above the 75th percentile of the data range was assessed by Pearson's correlations.

Results

80.6% were females, age 14.8 years. Major curvature was 55.4°, 9.7 levels fused. EBL was 879.9±754.2 ml, and CS transfused 253.9±318.7 ml. Significant correlation was observed between EBL and CS transfused (p<0.0001). When the relationship of the 2 parameters was assessed by institution, large variations in coefficient factors were observed (range 1.16- 2.75), indicating inconsistency exists in estimation of blood loss by each institution (figure). Risk factors for excessive EBL and CS transfused were major curvature, total operative time and # levels fused as well as ASF/PSF followed by PSF and ASF (p<0.0001).

Conclusion

Volume of CS transfused correlates with EBL and may act as a surrogate measure for BL; however, this relationship varies widely amongst institutions. The mean for all centers suggests EBL is ~ double (range 1 to nearly 3 times) the CS volume of blood returned. BL and risk factors for BL are similar whether or not EBL or CS is utilized as the measure. Future work should focus on standardization of BL estimates.



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66. Clinical Outcome of Intraoperative Lumbosacral Nerve Root Monitoring Changes Using Motor Evoked Potential Warning Criteria

Anil Mendiratta; Lawrence G. Lenke, MD; Lee A. Tan, MD; Meghan Cerpa, MPH; Ronald A. Lehman, MD; Mark Weidenbaum, MD; Yongjung J. Kim, MD; Charla R. Fischer, MD; Paul F. Kent; Earl D. Thuet

Summary

Clinical outcomes of using motor evoked potential (MEP) to

monitor lumbar nerve roots during 337 consecutive thoracolumbar spinal surgeries found that 14 patients(4%) met warning criteria for MEP nerve root monitoring, 12/14 had nerve root compression identified at the appropriate level, and 11/12(92%) had improvement of the MEP nerve root data. None of the patients with improved responses had a residual neurologic postop deficit.

Hypothesis
To evaluate the effectiveness of motor evoked potentials in monitoring lumbosacral nerve root function during spinal surgery

Design
Single-center cohort

Introduction
Somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs) can detect intraoperative (IO) spinal cord dysfunction with good reliability. However, the reliability of nerve root monitoring remains controversial. We report the clinical outcome of patients with IO MEP nerve root monitoring changes using a unique warning criteria.

Methods
337 patients who underwent thoracolumbar spinal surgery utilizing multimodality monitoring over a 12-month period were reviewed. We assessed the rates of 1) IO MEP nerve root monitoring changes meeting our warning criteria, 2) MEP changes resulting in identification of root compression, and 3) MEP changes associated with postoperative neurological deficits.

Results
14 patients (4%) had MEP nerve root monitoring changes that met our warning criteria. 12/14 (86%) patients with nerve root compression identified at the corresponding levels. IO nerve root decompression resulted in improvement of MEP signals in 11/12 (92%) patients; all these patients had either no postop deficits or only had transient deficits that completely recovered at follow-up visit. The MEP signal failed to improve despite nerve root decompression in one patient (8.3%) in the true positive group, who also had a persistent neurological deficit at the follow-up visit. 2/14 (14.3%) patients who had MEP nerve root monitoring changes but did not have any nerve root compression identified intraoperatively. Neither patient had a postoperative neurologic deficit. 7/14 (50%) cases, MEP responses were the only positive indicator of change in nerve root function.

Conclusion
IO MEP nerve root monitoring changes highly correlated with nerve root compression. We have found MEP nerve root monitoring to be an effective tool for IO identification of nerve root compression and should be considered to optimize surgical outcome.

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67. Surgical Teams Surgery Improve Quality, Safety and Value in Surgery for Adolescent Idiopathic Scoliosis (AIS)

John Smith, MD; John A. Heflin, MD; Cynthia Nguyen, MD; Jessica V. Morgan, BS; Graham Fedorak, MD, FRCS(C)

Summary
We reviewed quality assurance data for 590 consecutive cases of AIS surgery between 2006 and 2015 following the introduction of a dedicated spine surgery team. These data demonstrated improvements in surgical room times, operative time, average length of stay, reduced overall cost per encounter. With the introduction of Checklists and Best Practice Guidelines (BPG's) to prevent Surgical Site Infection in spine surgery in 2013, our infection rate in AIS surgery have been reduced to zero.

Hypothesis
Dedicated spine surgery teams, operative checklists, and following best practice guidelines will result in quality improvement, cost efficiency and fewer complications for AIS surgery.

Design
This is a retrospective review of AIS surgical cases using our own Electronic Data Warehouse from 2006-2015 to measure improvement of care and value when utilizing BPG's.

Introduction
Throughout industry, teamwork is known to be critical in achieving efficiency and safety. In 2006, we developed a dedicated team for AIS surgery including Surgical Techs, Nurses, Neuro-monitoring Techs and procedural roadmaps including checklists. In 2012, Best Practice guidelines (BPG's) were instituted for prevention of Surgical Site Infection. The purpose of this study is to determine the outcome of this process on quality, safety and value in AIS surgery.

Methods
Using Quality assurance data, we reviewed 590 consecutive cases of AIS surgery between 2006 and 2015. Demographics, outcomes, and complications were recorded. We also used the Intermountain Enterprise Database to study cost trends over the period. Non-AIS cases were excluded.

Results
590 cases of AIS were reviewed from 2006-2015. 83% were female; Average age was 14.5 years. Room times decreased by 11% over time and surgical times decreased 13%. Over the study period, the average length of stay decreased by 13% and the average cost per encounter decreased 22%. This was mostly related to a 13% decrease in implant costs. No transfusions were given. There were 23 neuro-monitoring alerts, but 0 neurologic injuries. Since implementing BPG's for infection prevention, there were no infections.

Conclusion
Since implementing surgical teams at PCH, AIS surgery has become faster, safer, and more cost efficient. Engaged dedicated teams, BPG's, and Checklists all contribute to improving outcomes and lowering costs.

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68. Preoperative Hemoglobin Levels and Risk for Transfusion After Adult Spinal Deformity Surgery: Analysis of Predictive Factors

Tina Raman, MD; Peter Zhou, BS; John Moon, BS; Dennis Vasquez-Montes, MS; Aaron Buckland, MBBS, FRACS; Thomas Errico, MD

Summary
Multilevel fusions and complex osteotomies to restore global alignment in adult spinal deformity (ASD) surgery can lead to significant blood loss perioperatively. In this regard, we assessed factors predictive of intra- and postoperative transfusion. We found that number of levels fused, performance of three column osteotomy (3CO), interbody fusion, operative time and preoperative hemoglobin < 11.7 g/dl were predictive of increased units of RBCs transfused perioperatively.

Hypothesis
Patient and surgical characteristics are related to extent of intraoperative blood loss, and need for perioperative transfusion.

Design
Retrospective review of prospectively collected database.

Introduction
An awareness of potential risk factors for transfusion in ASD surgery can optimize preoperative preparation, and perioperative management. The aim of this study is to identify patient and surgical characteristics predicting the need for blood transfusion in ASD surgery.

Methods
We assessed a single center multi-surgeon database of 418 ASD patients, age > 18 years, with greater than 4 levels fused. Preoperative and intraoperative patient and surgical characteristics were collected, and EBL, percent blood volume (BV) lost, RBC transfusions, and perioperative hemoglobin levels were assessed.

Results
418 patients (Age: 56 ± 18y; 283F, 135 M; Levels fused: 10.8 ± 4.2) were included in the analysis. 246/418 (59%) patients received at least 1 U RBCs intraoperatively. 94/418 (23%) patients received at least 1 U RBCs postoperatively. With regards to intraoperative transfusion, each level fused was associated with an additional 0.17 U RBC transfused (p<0.001). 3CO was associated with an additional 15.9% BV lost (p=0.016) and an additional .9 U RBCs transfused (p<0.001). Interbody fusion was associated with an additional 8.9% BV lost (p=0.016) and an additional 0.7 U RBCs transfused intraoperatively (p<0.001). A preoperative Hgb less than 11.7 (10.3% of all patients) was associated with an additional 1.3 U RBCs transfused intraoperatively (p<0.001). In terms of postoperative transfusion, operative time > 6.45 hours was associated with an additional 0.24 U RBCs transfused (p=0.001), and pelvic fixation was associated with an additional 0.14 U RBCs transfused (p=0.039).

Conclusion
Identification of predictors for percent BV lost and transfusion may facilitate preoperative planning and perioperative management. This study demonstrates that number of levels fused, 3CO, pelvic fixation, interbody fusion, preoperative hemoglobin < 11.7, and operative time > 6.45 hours were independent predictors of perioperative transfusion, and percent BV lost.

69. Cobalt Chromium-Titanium Versus Both Titanium Rods For Surgical Treatment of Adolescent Idiopathic Scoliosis(AIS); Which Has Better Correction?

Mohammadreza Etemadifar, MD; Abbas Rahimian, MD

Summary
To evaluate effect of rod material on deformity correction, we compared two groups of patients using either one Co-Cr and one Ti or twoTi rods for posterior surgery in AIS . There were 29 patients in Co-Cr and 30 patients in Ti groups. Average correction rate in coronal plan was 91% in Co-Cr and 81% in Ti group(P<0.01). There was no statistically significant difference in sagittal plan correction. Conclusion: using a Co-Cr rod could have better results.

Hypothesis
Our hypothesis was that if using Co-Cr & Ti rods is associated with better correction in coronal and/or sagittal planes than using both Ti rods in surgical treatment of AIS.

Design
A randomized prospective clinical trial was conducted in our institution and all AIS cases who were candidate for posterior surgery were randomly assigend to either Co-Cr,Ti or both Ti rods groups.

Introduction
Titanium (Ti), Stainless Steel (SS), and Cobalt-Chromium (Co-Cr) are the most commonly used alloys for rods in AIS surgery. In theory rigid rods may have more corrective effects during surgical corrective manuevers in AIS. There are few studies which have compared correction with different rod materials especially, Co-Cr versus Ti alloys. Our study has been conducted to compare spinal deformity correction using different alloys of Ti and Co-Cr.

Methods
All AIS cases who were eligible for posterior surgery in our institution were included. Surgery was performed in all cases using all pedicle screw with free hand technique and working rod was Co-Cr in first and Ti in second group. The second rod was Ti in both groups. Correction was performed with cantilever and translation of the apex toward the rod. All patients were followed for a minimum of two years.

Results
59 patients including 37 females and 22 males were included for final follow up. Mean age of the patients was 14.1±1.4 years. There were 29 cases in Co-Cr and 30 cases in Ti groups. Main coronal cobb angle was 55±11 and 58±11 respectively(p=0.39). Main curve flexibility in the two groups was almost the same(31.8% versus 34.4%, P=0.62). All patients had minimum 2 years follow up. Average fusion levels were 9.8 and 10.3 respectively(p=0.31). There was statistically significant difference in percent correction of (major) coronal cobb angles(91% Co-Cr versus 81% Ti, p=0.01). In Co-Cr group thoracic kyphosis was more than Ti group but, difference was not statistically significant. SRS-22 scores were not statistically different in two groups at final follow up.

Conclusion
Using Co-Cr & Ti instead of Ti alloy rods is accompanied by better coronal correction at final follow-up.

70. A 10-Year Radiographic Outcome Study of Anterior and Posterior Instrumented Spinal Fusion in Patients with Lenke Type 5 Adolescent Idiopathic Scoliosis: Are We Preparing Our Patients for Adult Deformity Targets?

Hwee Weng Dennis Hey, MD; Joel Lim, MBBS, MRCS (Glasgow); Leok-Lim Lau, FRCS; Joseph Thambiah, MBBS, FRCS, FAMSOrth; Naresh Kumar, MBBS, FRCS, MS, DNB(Orth)FRCS (Orth)DM(Orth); Gabriel KP Liu, FRCS; Hee-Kit Wong, FRCS

Summary
A comparison of anterior and posterior instrumentation surgical approaches in Lenke 5 Adolescent Idiopathic Scoliosis (AIS) showed that posterior surgery had a shorter operative time and hospital stay. Coronal plane deformity improved by > 70% in both groups and was maintained up to 10-years. Sagittal alignment parameters met SRS-Schwab standards and were unchanged up to 10-years. There was a higher incidence of proximal junctional kyphosis in the posterior compared to the anterior group.

Hypothesis
To compare the coronal and sagittal radiographic outcomes of the anterior and posterior instrumentation approaches in Lenke 5 Adolescent Idiopathic Scoliosis (AIS) surgery up to 10 years of follow-up.

Design
Prospective cohort study.

Introduction
Both approaches have been found to be safe and effective for the treatment of AIS up to 2 to 5 years of follow up. Studies are limited beyond this duration.

Methods
A total of 36 patients who underwent anterior or posterior instrumented spinal fusion for Lenke 5 AIS between 2000-2003 are recruited and prospectively followed up to 10 years. Preoperative data recorded include patient's age, risser stage and age of menarche. Operative data included instrumented levels, duration of surgery and blood loss. Postoperative data included duration of hospital stay, ICU stay , duration of parenteral analgesia, and complications. Pre- and postoperative radiographic data collected include coronal Cobb angles for structural thoracolumbar/lumbar curves, as well as sagittal angles – sagittal vertical axis, thoracic kyphosis, global lumbar angle, pelvic incidence, pelvic tilt, sacral slope, and upper and lower end vertebrae.

Results
Posterior surgery had a shorter operative time (P<0.010) and hospital stay (P<0.010) compared to anterior surgery. Coronal plane deformity improved by a mean of 74% in the anterior group and 71% in the posterior group. There was no significant change at 10 years in both groups (anterior P = 0.455 and posterior P=0.325). Sagittal parameters met SRS-Schwab Classification standards and remained unchanged throughout follow up. There was a higher incidence of proximal junctional kyphosis in the posterior compared to the anterior group.

Conclusion
Both anterior and posterior instrumentation and fusion are successful surgeries after 10 years of follow up. They are comparable with regards to their ability to achieve and maintain good correction of scoliotic deformities and have a low rate of pseudoarthrosis and instrument failure. Ideal sagittal parameters are maintained up to 10 years of follow-up.

71. Trends in Complications in Operative Adolescent and Adult Idiopathic Scoliosis From the SRS Morbidity and Mortality Database

Swamy Kurra, MBBS; Baron Lonner, MD; Katherine Sullivan; Isador Lieberman, MD, FRCS(C); Shay Bess, MD; William Lavelle, MD

Summary
Over 12 years, complications rates in ADS increased even with the evolution of surgical techniques compared to AIS population.

Hypothesis
Assess trends in complication rates in AIS and ADS.

Design
AIS and ADS operative complications rates obtained from SRS Morbidity and Mortality (M&M) database over 12 years (2004-2015).

Introduction
Surgical techniques in adolescent idiopathic scoliosis (AIS, age=10-18 years) and adult idiopathic scoliosis (ADS, age >18 years) surgery have evolved over the past 10 years.

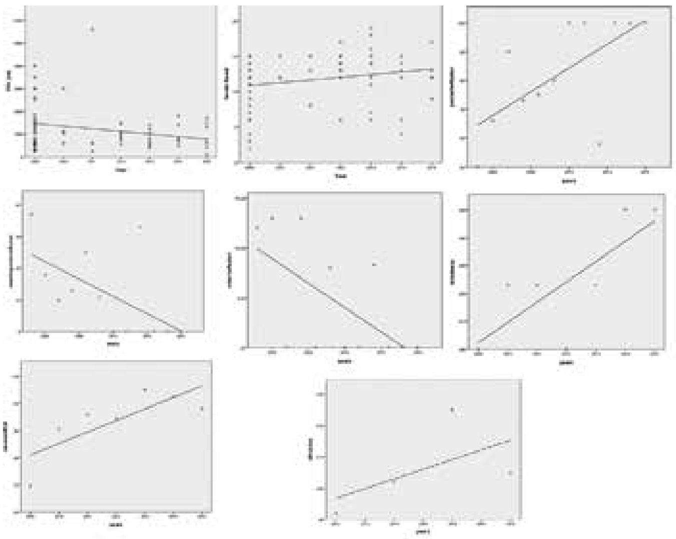
Methods
Reviewed complications rates over 7 years (2009-2015) of AIS (n=63,574) and ADS (n=27,990) surgeries in one file. A second file contained demographics, surgical data and types of complications (2004-2015) of patients who had only complications (AIS =1165 and ADS=139). ADS patients' ages were between 18 and 30 years. Neurological deficit, blindness and death rates over 7 years, and infection rates over 4 years (2012-2015) analyzed for both populations. In patients with complications data, we analyzed blood loss, levels fused, neurological recovery rate, and type of surgery. Linear regression was used to analyze the trends of changes. P<0.05 was considered statistically significant.

Results
The amount of blood loss was reduced (from 2009 to 2015) both in AIS (from 957 to 750 mL, p=0.02) and ADS (from 1.4L to 904mL, p=0.02). The number of levels fused increased (from 2009 to 2015) in both AIS (from 11 to 12, p=0.02) and ADS (from 10.4 to 12.7, p=0.04). In AIS (p=0.052) and ADS (p=0.03) fusion levels increased over 7 years for Lenke type 1 curves. Posterior fusion rates increased in both AIS (p=0.002) and ADS (p=0.02), anterior fusion rate reduced in both AIS (p=0.001) and ADS (p=0.03), and combined surgeries reduced

only in ADS (p=0.04) over the 12 year analysis (2004 -2015). In AIS population, complication rates were constant over the 7 year analysis, neurological deficits recovery rate decreased (p=0.05). In ADS, blindness (p=0.04) and neurological deficit (p=0.04) rates increased over the 7 years of analysis. (Figure 1)

Conclusion

The amount of blood loss and anterior surgery rates decreased, and posterior fusion rates and fused levels increased in both populations. Neurological deficit and blindness rates increased in the ADS population.



72. Magnetically Controlled Growing Rod Systems Have Higher Hazard of Adverse Events Compared to Prosthetic Rib Constructs

Chun Wai Hung; Hiroko Matsumoto, PhDc; Megan Campbell, BA; Michael Vitale, MD; David Roye, MD; <u>*Benjamin Roye, MD, MPH*</u>

Summary

MCGR has 5.6 times higher hazards of device-related complications and 4.6 times higher hazards of unplanned return to OR compared to PRC in our institution when adjusted for age, sex, tone, major coronal curve, kyphosis, and number of surgeries. Though a construct with fewer surgeries holds its own merit, careful attention should be paid to the circumstances around which MCGRs are utilized.

Hypothesis

EOS patients treated with primary MCGR have higher hazard of implant complications & unplanned return to OR compared to those with primary PRC at 2 years postoperatively.

Design

Retrospective cohort study

Introduction

Magnetically Controlled Growing Rods (MCGR) were designed to treat Early Onset Scoliosis (EOS) without the need for iterative surgeries. Initial enthusiasm for MGCR has been high, but complication data is limited compared to traditional distraction devices such as prosthetic rib constructs (PRC).

Methods

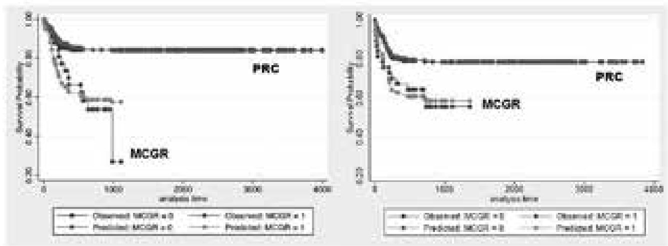
Consecutive EOS patients undergoing primary implants of MCGR or PRC between 2009-2016 were included. Outcomes were implant complications (rod breakage, anchor migration, lengthening failure, failure to correct curve) and unplanned return to OR (includes visits that deviated from original plan to accommodate a complication). Cox regression was used to address unequal follow-up (PRC group had longer follow up); covariates changing more than 10% in crude beta were included in the final model. Interaction terms between construct type and patient characteristics were tested to investigate the presence of co-existing effect on outcomes.

Results

There were 74 patients (22 MCGR/52 PRC) & 243 procedures (37 MCGR/206 PRC) with mean follow-up of 5.6y. 12 MCGR patients (55%) had 14 implant complications & 36% required unplanned OR visits (15 surgeries). 23 PRC patients (44%) experienced 31 device complications, & 50% had unplanned OR visits (44 surgeries). MCGR patients had 5.6 times higher hazard of implant complications (Fig1, p=0.001, 95% CI: 2.0-16.0) & 4.6 times higher hazard of unplanned OR visits (Fig2, p=0.002, 95% CI: 1.8-11.8) than PRC patients after adjusting for tone, major coronal curve, kyphosis, and number of surgeries. There were no interactions, indicating there is no evidence that MCGR & patient characteristics would together change the magnitude of above hazard.

Conclusion

In our institution, MCGR procedures had increased hazards of implant complications & unplanned OR visits compared to PRC procedures. Early enthusiasm should be tempered to carefully consider patient specific scenarios which dictate use of MCGR.



73. Diminishing Returns of Magnetically Controlled Growing Rod Lengthenings Over Time

<u>*Stephanie Ihnow, MD*</u>; Viral Jain, MD; Sarah Gilday, PA-C, MS; William McKinnon, MD; Peter Sturm, MD

Summary

The law of diminishing returns appears to apply to distraction of magnetically controlled growing rods (MCGR) as the number of attempted lengthenings increases in patients with early onset scoliosis. In this series of 34 patients with a mean of 8.88 lengthening attempts, the average distraction achieved decreased from 88.49% with the first lengthening attempt to 31.0% for the thirteenth attempt.

Hypothesis

The amount of distraction of magnetically controlled growing rods (MCGRs) decreases over time.

Design

Retrospective review of prospectively collected data

Introduction

Magnetically controlled growing rods are used in early onset scoliosis (EOS) to stabilize the curve while maintaining some spinal growth and avoiding repeated exposures to anesthesia. It has been established that the law of diminishing returns applies to traditional growing rods but few studies have looked at the repeated ability to distract MCGRs over time.

Methods

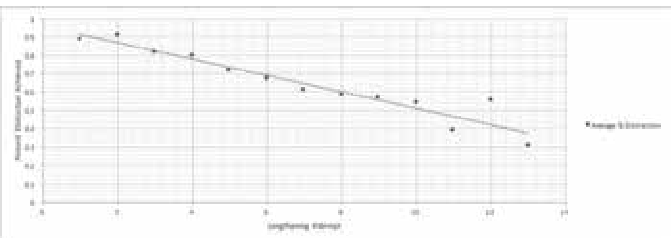
A retrospective analysis of prospectively collected data was performed. Patients who underwent MCGR placement for EOS with a minimum of two years follow-up were identified. Demographics, lengthening data (number of lengthenings, time between lengthenings, percent distraction achieved), and complications were analyzed. Distraction was measured by ultrasound for all but 7 of the 302 lengthening, which were measured by x-ray.

Results

34 patients met inclusion criteria, 19 males and 15 females. Diagnoses consisted of 8 idiopathic scoliosis, 2 spinal muscular atrophy (SMA) I, 2 SMAII, 2 tethered cords, 1 congenital, and other syndromes. There were 20 primary and 14 conversion procedures. Mean age at MCGR insertion was 7.8±2.77 years (range 4.1-12.2). Mean follow-up was 31.8±5.54 months (range 24.1-42.0). A total of 302 lengthening attempts were made. Each patient underwent an average of 8.88±1.96 (range 3-13) attempted lengthenings. Average distraction achieved at first lengthening attempt was 88.49% and decreased to 31.0% at the thirteenth lengthening attempt (Fig. 1). All patients initially had two rods placed but one patient had conversion of one rod to a traditional growing rod after four lengthenings. There were five complications in five patients. Four patients required hardware revision while one patient had an infection requiring irrigation and debridement with retained hardware.

Conclusion

The amount of distraction obtained over time of MCGR rods for EOS decreased as the number of attempted lengthenings increased. The law of diminishing returns applies to MCGRs as it does to traditional growing rods.



74. The Oxford 5 Year Observational Study of 31 Patients With Magnetically Controlled Growing Rods (MGCR)

Thejasvi Subramanian, BABMBCh; Adil Ahmad, MBBS, BSc MRCS; Dan Mihai Mardare, MD, MSc; David Kieser, PhD, MBChB, FRACS, FNZOA; David Mayers, RN (Child); Colin Nnadi, MBBS, FRCS

Summary

This prospective observational study reveals both primary and conversion MCGR systems provide significant, stable clinical and radiological deformity correction of EOS over, an average of, 3 years post-initial insertion. Additionally, MCGRs are associated with significant, sustained improvements in specific functional skills sets (personal care and standing skills). Despite these advantages, we observed a high complication rate with nearly half occurring in conversion patients, suggesting a more considered approach to the use of MCGR in such cases.

Hypothesis

Review the efficacy of MCGR in EOS patients

Design

Prospective observational study

Introduction

Magnetically controlled growing rods (MCGR), for the treatment of early onset scoliosis (EOS), use a system of non-invasive spinal lengthening. The aim of this study was to evaluate device performance and safety in the prevention of scoliosis progression.

Methods

An observational study of 31 (15 male) consecutive patients with EOS was completed from December 2011 to October 2017 at Oxford University Hospitals Trust. Mean age of patients was 7.7 (2-14) years with mean follow up of 47 months (24–69). Distractions were completed using the tail-gating technique (TGT). Response to treatment was assessed clinically and radiologically at set time points.

Results

Mean coronal cobb angle was 54° (14-91°) pre-operatively versus 37° (11-69°) at latest follow-up (p<0.001). Mean thoracic kyphosis (TK) was 45° (10-89°) pre-operatively versus 42° (9-84°) at latest follow-up. Mean T1–T12 height improved from 168mm (107-228) pre-operatively to 198mm (124-269) (p=0.003). Similarly, mean T1–S1 height increased from 287mm (209-378) to 338mm (240-427) (p<0.001). Sagittal balance reduced from 68mm (-76 – 1470) pre-operatively to 18mm (-32 - 166) at latest follow-up. Mean pre-operative coronal balance was 3mm (-336 - 64) compared to 8mm (-144 - 64) at latest follow-up. Increases in weight, sitting and standing height at latest follow-up were 45%, 10% and 15%, respectively. Activity Scale for Kids (ASK) scores increased across all domains with only personal care and standing skills being significant at latest follow-up (p=0.02, p=0.03 respectively). 21 patients developed a total of 23 complications at a rate of 0.23 complications per patient per year. Seven patients had MCGR-specific complications and a significant majority of the conversion cases developed complications (11/15). Average time to complication was 38 months post-index procedure requiring 22 unplanned returns to theatre.

Conclusion

MCGR controls scoliosis progression, allows growth and improves functional activity. Primary infection rates are low, however, overall rates of unplanned return to theatre are still high.

75. Minimum 5 year follow-up of Mehta Casting to Treat Idiopathic Early-Onset Scoliosis: Correction in The First Cast Predicts Outcome

Graham Fedorak, MD, FRCS(C); Jacques L. D'Astous, MD, FRCS(C); Alexandra Nielson, BS; Bruce MacWilliams, PhD; John A. Heflin, MD

Summary
At a mean of 7.6 and minimum of 5 years follow-up, this study assesses predictors of sustained cure in children with idiopathic early-onset scoliosis treated with EDF casting (elongation derotation flexion, Mehta). Cobb angle and rib vertebral angle (RVAD) on an upright x-ray in the first cast were predictive of sustained cure. We propose a first cast Cobb < 30˚ and RVAD < 20˚ as associated with sustained cure at a minimum 5 year follow-up.

Hypothesis
Correction in the first cast is predictive of ≥ 5 year outcomes in EDF casting.

Design
IRB approved retrospective review of all children casted for idiopathic early onset scoliosis at a single institution.

Introduction
Aside from Ms Mehta's work, the results of EDF casting to treat EOS have not been reported with greater than minimum one or two year follow-up. We sought to assess the results of EDF casting at minimum 5 year follow-up and identify predictors of sustained resolution of scoliosis.

Methods
Retrospective review of children treated for idiopathic EOS with EDF casting at a children's hospital between 2000-2012 with minimum 5 years follow-up. Cure was defined as Cobb angle < 15˚ and Improvement as a decrease in Cobb angle of > 20˚ at final follow-up. Differences between groups based on Cure and Improvement criteria were tested with Student t-tests with alpha = 0.05.

Results
34 children were identified with a mean follow up of mean 7.6 (5.1-16.5,) years. The age at first cast was 2.25 (0.8-7.9) years, with a Cobb angle of 52.3 (22-95)°. 38.2% of children (13/34) were cured at final follow-up and 64.7% (22/34) were improved. Comparing cured and uncured, there were no significant differences in initial Cobb angle, supine AP traction Cobb, age at first cast, or initial RVAD. There were substantial differences between the cured and uncured groups in measurements made in the first cast on a standing film. First cast RVAD was 24.4˚ (0-57) in uncured versus 7.5˚ (0-31) (p < 0.001) in cured. First cast Cobb angle exhibited a trend (p=.06) with uncured 32.4 (10-68)° and cured 22.3 (14-45)°. 62.5% (10/16) patients who met both criteria met cure criteria.

Conclusion
At minimum 5 year follow-up, first cast RVAD and Cobb angle were the best predictors of sustained cure. We suggest that with an in first cast Cobb < 30˚ and RVAD < 20˚ one can hope for a cure with EDF cast treatment. 38.2% of children were cured and 64.7% had greater than 20 degrees improvement in initial Cobb angle.

76. Non-Anesthetized Alternatively-Repetitive Cast/Brace Treatment for Early Onset Scoliosis

Kazuki Kawakami, B.Kin; Toshiki Saito, MD; Ryoji Tauchi, MD; Tetsuya Ohara, MD; Noriaki Kawakami, MD

Summary
Outcomes of non-anesthetized cast treatment (Tx) for pts with Early Onset Scoliosis (EOS) with scoliosis of various etiologies were investigated and had their curve parameters and cardiopulmonary function assessed throughout the multiple casts they received. Cast Tx without general anesthesia (GA) is a viable Tx option that can be done effectively in the clinic and provides as an effective delaying method in sparing time until surgery in other etiologies.

Hypothesis
ARCB Tx without GA can provide clinically relevant level of suppression to scoliosis progression and spare time until surgery in pts with EOS.

Design
Retrospective Cohort Study

Introduction
Use of cast is a standard Tx choice for EOS. Recently, toxicity from repetitive use of GA has received attention by the FDA and is a problem that must be addressed. We introduce a non-anesthetized cast Tx protocol called Alternatively-Repetitive-Cast-and-Brace (ARCB) that we have used since 1995 and have conducted an extensive follow-up on these pts to verify the efficacy of this protocol.

Methods
Out of a consecutive series of 155 pts who have undergone cast Tx at a single institution, 98 pts (M:36, F:62) have been identified under the following criteria: 1) Initial age prior to ARCB of ≤ 6; 2) Follow-up period of ≥ 2 years; 3) Initial scoliosis ≥ 35°. Pts consisted of the following: Congenital/Structural: 45, Idiopathic: 23, Neuromuscular: 6, Syndromic: 24. Pre-Cast, Post-final Cast, minimum in-cast Cobb, as well as thoracic and T1-S1 heights were measured. 56 out of these pts had available pulse oximetry on days before and after initial cast, and these were also evaluated to assess cardiopulmonary effects that the cast have on the pts.

Results
Pts were casted 6.6 times, with a mean initial Cobb of 56.5°and a final follow-up Cobb of 57.1°. Follow-up period was 5.0 yrs. Mean curve progression per follow-up period was 0.5°/yr. Minimum in-cast Cobb was 25.6°. Initially pts had a thoracic and T1-S1 height of 12.6 cm and 22.5 cm, respectively. At final cast, these were 15.3 cm and 27.2 cm, respectively. Out of these pts, 39 had progression >1°/y, of which 83.1% had resulted in surgical correction, while this was true for only 37.3% of those that did not show such progression. Pulse-oximetry results were not significant amongst pts before and after cast placement.

Conclusion

ARCB is a versatile and practical Tx choice. It is an effective delaying method in sparing time until surgery with no apparent cardiopulmonary compromise. Curve control was most effective in Idiopathic pts while some curve control was achieved in other etiologies which may have spared time until their eventual surgery.

77. Analysis of Chest and Diaphragm Motion in Early Onset Scoliosis with Thoracic Insufficiency Syndrome Using Dynamic MRI

Toshiaki Kotani, MD, PhD; Noriaki Kawakami, MD; Taichi Tsuji, MD; Toshiki Saito, MD; Ryoji Tauchi, MD; Tetsuya Ohara, MD; Tsuyoshi Sakuma, MD, PhD; Keita Nakayama, MD; Tsutomu Akazawa, MD, PhD; Seiji Ohtori, MD, PhD; Shohei Minami, MD, PhD

Summary

Our study analyzed chest wall and diaphragm motion in patients with thoracic insufficiency syndrome using dynamic MRI. We found no relationships between Cobb angle and respiratory motion, i.e. chest wall and diaphragm motion. However, increased Cobb angles have a negative impact on diaphragm dimensions, which can cause respiratory deterioration.

Hypothesis

There are negative relationships between Cobb angle and respiratory motion, i.e. chest wall and diaphragm motion, in patients with thoracic insufficiency syndrome.

Design

Cross sectional study

Introduction

Several studies have shown negative pulmonary function with early onset scoliosis with thoracic insufficiency syndrome. However, little is known about respiratory motion in patients. The purpose of this study was to evaluate chest wall and diaphragm motion in patients with thoracic insufficiency syndrome.

Methods

Dynamic MRI was used for 21 preoperative patients (15 females, 6 males; age 6.7 ± 1.5 years, Cobb angle 80.1° ± 23.5°) with thoracic insufficiency syndrome. Chest wall and diaphragm motions were analyzed quantitatively by measuring displacements using a cineloop view. Patients were divided into severe (Cobb angle > 80°) and mild (Cobb angle < 80°) scoliosis groups.

Results

There was no difference in chest wall and diaphragm motion between severe and mild scoliosis groups. The distance from the apex of the lung to the diaphragm at its highest point on inspiratory and expiratory coronal imaging (maximum and minimum diaphragm dimension) in the severe scoliosis group was significantly smaller than in the mild scoliosis group ($P<0.05$). There was no correlation between Cobb angle and respiratory motions. However, there was a negative correlation between Cobb angle and diaphragm dimension at inspiration and expiration ($r = -0.535, -0.508$, respectively).

Conclusion

We found no relationships between Cobb angle and respiratory motion in patients with early onset scoliosis with thoracic insufficiency syndrome. However, increased Cobb angles have a negative impact on diaphragm dimensions, which can cause respiratory deterioration.

78. Does Decreased Surgical Stress Really Improve the Psychosocial Health of EOS Patients? A Comparison of TGR and MCGR Patients Reveals Disappointing Results

Cihan Aslan, MD; Gokhan Ayik, MD; Z. Deniz Olgun, MD; Remzi Karaokur, MD; Seniz Ozusta, PhD; Gokhan Demirkiran, MD; Fatih Ünal, MD; Muharrem Yazici, MD

Summary

Magnetically-controlled growing rods (MCGR) were developed to decrease the number of surgical procedures associated with the traditional growing rod (TGR). Although the number of surgeries is decreasing, the effects on patients psychology is yet unknown. This study aims to reveal the effects of decreasing number of surgeries on patient psychology comparatively by using various psychological tools.

Hypothesis

Decreased surgical stress and number of surgeries improve the psychology of MCGR patients.

Design

Cross-sectional comparative study

Introduction

MCGR were developed to decrease the number of surgery associated with the TGR. Its clinical and radiographic efficacy have been shown to be equivalent to the TGR. The purpose of this study is to compare the psychosocial status of children undergoing MCGR and TGR procedures utilizing standardized psychiatric tools.

Methods

Inclusion criteria: EOS patients requiring surgery with MCGR or TGR; ambulatory children with normal mental parameters. Conversion patients were excluded. Psychosocial tools utilized aimed to assess quality of life and the incidence of common psychiatric disorders(Table) and were administered to children or their caregivers as appropriate by clinical staff.

Results

27 patients(17 TGR, 10 MCGR) met criteria. While average age at index surgery(6.47 yrs vs. 5.45); curve etiologies and severities were similar. Age at psychiatric assessment (13.3 yrs vs. 9.1) and length of follow-up (82.8mos vs. 45.6) were significantly different. There was no significant difference in the incidence of psychiatric diagnoses. Behavioural difficulties, hyperactivity and concentration difficulties, total difficulty and impact scores of Strengths and Difficulties Questionnaire were higher in MCGR. On the other hand, TGR group scored significantly higher in emotional functioning, school functioning, psychosocial health summary and total score of Peds Quality of Life (Table).

Conclusion
Most psychosocial parameters in this study revealed that the MCGR scored inferiorly to the TGR. The expected improvement of psychosocial status by MCGR due to decrease in surgical sessions was not observed. This may be due to the increased coping skills in TGR patients during treatment(MCGR patients may not have had enough time to adjust to their management plan); psychosocial parameters may improve with longer follow-up. However, with current data, it is impossible to report that the MCGR has brought a significant psychosocial advantage over the TGR.

Psychiatric Diagnosis	TGR(%)	MCGR(%)	General Population(%)
Depression	5.9	-	6-11
GAD	47.1	30	1.7-5
Acute Stress Disorder	-	-	8-10
Seperation Anxiety Disorder	-	10	3-5
Social Phobia	5.9	-	4-10
Specific Phobia	11.7	-	8.7
ADHD	11.8	50	5
ODD	5.9	10	2-10
Enuresis	-	10	1-2

Psychiatric Tool	TGR	MCGR	p values
SDQ - Patient Behavioral Difficulties	1	2	P=0.044
SDQ - Patient Hyperactivity and Concentration Difficulties	2.07	4.2	p= .003
SDQ - Patient Impact of Any Difficulties on the Child's Life	11	14.6	p= .032
SDQ - Patient Total Difficulties Score	5.7	10.1	p= .001
PedsQL- Patient Emotional Functioning	84.6	68.5	P= .04
PedsQL- Patient School Functioning	80	70	P= .031
PedsQL-Patient Psychosocial Health Summary Score	87.4	63.9	P= .021
PedsQL- Patient Total Score	81.2	69.5	P= .045

79. 15 year Trend Analysis of Early Onset Idiopathic Scoliosis Surgeries

Swamy Kurra, MBBS; Katherine Sullivan; Ravi Dhawan; William Lavelle, MD

Summary
Over 15 years, the complication rates and anterior surgeries were constant, posterior surgeries increased, combined surgeries decreased and hospital charges increased for idiopathic early onset scoliosis.

Hypothesis
The primary purpose of this study was to evaluate US trends in early onset idiopathic scoliosis surgeries from 1997 to 2012.

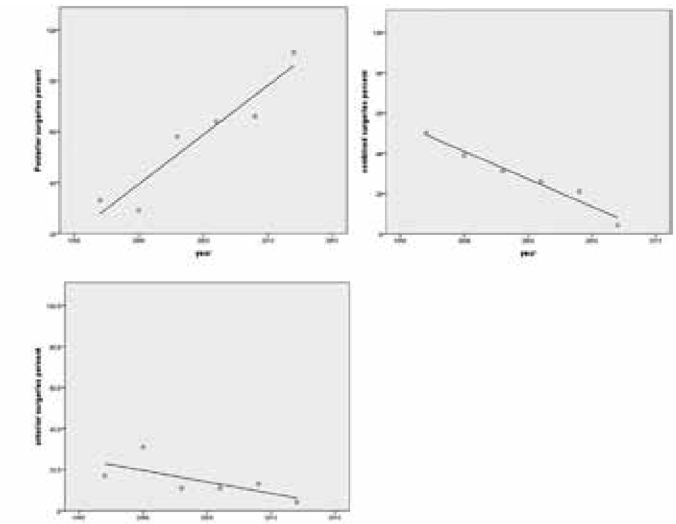
Design
Retrospective study, idiopathic scoliosis patients aged between 0 and <10 years were identified with ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) code 737.30 in the Kids Inpatient Database between 1997 and 2012.

Introduction
Early onset idiopathic scoliosis (EOS) can cause substantial morbidity and may require surgical intervention.

Methods
Posterior, anterior and combined spinal surgeries were identified for EOS through ICD-9 CM procedure codes. The patients' comorbidities, in-hospital complications, length of hospital stay (LOS) and hospital charges were analyzed for all EOS surgery patients and separately in posterior, anterior and combined surgeries. Linear regression was used to access the trend of changes.

Results
The study identified 545 patients (37% male, 63% female) who had been admitted for EOS surgery during the 15-year study period. With EOS surgery, 57% had posterior surgeries, 15% had anterior surgeries, and 28% had combined (anterior and posterior) surgeries. The mortality rate was 0.1%; length of hospital stay had a mean of 8 days; the number of co-morbidities had a mean of 5; and the mean complication rate was 6%. Hospital charges as per 2012 dollars had a mean of $119,613. Female gender, LOS, complications and co-morbidity rates were constant over the study period. Posterior surgeries increased (p=0.004), combined surgeries decreased (p=0.001), and anterior surgeries were constant (p=0.126) during this study period. (Graph 1) Complication and co-morbidity rates were constant for posterior, anterior and combined surgeries throughout. LOS significantly decreased for anterior surgeries (p=0.008), but remained constant for posterior and combined surgeries. Hospital charges significantly increased for all surgeries.

Conclusion
Over the 15-year study period, there was no change in complication rates, co-morbidity rates and length of hospital stay for early onset idiopathic scoliosis surgeries. Posterior surgery rates and hospital charges increased and combined surgeries decreased significantly.



80. Vertebral Growth Can Be Influenced by Distraction Force From Dual Growing Rods Technique: An Imaging Study Over 10 Years

Tianhua Rong, MD; Haining Tan, MD; Youxi Lin, MD; Chong Chen, MD; Xingye Li, MD; Zheng Li, MD; Jianxiong Shen, MD

Summary

Report is rare on the effect of dual growing rods distraction on vertebral growth. This study reviewed spinal radiographs of 21 scoliotic patients with at least 3 year follow-up (range, 3.0-8.5 years). Vertebral body height (VBH) was measured, and the increase percentage was calculated. The increase percentage in VBH was significantly higher in 2 segments proximal to distal instrumented vertebra (DIV) than in DIV, which indicated that distraction forces from dual growing rods may stimulate the growth of distracted segments.

Hypothesis

Dual growing rods treatment with routine distraction is able to accelerate the longitudinal growth of distracted segments.

Design

Retrospective imaging study

Introduction

Report is rare on the effect of growing rods (GR) distraction on vertebral growth. The aim of this study is to investigate the longitudinal growth near distal anchors by X-ray measurement in patients with early onset scoliosis who receive dual growing rods treatment.

Methods

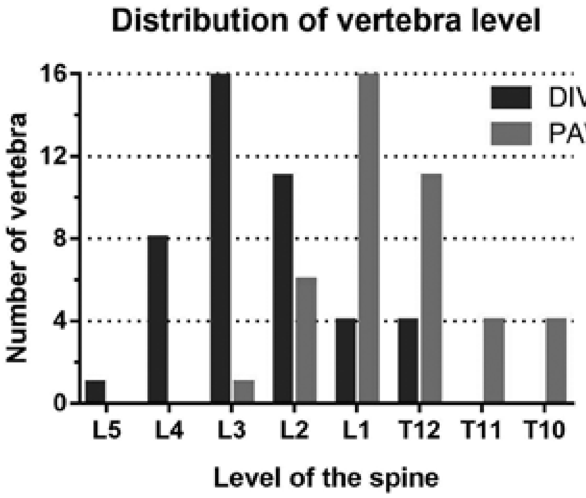
The present study enrolled 21 patients treated in our center from 2008 to 2017. Congenital scoliosis was diagnosed in 16 patients, neurofibromatosis in 3, neuromuscular and idiopathic scoliosis in 1 each. The mean age at diagnosis was 8.2±2.3 years. Average follow-up duration was 4.8 years (range, 3.0-8.5 years), during which 134 GR distractions and 9 final fusion procedures were performed. All patients were evaluated with posteroanterior spinal radiographs before initial GR implantation and after the latest surgery. The vertebral body height (VBH) was measured, and the increase percentage was calculated. Malformed vertebras were excluded. Student t test was used to compare the results between groups.

Results

The vertebras under observation were divided into distal instrumented vertebra (DIV) group (n=44) and proximal adjacent vertebra (PAV) group (i.e. 2 segments proximal to DIV, n=42). Detailed distribution of vertebra level was showed in table 1. The pre-implantation VBH was higher in DIV group, but the difference was not statistically significant (18.9±2.5mm vs. 18.0±2.2, P=0.094). At the latest follow-up, the VBH was similar in 2 groups (24.6±3.1mm vs. 25.4±2.9mm, P=0.221). However, the increase percentage in VBH was significantly higher in PAV group (41.7±11.8% vs. 30.7±9.7%, P<0.001).

Conclusion

The dual GR instrumentation do not inhibit the growth of DIV. Distraction forces from dual GR may stimulate the growth of the 2 segments proximal to DIV.



81. Reoperation in Patients with Cerebral Palsy After Spinal Fusion: Incidence, Reasons, and Impact on HRQoL

James Bennett, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Baron Lonner, MD; Peter Newton, MD; Firoz Miyanji, MD, FRCS(C); Suken Shah, MD; Burt Yaszay, MD; Paul D. Sponseller, MD; Patrick Cahill, MD; Harms Study Group; Steven Hwang, MD

Summary

Patients with cerebral palsy (CP) undergoing spinal fusion experience a high rate of reoperation, although this has not been previously quantified. This report seeks to establish rate and major reasons for reoperation in this population. We report a 13.9% reoperation rate with 7.1% due to infection and 6.8% instrumentation failure. Patients with lower percent correction were at highest risk. Reoperation impacted HRQoL scores.

Hypothesis

The reoperation rate in patients with CP is high and lowers HRQoL scores.

Design

Retrospective review of a prospective data set.

Introduction

Patients with cerebral palsy (CP) undergoing spinal fusion experience a high rate of reoperation, although this has not been previously quantified. This report seeks to establish a rate, major reasons, and effect of reoperation on HRQoL, and explore potential risk factors.

Methods

A prospectively collected multicenter database was retrospectively reviewed to identify consecutive patients with CP who had undergone spinal fusion with a minimum 2-year follow-up. We compared patients who underwent reoperation (Y) versus those who did not (N) with respect to preoperative, intraoperative, and postoperative factors.

Results

A total of 251 patients were identified with an average of 2.34 years of follow-up (SD 0.56 years). 35 patients (13.9%) underwent a total of 37 reoperations. Of the 35 patients reoperated, 18 (7.1%) were for infection and 17 (6.8%) were instrumentation related. The majority of infections were deep (17/18). Of the 17 instrumentation related reoperations, the majority were for loosening (5), prominence (5), followed by junctional kyphosis (3), broken instrumentation (2), and pseudarthrosis (2). The patients with lower percent correction of the major curve were at highest risk for a reoperation (Y=54.3% correction versus N=63.6% correction, p=0.02). Patients who underwent an unplanned return to the OR had longer hospitalizations (Y=19.5 days versus N= 10.7 days, p=<0.01, Table 1). These patients had lower comfort and emotions CPCHILD domain scores at 2 years after surgery (p=0.04), with a trend toward lower personal care scores at 2 years (p=0.08).

Conclusion

At an average of 2.34 years post-op, patients with CP who undergo spinal fusion have a significant rate of reoperation (13.9%), which impacts HRQoL and hospital length of stay. Infection, proximal junctional kyphosis, and instrumentation prominence/loosening are the most common reasons for reoperation.

Table 1

	Yes (n=35)	No (n=216)	p value
Age at Surgery ± SD (years)	14.4 ± 2.9	13.7 ± 2.6	0.15
Females N (%)	14 (41.2)	105 (48.4)	0.47
Primary Indication For Surgery			
Scoliosis N (%)	29 (82.9)	200 (92.2)	0.10
Kyphosis N (%)	6 (17.6)	17 (7.8)	
Major Cobb			
Pre-op ± SD (°)	83.9 ± 32.3	82.2 ± 23.6	0.71
2 Year ± SD (°)	33.9 ± 18.7	29.8 ± 15.6	0.17
Percent Change ± SD (%)	54.3 ± 40.0	63.6 ± 16.8	**0.02**
Pelvic Obliquity			
Pre-op ± SD (°)	26.7 ± 16.6	27.8 ± 15.7	0.73
2 Year ± SD (°)	9.9 ± 9.5	9.1 ± 8.9	0.68
Kyphosis (T5-T12)			
Pre-op ± SD (°)	42.2 ± 23.1	36.3 ± 23.3	0.19
2 Year ± SD (°)	23.3 ± 10.1	21.9 ± 10.5	0.49
Lordosis (T12-S1)			
Pre-op ± SD (°)	28.5 ± 30.6	41.0 ± 32.2	0.06
2 Year ± SD (°)	49.7 ± 19.0	54.5 ± 16.0	0.13
Estimated Blood Loss ± SD (cc)	1934.7 ± 1500.4	1658.8 ± 1206.0	0.23
Surgical Time ± SD (minutes)	427.2 ± 179.2	388.7 ± 109.7	0.09
Hospital Length of Stay ± SD (days)	19.5 ± 17.6	10.7 ± 6.9	**<0.01**
ICU Length of Stay ± SD (days)	6.3 ± 9.0	4.7 ± 5.3	0.15
Staged Procedure N (%)	4 (19.0)	21 (9.7)	0.77
Spastic CP N (%)	28 (80.0)	178 (82.0)	0.37

82. Assessing HRQOL in Cerebral Palsy Following Scoliosis Surgery

Firoz Miyanji, MD, FRCS(C); Luigi Nasto, MD, PhD; Tracey P. Bastrom, MA; Paul D. Sponseller, MD; Amer F. Samdani, MD; Suken Shah, MD; David H. Clements III, MD; Burt Yaszay, MD; Unni Narayanan, MBBS, FRCS(C), MSc; Peter Newton, MD

Summary

There is an imperative to measure meaningful benefits of scoliosis surgery in CP. The CPCHILD was developed to evaluate outcomes for this population, but its responsiveness with respect to scoliosis surgery remains unreported. We evaluated the CPCHILD questionnaire prospectively in a large, multicentre study of CP patients undergoing scoliosis surgery and found it to be responsive at 1 and 2-yr f/u in the domains of (ease of) Personal Care & ADLs; Comfort & Emotions; and overall Quality of Life.

Hypothesis

The CPCHILD is a responsive and valid tool to assess HRQoL following scoliosis surgery in CP

Design

Prospective observational cohort

Introduction

The CPCHILD questionnaire is a reliable and validated condition specific parent reported multi-dimensional outcome measure of health related quality of life for children with severe (non-ambulant) CP. Recently it has been used to assess outcomes of spinal fusion in this population with conflicting results. The aim of this study was to assess the responsiveness (sensitivity to change) of the CPCHILD questionnaire after scoliosis surgery.

Methods

Parents/primary caregivers of consecutive CP patients with ≥ 2 yrs f/u following scoliosis surgery completed CPCHILD at baseline,1 and 2-yrs post-op.Concurrently,caregivers were asked to rate on a 5 level ordinal scale their perception of the effects of surgery with respect to four items: Ease of care(EOC);Comfort(COM), General Health(GH);& overall Quality of life(QOL), at 1 and 2-year f/u.Effect size(ES) and Standardized Response Mean(SRM) for CPCHILD total and domain scores were calculated. Spearman correlation coefficients were calculated between CPCHILD score changes post-op and caregivers' responses to the 4 questions.

Results

173 patients were included. Mean age was 14yrs+/-2.6,majority were GMFCS 5 (81%).Most patients rated effect of surgery as significantly "improved" in all anchor domains(p<0.001). At 2-yr f/u CPCHILD scores also significantly improved in the Total Score(p<0.001);and for all expected domains (Personal Care(p=0.002);Positioning&Mobility(p<0.001);Comfort(p=0.005);General health(p=0.004);&Overall Quality of Life(p<0.001);but not for Communication(p=0.145). A moderate(0.50≤ES<0.80) responsiveness was observed at 2-yr f/u across the anchor responses.Strongest correlation at 2-yr f/u was noted between Total Score and anchors QOL,COM,EOC(r=0.33,0.39,0.31 respectively);quality of life domain and anchor COM(r=0.33);personal care and comfort domain and EOC(r=0.3,0.34, respectively).

Conclusion

A high level of satisfaction was noted among caregivers following scoliosis surgery at 2-yr f/u in CP patients.CPCHILD demonstrated responsiveness in domains of Quality of Life,Personal Care,Comfort,and Total Scores.

	1 YEAR F/U				2 YEAR F/U			
	QOL	COM	EOC	GH	QOL	COM	EOC	GH
Effect of Surgery:	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Improved a lot	125 (72)	121 (70)	86 (50)	94 (55)	125 (72)	116 (67)	88 (51)	100 (58)
Improved a little	34 (20)	32 (18)	41 (24)	42 (24)	27 (16)	29 (17)	44 (25)	35 (20)
% Improved	92	88	74	79	88	84	76	78
No change	2 (1)	6 (3)	25 (14)	22 (13)	4 (2)	10 (6)	17 (10)	25 (14)
Deteriorated a little	8 (5)	9 (5)	17 (10)	10 (6)	11 (6)	11 (6)	15 (9)	4 (2)
Deteriorated a lot	4 (2)	5 (3)	4 (2)	4 (2)	3 (2)	2 (1)	4 (2)	5 (3)
% No change / Deteriorated	8	11	26	21	10	13	21	19
	QOL	COM	EOC	GH	QOL	COM	EOC	GH
Responsiveness [ES (SRM)]	0.40 (0.37)	0.46 (0.43)	0.54 (0.47)	0.54 (0.84)	0.49 (0.60)	0.61 (0.67)	0.56 (0.62)	0.52 (0.51)
CPCHILD domain:	Spearman correlation coefficients (r)							
Personal care	0.16	0.26*	0.39*	0.26*	0.22*	0.21*	0.29*	0.17
Positioning	0.14	0.22*	0.25*	0.17	0.21*	0.23*	0.22*	0.13
Comfort	0.20*	0.37*	0.31*	0.23*	0.20*	0.24*	0.34*	0.16
Communication	0.13	0.21*	0.17*	0.10	0.19*	0.24*	0.08	0.12
General health	0.10	0.16*	0.10	0.08	0.12	0.10	0.11	0.13
Quality of life	0.28*	0.26*	0.24*	0.16	0.27*	0.33*	0.23*	0.27*
Total score	0.17	0.30*	0.34*	0.21*	0.33*	0.39*	0.31*	0.23*

* $p<.05$

83. Pelvic Fixation Improves Coronal Balance, Decreases Pelvic Obliquity, But is Not Essential in Neuromuscular Scoliosis (NMS)

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Summary

In non-ambulatory NMS, pelvic fixation is frequently used to improve coronal correction and level the pelvis. This study found that the change in pelvic obliquity (PO) and coronal balance was similar regardless of pelvic fixation. However, pelvic fixation does appear to achieve superior coronal and PO correction.

Hypothesis

Pelvic fixation is not required to maintain a leveled pelvis and decompensation in NMS patients undergoing PSF with all pedicle screw fixation

Design

Ambispective study

Introduction

Non-ambulatory NMS patients are typically fused to the pelvis to augment fixation, prevent loss of correction and improve seating balance. However, pelvic fixation extends the length of surgery, increases EBL, and may increase pain. This study evaluates the radiographic outcomes after PSF with all pedicle screws in NMS fixated (FP) and not fixated at the pelvis (NFP).

Methods

Radiographic measurements, OR parameters and demographics were recorded for surgeries between 2005-2016. Patients were divided into NFP and FP. Median values and Wilcoxon rank sum tests were used. Subanalysis was performed for patients with preop PO < and > 20°.

Results

There were 121 patients; 74 were non-ambulatory. Between NFP (n=47) and FP (n=27), preop Cobb (78.7 vs 66.1,p=0.14), PO (11.6 vs 16.6,p=0.09), and coronal balance (123.2 vs 86.8,p=0.41) were similar. Both had similar final Cobb (29.2 vs 20.8,p=0.09) and PO (9.3 vs 6.5,p=0.06), but NFP had significant coronal imbalance (104.4 vs 24,p<0.001). PO worsened (% change) in the NFP group from postop to final (-17.4 vs. 41.6,p=0.003). With preop PO<20 (n=46), the NFP and FP had similar preop PO (8.0 vs 9.5, p=0.73) and coronal imbalance (78.9 vs 67.1,p=0.09). At final, NFP had similar PO (7.2 vs 4.4, p=0.07) and coronal balance (59.0 vs 29.7,p=0.09) to FP. Change in PO (%) from post to final was significantly worse in NFP (-15.8 vs 51.7,p=0.002). With preop PO>20, patients had similar preop PO (22.9 vs 29,p=0.31), but significant coronal imbalance (232.3 vs 155.2,p=0.031). NFP had significantly higher final PO (20.7 vs 10.2,p=0.029) and coronal imbalance (165.1 vs 5.9,p=0.002). The change in PO (-57.7 vs -2.4,p=0.31) and coronal imbalance (-11.4 vs 4.0,p=0.71) from postop to final was similar.

Conclusion

NFP with preop PO>20 had significant coronal imbalance and PO at final follow up. Change in PO and coronal balance over time was similar between the two groups in less severe PO. PF achieves better coronal and PO correction.

84. Neural Axis Abnormalities in EOS Patients Can Be Detected With Limited MRI Sequences

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Summary

Limited spine screening MRI's with sagittal T1 and T2 for EOS patients can allow for a 67% (4/6) reduction in MRI sequences and more than 50% reduction of anesthesia time without losing the ability to detect neural axis abnormalities.

Hypothesis

Neural axis abnormalities in EOS patients can be detected on limited sequence MRI's for EOS patients.

Design

Diagnostic accuracy

Introduction

Routine spine MRI screening is recommended for the detection of neural axis abnormalities in EOS patients. However, routine MRI's are expensive, lengthy, and in this patient population generally require sedation or general anesthesia. The purpose of this study was to determine if neural axis abnormalities in EOS patients can be reliably detected with limited MRI sequences (sagittal T1, sagittal T2, axial T2).

Methods

A retrospective review of consecutive EOS patients in 2017 who received a screening cervical, thoracic, and lumbar MRI was conducted. MRI images were reviewed for pertinent neural axis abnormalities: cerebellar tonsillar ectopia, normal termination of the conus medullaris, cord signal abnormalities, and fatty filum. Three sequences (sagittal T1, sagittal T2, axial T2) of these previously reviewed MRIs were read at a separate time by an attending neuroradiologist. The imaging findings from these 3 sequences were then compared to the prior radiology report based on all of the standard MRI sequences.

Results
50 patients met criteria. 10/50 (20%) of patients had pertinent neural axis abnormalities detected on sagittal T1 + sagittal T2. No additional pertinent neural axis abnormalities were detected on review of the axial T2 sequence. When compared to the prior radiology report based on all sequences, all pertinent neural axis abnormalities were detected on sagittal T1 + sagittal T2 images. However, patient's required 90±22 minutes of anesthesia for full MRI's. Sagittal T1 + sagittal T2 sequences lasted 20±7 minutes.

Conclusion
Limited spine screening MRI's with sagittal T1 and T2 for EOS patients can allow for a 67% (4/6) reduction in MRI sequences and more than 50% reduction of anesthesia time without losing the ability to detect neural axis abnormalities.

85. Corrective Surgery for Scoliosis Associated With Spinal Cord Malformation: Is Neurosurgical Intervention Always Necessary?

Hongqi Zhang, MD; Yuxiang Wang, MD

Summary
Traditionally, neurosurgery intervention was recommended for scoliosis with SCM. In current study, for patients with no neural deficit, direct correction without neurosurgical intervention can obtain good clinical efficacy with the help of preoperative flexibility evaluation and intraoperative neuromonitor.

Hypothesis
Patients with scoliosis associated with SCM can safely and effectively undergo spinal deformity correction without neurological intervention with the help of preoperative flexibility evaluation and intraoperative neuromonitoring. For such patients with no neural deficit, neurosurgical intervention before scoliosis surgery may not be necessary.

Design
A retrospective study

Introduction
Traditionally, neurosurgery intervention was recommended for scoliosis with SCM. The objective of this study was to investigate the clinical outcomes of the surgical treatment of patients with scoliosis associated with SCM and to evaluate the necessity of neurosurgical intervention before corrective surgery.

Methods
We enrolled 127 patients with scoliosis associated with SCM who were undergoing correction surgery without neurosurgical intervention.The mean follow-up was 57 months (28-131 months). All patients are neurologically asymptomatic

Results
The groups did not differ significantly with respect to preoperative characteristics or number of levels fused. In the syringomyelia (SM) group, the correction rate was 57.2% at the last follow-up. In the tethered spinal cord (TSC) group, the correction rate was 50.7% at the last follow-up. In the type-I split spinal cord malformation (SSCM) group, the correction rate was 43.2% at the last follow-up. In the type-II SSCM group, the correction rate was 48.7% at the last follow-up. No neural injury was observed.

Conclusion
Patients with scoliosis associated with SCM can safely and effectively undergo spinal deformity correction without neurological intervention with the help of preoperative flexibility evaluation and intraoperative neuromonitoring. For such patients with intact neurological status, neurosurgical intervention prior to scoliosis surgery may not be necessary.

86. Is Prophylactic Surgery for Chiari I Malformation Necessary Previous to Scoliosis Correction?

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Summary
The association between Chiari type 1 malformation and scoliosis has been broadly described in the literature. Evidence is lacking on the need for prophylactic decompression of Chiari I previous to scoliosis surgery. Overall, 249 articles were reviewed, of which five met the inclusion criteria of the study. None of the articles had evidence level I. The results of the systematic review were inconclusive regarding data that support the recommendation of prophylactic surgery of Chiari I previous to scoliosis correction.

Hypothesis
It is possible to perform scoliosis correction in patients with Chiari type 1 without previous prophylactic decompression.

Design
Systematic review

Introduction
The association between Chiari type 1 malformation and scoliosis has been broadly described in the literature. Prophylactic suboccipital decompression of Chiari 1 malformation for the subsequent correction of scoliosis has been a common surgical procedure although in what way the spinal cord would be damaged when the procedure is not performed has not been elucidated. The aim of this study was to conduct a systematic review of the literature to look for data that would confirm our hypothesis that scoliosis correction may be performed without previous suboccipital decompression to resolve the Chiari I malformation.

Methods
A systematic review of the literature was conducted searching the MEDLINE, PUBMED, and EMBASE databases to identify articles in the English language published between 1972 and 2018 on scoliosis correction with or without prophylactic surgery for Chiari I and on the possible pathophysiological mechanisms of spinal cord damage when prophylactic intervention is not performed. Exclusion criteria were patients with bone and intraspinal congenital anomalies, tumors, inflammatory processes, among others, and patients older than 20 years.

Results
Overall, 249 articles were reviewed and only five met the inclu-

sion criteria. Two articles were retrospective studies, one was an expert opinion, and two were case reports. All studies presented recommendations type c and b, none had evidence level type I, and internal validity was weak.

Conclusion
The results of the systematic review were inconclusive regarding the recommendation of prophylactic surgery for Chiari I in patients with spine deformity due to a lack of scientific evidence in the literature on this procedure.

87. Spinal Correction Surgery Enables Long-Term Relief of Gastroesophageal Reflux Disease Symptoms in Adult Spinal Deformity

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Summary
We investigated gastroesophageal reflux disease (GERD) symptoms by using questionnaire of frequency scale for the symptoms of GERD (FSSG) in 230 adult spinal deformity patients. Mean follow up periods was 4.2 years. 90(39%) patients had GERD symptoms. In 78 (87%) of the 90 patients, GERD symptoms immediately improved directly after operation. Furthermore the improvement was maintained throughout the second postoperative year in 67(87%) of the 78 patients.

Hypothesis
Adult spinal deformity patients frequently have gastroesophageal reflux disease (GERD) symptoms. Spinal corrective surgery can improve the symptoms and maintain the improvement.

Design
Case series

Introduction
GERD is reported to be one of the complications for adult spinal deformity. We previously reported the impact of spinal correction on GERD mucosal damage relief. However the long-term effect of the spinal correction on GERD symptom is yet to be revealed.

Methods
We investigated 230 adult spinal deformity patients over the age of 18. We estimated the patients using the frequency scale for the symptoms of GERD (FSSG) with cut-off value 8 points for diagnosis. Patients were also investigated TK, LL, PT, SS, PI, T1 slope, SVA, coronal Cobb angle and existence of vertebral fractures in whole spine standing X-ray film at preoperatively, first standing, 1 year, 2 years and 5 years after the operation.

Results
230 cases consisted of 35 males and 195 females. Mean age was 63.7. Mean BMI was 22.6. Mean number of fusion vertebrae was 9.9. Mean preoperative FSSG was 7.8. Mean follow up period was 4.2 years. All cases were followed at least 2 years and 29 cases were followed over 5 years. In these cases, radiographic parameters significantly improved ($P<0.001$ respectively). Preoperatively 90 (39.1%) patients were diagnosed GERD with having 8 points or more examined by FSSG. Among these 90 patients, 78 (86.7%) showed any improvement of the score immediate after surgery. Preoperative FSSG values significantly improved from 16.0 to 4.8 immediately after the operation and was maintained at the first and second postoperative year with the scores of 8.6 and 8.6 ($p<0.001$). 29 patients were followed over 5 years and their FSSG values (7.3) at fifth year maintained significantly lower than preoperative scores ($p<0.001$).

Conclusion
In adult spinal deformity patients, GERD symptoms are immediately improved directly after operation and the improvement is maintained throughout the second postoperative year. Thus patients with GERD symptoms due to adult spinal deformity have good operative indication for deformity correction.

88. Patient Expectations About Relief of Back Pain Are Predictive of Pain Levels at Long Term Follow Up in Adult Spinal Deformity Surgery

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Summary
Patient expectations about improvement in outcomes have been recently gaining attention as important psychosocial modulators of pain perception in various disease states. Our results show that adult spinal deformity (ASD) patients with lower preoperative expectations for relief of back pain only differed with respect to mental health status From their counterparts. Despite the similarities, our results show that patients with higher expectations have lower pain levels on two different outcome measures on long term follow up.

Hypothesis
Preoperative patient expectations for pain relief are predictive of pain levels at long term follow up.

Design
Retrospective cohort.

Introduction
Patients' expectations have been recently gaining attention as commonly overlooked, yet important psychosocial modulators of pain perception. We aim to identify risk factors for having low expectations and the implications of that on long term pain perception in ASD surgery patients.

Methods
A two-year follow up ASD surgery registry at our institution was analyzed for patients who completed a survey question about their expectation for relief from back pain. Preoperative patient education was standardized. 5 ordinal answer choices to "I expect my back pain to improve" were used to divide patients into 2 groups: 1) Low: Not at all, slightly or somewhat likely 2) High: Very or Extremely likely to gain relief from back pain. 2 groups were compared with respect to demographics, surgical factors, baseline radiographic deformity and Patient Reported Outcomes

(PRO).

Results
Of the 134 ASD surgical patients with minimum 2-year follow up, 105 (78%) had preoperative data on patient expectations. 85 of those had high expectations. The high and low groups were similar with respect to age, gender, number of instrumented vertebrae and whether a 3-column osteotomy was performed ($p>0.05$). At baseline, patients had similar radiographic deformity parameters ($p>0.05$). Back pain levels measured by an 11-item numeric rating scale (NRS) and SRS22r-Pain were also similar at baseline($p>0.05$). Interestingly, only SRS-22r Mental Health was lower in patients with low expectations (2.88 vs 3.33, $p=0.02$). Figure1. After controlling for baseline NSR, "High Expectations" had significantly lower pain levels at last follow up (Diff: -1.9; CI [-3.7, -0.16]; $p=0.03$). Similarly, higher SRS22r-pain in "High Expectations" group was seen at last follow up (Diff: 0.65; CI [0.09, 1.2]; $p=0.03$).

Conclusion
Despite the similarities between patients with high and low expectations, the latter seems to have higher levels of pain at long term follow up based on two outcome measures.

	Low Expectations (N=20)	High Expectations (N=85)	p-Value
Age	57 (SD=11)	59 (SD=12)	0.23
Women	65% (N=13)	79% (N=64)	0.35
Number of Instrumented Vertebrae	9.7 (SD=3.5)	9.4 (SD=3.6)	0.79
3 Column Osteotomy	45% (N=9)	34% (N=29)	0.36
Baseline Radiographic Deformity			
C7-S1 Sagittal Vertical Axis (cm)	10.5 (SD=8.4)	9.5 (SD=10.1)	0.67
T12-T4 Thoracic Kyphosis	39 (SD=21)	36 (SD=20)	0.57
Thoracolumbar Cobb (T12-L4)	17 (SD=17)	15 (SD=20)	0.09
Baseline PRO			
Analogue Scale- Back Pain (0-10)	8.1 (SD=2.3)	7.1 (SD=3.6)	0.23
ODI	51.7 (SD=19)	46.4 (SD=16)	0.2
SRS22r-Pain	2.25 (SD=0.86)	2.4 (SD=0.83)	0.6
SRS22r-Physical Function	2.5 (SD=0.69)	2.6 (SD=0.73)	0.9
SRS22r-Self Image	2.26 (N=0.82)	2.39 (SD=0.79)	0.51
**SRS22r-Mental Health ** **	**2.88 (SD=0.80)**	**3.33 (SD=0.75)**	**0.02 ** **
SRS22r-Satisfaction	2.5 (SD=0.99)	2.76 (SD=1.03)	0.39

89. Gait Analysis to Evaluate Global Compensatory Mechanisms Including Spine, Pelvis, and Lower Extremities in Patients with Fixed Sagittal Imbalance

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Summary
42 patients with fixed sagittal imbalance (FSI) underwent 3-dimensional gait analysis to evaluate global compensatory mechanisms including spine, pelvis, and lower extremities. Large pelvic-retroversion (LR) group demonstrated more severe sagittal imbalance than small pelvic-retroversion (SR) group at all time points of measurement. All the patients with FSI kept their hip and knee flexion to prevent falling forward during walking. Tendency of the walking manner with hip and knee flexion was more apparent in LR group than SR group.

Hypothesis
Dynamic compensatory mechanisms can work by not only spinopelvic complex but lower extremities during walking.

Design
Gait analysis to evaluate global compensatory mechanisms using 3D motion analysis system (3D-MAS).

Introduction
Aim was to evaluate global compensatory mechanisms including spine, pelvis, and lower extremities using 3D-MAS in patients with fixed sagittal imbalance (FSI).

Methods
42 FSI patients underwent gait analysis. Trunk angle (TA) was the angle between vertical axis and the line connecting reflection markers on C7 and S1. Sagittal trunk shift (STS) was the distance between two vertical lines running through C7 and S1. Pelvic angle (PA) was the angle between horizontal axis and the line connecting posterior and anterior superior iliac spine. PA represents retroversion (-) or anteversion (+). Hip angle (HA) and knee angle (KA) was the angle of trunk-femoral axis and femoral-tibial axis, respectively. Maximum extension and flexion in HA and KA was HEmax, HFmax, KEmax, and KFmax, respectively. These parameters were measured before walking, at the first fifth step (F5), and at the last fifth step (L5). They were compared between large pelvic retroversion (LR) group (PA ≤ 0°) and small pelvic retroversion (SR) group (PA>0°).

Results
There were 30 patients in LR group and 12 in SR group. TA (°) at each measurement time point (LR vs SR) was 17.9 vs 11.6*, 24.6 vs 14.5*, 33.6 vs 20.9*. STS (cm) was 13.3 vs 8.2*, 17.6 vs 11.1*, and 25.6 vs 15.7*. PA (°) was -7.7 vs 3.2*, 21.6 vs 20.1, and 27.9 vs 24.2. HEmax and HFmax (°) at F5 was 26.8 vs 15.0* and 58.3 vs 46.1*. HEmax and HFmax (°) at L5 was 33.4 vs 26.3 and 58.4 vs 50.4. KEmax and KFmax at F5 was 19.9 vs 12.8** and 57.7 vs 55.2. KEmax and KFmax at L5 was 19.8 vs 15.0 and 54.6 vs 55.5. (*$p<0.05$, **$p=0.06$).

Conclusion
LR group demonstrated more severe sagittal imbalance than SR group at all time points of measurement. All the patients with FSI kept their hip and knee flexion to prevent falling forward during walking. Tendency of these walking manner was more apparent in LR group than SR group.

90. Restoring The Spinal Shape In Adult Spinal Deformity According To The Roussouly Classification And Its Effect On Mechanical Complications: A Multicentric Study.

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Summary
Adult Spine Deformity (ASD) surgery still lacks clear treatment consensus. This retrospective multicentric study with a minimum 2 years follow up performed on 314 patients operated on with fusion for ASD evaluated the incidence of mechanical complications (proximal junctional kyphosis, instrumentation failure, etc.) according to a treatment algorithm that is based on Rous-

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souly's recent classification of the degenerative spine. This study shows that ignoring this algorithm is associated with a fivefold increase in mechanical complications occurrence.

Hypothesis

Evaluate the incidence of mechanical complications according to a proposed treatment algorithm based on the Roussouly's classification of degenerative spine.

Design

Retrospective multicentric study with a minimum 2 years follow-up.

Introduction

Surgery of adult spinal deformity (ASD) is associated with high rates of mechanical failures (non-union, proximal junctional kyphosis (PJK) etc) still lacking clear treatment consensus. Implementing the newly proposed Roussouly classification for the degenerative spine could potentially allow for a new algorithm in the treatment of ASD based on spinal shape. The restoration of original spine shape according the original Roussouly classification has never been evaluated in a consecutive cohort of ASD patients,

Methods

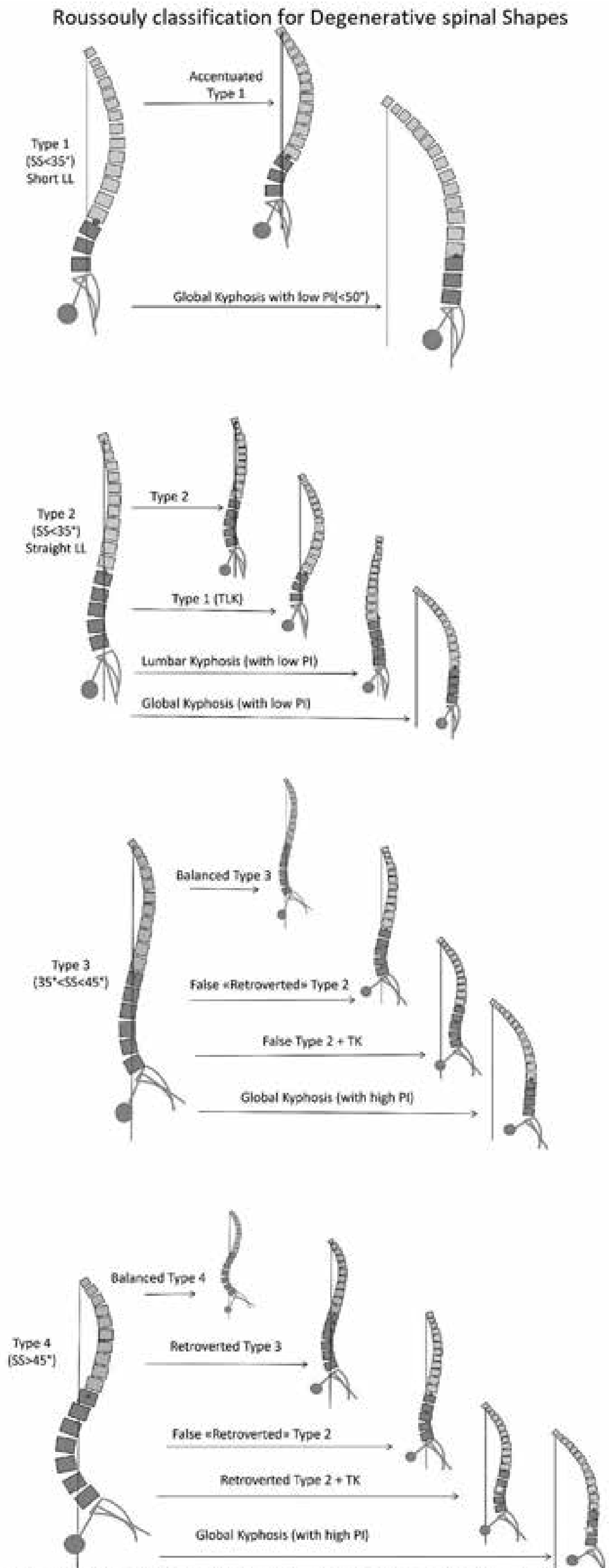
Patients operated on with fusion for ASD (minimum a fusion of L2 to the sacrum performed) were included. Patients with a history of previous spinal fusion of more than three levels were excluded. Spinal and pelvic parameters were measured on the preoperative and their immediate postoperative follow-up. All mechanical complications were recorded.

Results

314 patients met the criteria of inclusion with a minimum follow-up of 2 years. Mechanical complications occurred in 34% of the cohort. The most common complication was PJK with an incidence of 20.5% while non-union or instrumentation failure (rod breakage, implant failure) occurred in 14.4%. Sixty-five percent of the patients were operated according to the proposed algorithm and had mechanical complication rate of 22% whereas the remaining patients had a complication rate of 51.4% ($p<0.001$). The relative risk for developing a mechanical complication if the algorithm was not met was 4.97 (CI: 2.8-9; $p<0.001$)

Conclusion

In the recent literature, there are no clear guidelines for ASD correction. The proposed algorithm could serve as a guideline for the treatment of ASD since it focuses on the entire spinal shape according to the Roussouly classification. Ignoring this algorithm have a fivefold risk of increasing mechanical complications. We recommend this algorithm for treatment of ASD.



Sebaaly A, Grobost P, Mallam L, Roussouly P. Description of the sagittal alignment of the degenerative human spine. Eur Spine J. 2017 Nov 24

91. Is it Possible to Classify Adult Scoliosis Patients by Roussouly´s Classification?

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Summary
It is important to determine the appropriate individual sagittal profile when planning surgical spine restoration. A prospective, multicenter, adult deformity database was analyzed to determine whether the Roussouly sagittal profile classification could be applied to 190 adult scoliosis patients. We found that the 4 Roussouly types can be recognized in this population. In addition, we defined 2 new parameters that help classify the sagittal profile (T10-L2 angle and L4-S1 percentage contribution to total lordosis).

Hypothesis
Roussouly´s classification is reproducible in adult scoliosis patients.

Design
Retrospective analysis of adult scoliosis patients recorded in a prospective multicenter database.

Introduction
Roussouly described a 4-type sagittal profile classification in healthy individuals. Surgical restoration of the appropriate sagittal profile in patients with degenerative spinal disease is gaining importance. It remains uncertain which parameters indicate the sagittal profile type in deformity patients.

Methods
Preoperative sagittal radiographs were analyzed using the image software programme to measure pelvic parameters, global sagittal alignment, and the various criteria/parameters used in the Roussouly classification. A comparative analysis was performed by ANOVA wit

Results
In total, 190 adult scoliosis patients were analyzed (mean age 49±18 years, coronal thoracic Cobb angle 40.7º±21, coronal lumbar Cobb angle 43.4º±17). The results enabled classification of patients according to the 4 sagittal profiles. Types 3 and 4 were associated with younger age and idiopathic etiology (P<0.001). Type 1 was associated with older patients (P=0.02) and those with greater pelvic incidence-lumbar lordosis mismatch (P=0.012), suggesting that the higher types may end up in type 1 due to the degenerative process. Roussouly type was not associated with sagittal alignment parameters (T1ST, GT, SVA). In addition to the Roussouly criteria (pelvic incidence, number of lordotic vertebra, lumbar apex, and inflexion point), we defined 2 new parameters that helped differentiate between the various profiles: T10-L2 angle (24º±19 type 1; 14º±15 type 2; 3º±15 type 3; 0.4º±14 type 4) (P<0.001) and L4-S1 percentage contribution to total lordosis (90%±17 type 1; 83%±16 type 2; 73%±21 type 3; 63%±16 type 4) (P<0.001).

Conclusion
The results of this study show (for the first time) that Roussouly's 4 sagittal profile types can be recognized in patients with adult scoliosis, thus facilitating appropriate planning for surgical restoration of the profile. In addition, 2 parameters that help classify the sagittal profile were defined (T10-L2 angle and percentage of L4-S1 contribution to total lordosis).

92. Any Vertebral Segment May Be Chosen as Upper-Instrumented Vertebra If Ideal Individualized Sagittal Shape and Alignment is Reached

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Summary
In an analysis of 379 adult spinal deformity patients, PJK/PJF rates were found to be lower for all UIV locations , when sagittal plane restoration was performed according to the individualized sagittal plane shape and alignment.

Hypothesis
Occurrence of PJK/PJF is more related to the post-operative sagittal alignment than the selection of UIV.

Design
Retrospective analysis of a prospectively collected data of adult spinal deformity patients.

Introduction
PJK/PJF incidence has been reported to decrease as UIV gets higher, due to reduction of stressors at the proximal junctional segments. Thus, selecting a higher UIV and avoiding to stop at TL junction and kyphotic apex was recommended. However, the role of proper sagittal plane reconstruction for different UIV levels in avoiding PJK/PJF has not been well investigated. The aim was to compare PJK/PJF rates of different anatomic UIV locations in patients that reached different postoperative sagittal shape and alignment.

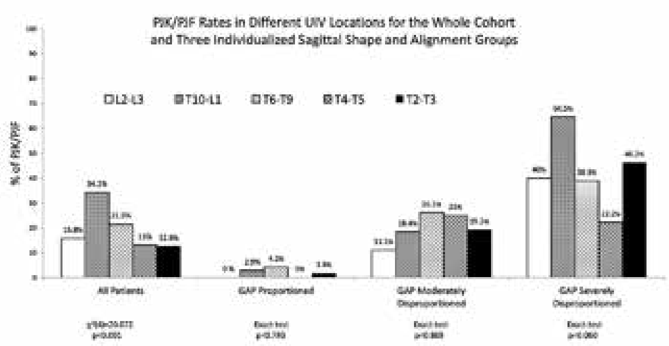
Methods
Inclusion criteria: ≥4 levels fusion, and ≥2y f/up. PJK was defined as UIV - UIV+2 angle ≥20° and to have ≥10° increase between early postop and follow-up radiographs. PJF was defined as fracture of UIV or UIV+1, hook dislodgement, pullout or cutout of instrumentation at UIV, and/or sagittal subluxation. UIV location was divided into 5 anatomic regions: L2-L3, T10-L1, T6-T9, T4-5 and T2-3. The Global Alignment and Proportion (GAP) score was used to postoperatively divide patients into 3 sagittal shape and alignment groups: Proportioned (GAP-P), Moderately Disproportioned (GAP-MD) and Severely Disproportioned (GAP-SD). PJK/PJF rates were compared using Chi-squared tests.

Results
379 pts (303F, 77M) were included. Mean age: 53.1±19.3(18-84) years. Mean f/up: 32.0±10.2(24-65) months. 150 pts were GAP-P, while 128 and 108 were GAP-MD and GAP–SD, respectively. For the whole cohort, PJK/PJF rates differed in UIV

categories, TL junction having the highest, and Upper Thoracic having the lowest rates (p<0.001). When each GAP group was analyzed, PJK/PJF rates were similar in all UIV categories (p=0.793, p=0.869, and p=0.060, respectively). PJK/PJF rates were lower in GAP-P groups (p<0.01) (Fig 1).

Conclusion

None of the UIV locations are immune to PJK/PJF. However, in case of proper sagittal plane reconstruction to the individualized ideal shape and alignment, all anatomic UIV levels are less prone to PJK/PJF.



93. Spinal Sagittal Realignment after Osteotomy on Healed Thoracolumbar Osteoporotic Fracture-related Kyphosis

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Summary

Forty-eight consecutive healed thoracolumbar osteoporotic fracture (TLOF)-related kyphosis patients underwent osteotomy were included in this cohort. Osteotomy effectively realigned the global spine and the realignment of thoracolumbar sagittal segments significantly improved the HRQoL.

Hypothesis

Osteotomy on healed TLOF-related kyphosis could realign the global spine and improve the HRQoL.

Design

A Prospective study.

Introduction

Healed TLOF-related kyphosis is likely to develop into severe sagittal malalignment which permanently influences patients HRQoL. Few study reported the change of global spinal alignment and improvement of HRQoL after osteotomy in this scenario. This study is to investigate the effect of osteotomy on realign the global spine as well as the significant sagittal parameter associated with the improvement of HRQoL.

Methods

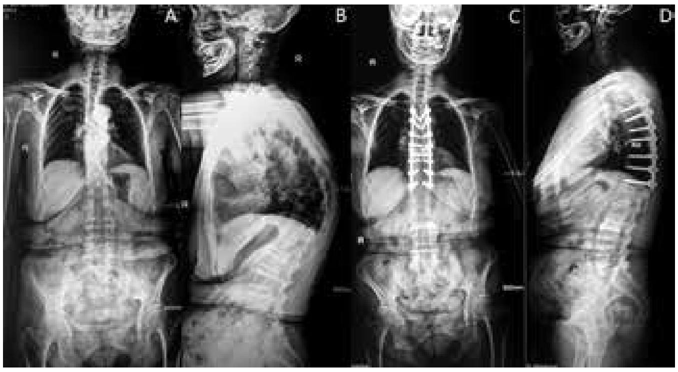
Consecutive healed TLOF-related kyphosis patients underwent osteotomy with 2-year follow-up were included in this cohort. MRI, CT and upright X-ray of spine were taken pre- and postoperatively. Spinal sagittal alignment parameters including T2-T12 cobb angle (TK), T10-L2 cobb angle (TL), L1-S1 cobb angle (LL), T9 tilt, L1 tilt, sacral slope (SS), pelvic tilt (PT), SVA, pelvic incidence (PI) and sacral spinal angle(SSA) were measured. ODI, SF-36 PCS and SRS-22 were assessed pre- and postoperatively. Significant independent parameters associated with HRQoL were analyzed first by correlation analysis, and then by stepwise regression analysis.

Results

Total 48 patients (35 female, 13male) were included with mean age of 62.9±9.6. The mean BMI was 23.7±4.2 and T-score was -2.67±0.65. TK, TL, LL, T9 tilt, L1 tilt, SS, PT, SVA, SSA except PI were significantly improved after osteotomy(P<0.05). ODI, SF-36 PCS and SRS-22 were significantly improved from 55.4 ± 14.3, 30.7 ± 11.4, 2.7 ±1.1 to 30.2 ± 10.5(P<0.001), 39.6±7.8(P<0.001), 3.9 ± 0.7(P<0.001), respectively. Correlation analysis showed that the change of TL, LL, PT, SVA, SSA were associated with the improvement of ODI, SF-36 PCS and SRS-22. Stepwise regression indicated that the change of TL and PT were identified as parameters significantly correlated with ODI, the change of TL and SVA were correlated with SF-36 PCS, the change of TL was correlated with SRS-22.

Conclusion

Osteotomy can effectively correct the healed TLOF-related kyphosis and realign the global spine. The realignment of TL was the independent parameter to improve the HRQoL.



94. Comparison of 3 Lumbopelvic Fixation Techniques in Long Fusion to the Sacrum in Osteoporotic Adult Spinal Deformity Pts (>60 Yrs): Clinical and Radiological Outcomes

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Summary

When three different lumbopelvic fixation techniques; traditional iliac screw (TIS), distal iliac screw (DIS) and S2 alar-iliac screw (S2AI) were compared with respect to complication rates, S2AI fixation had the lowest rate of complications including implant related complications, hematoma, surgical site infections (SSI), and sacroiliac joint dissociation (SID) in severe osteoporotic adult spinal deformity (ASD) patients.

Hypothesis

S2AI fixation technique had the lowest complication rates when widest & longest screws were used in osteoporotic ASD

Design
Retrospective

Introduction
Iliac screw techniques provide additional biomechanical stabilization to S1 in long fusion to the sacrum. Recently S2AI fixation became more popular than TIS (entry point posterior superior iliac spine), and DIS (entry point posterior inferior iliac spine) due to the lower implant profile and need for less extensive soft tissue dissection. S2AI fixes the SI joint differently from TIS and DIS. This study aimed to compare the clinical and radiologic outcomes between TIS, DIS & S2AI fixation in osteoporotic ASD pts

Methods
158(103f, 55m) ASD pts who underwent long fusion to the sacrum with 3 different iliac screw techniques (TIS, DIS, S2AI) were reviewed. Radiologic parameters were compared between preop and f/up standing x-rays.Hospital charts and f/up CT scans were used to compare the screw lengths, diameters,and implant related complications including S1 and iliac screw loosening,rod breakage, SID, SSI,& hematoma.ODI scores were compared for clinical assessment

Results
54 pts had TIS,51 pts had DIS, 53 pts had S2AI fixation.Mean ages were 67, 71,68; mean f/up was 54.2(24-174) months,respectively. Iliac screw lengths were 85 mm, 90 mm, 105 mm;-diameters were 9.0mm,8.5mm,9.5mm for TIS,DIS, S2AI respectively. There were 7 pts(12.9%) in TIS, 6 pts(11.7%) in DIS & 3 pts(5.6%) in S2AI with implant related complications. 1 pt(1.8%) in TIS and 1 pt(1.9%) in DIS group showed SID (TIS=1,DIS=1,S2AI=0). Postop hematoma was detected in 14 pts(8.8%) (TIS=4, DIS=7, S2AI=3) and SSI developed in 2 pts(1.2%)(TIS=1, DIS=1, S2AI=0). ODI scores improved in all groups

Conclusion
All techniques provided sufficient stability for lumbosacral fusion in ASD pts. S2AI technique showed lower implant related complication rates when compared to both iliac screw techniques. TIS &DIS had higher rates of hematoma & SSI due to extensive soft tissue dissection compared to S2AI. S2AI does not lead to SI joint dissociation as it provides stability by fixing the SI joint.

	Traditional Iliac Screw (n=54)	Distal Iliac Screw (n=51)	S2 alar-iliac screw (n=53)
Implant related complication	7 (12.9%)	6 (11.7%)	3 (5.7%)
Sacroiliac joint dissociation	1 (1.8%)	1 (1.9%)	0
Hematoma	4 (7.4%)	7 (13.7%)	3 (5.7%)
Surgical site infection	1 (1.8%)	1 (1.9%)	0

95. Outcome Evaluation: HRQoL vs Patient Satisfaction

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Summary
For ASD patients the relationship between health-related quality of life (HRQoL) measures, post-operative complications, and self-reported satisfaction remains unclear. This study suggests that low satisfaction might be a relevant driver of surgery. Surgery is associated to an increase in satisfaction that has its peak at 6mFU, progressively diminishing and being almost gone at 2yFU. At 2yFU, patients having experienced a major complication are less satisfied than nonop patients.

Hypothesis
Patient self-reported satisfaction behaves differently than the HRQoL scores.

Design
Multicenter retrospective analysis of prospectively enrolled ASD patients.

Introduction
The surgical treatment of adult spinal deformity (ASD) improves HRQoL but is associated with a non-negligible rate of complications. Patient's satisfaction after the treatment can be altered by the event of complications and be more relevant to the HRQoL scores. For ASD patients receiving operative (op) and non-operative (nonop) treatment, the relationship between HRQoL measures, complications, and self-reported satisfaction remains unclear. The objective of this analysis is to study non-linear association dynamics between ASD patient satisfaction, HRQoL and complications over a 2yFU time horizon.

Methods
1546 patients included in a prospective multicenter ASD database (688 op and 858 nonop) were analyzed. Major complications were identified (McDonnel et al). We performed a total of 12 LOESS (local polynomial fit) regressions between patient satisfaction (SRS22 item 21) and HRQoL measures (ODI, SF-36PCS and SRS22subtotal) interacting with surgery and surgical complication dummies at baseline, 6mFU), 1yFU and 2yFU.

Results
There are no significant differences in satisfaction at baseline between op and nonop patients at low levels of HRQoL (table). For better HRQoL scores, satisfaction is significantly lower in op patients. At 6mFU op patients (with or without complications) are significantly more satisfied at all HRQoL levels ($p<0.001$). At 1yFY, these differences are reduced by 50% and are significant only for intermediate HRQoL. Major complications are associated with a decrease in satisfaction after 1yFY. At 1yFU, the 6mFU increase in satisfaction has reduced almost to a fifth of the original size and is only significant between intermediate HRQoL.

Conclusion
This study suggests that at baseline, satisfaction might be the driver of surgery. Op patients report an increase in satisfaction after surgery that has its peak at 6mFU, progressively diminishing and being almost gone at 2yFU. At 2yFU, patients having experienced a major complication experience even lower levels of satisfaction than nonop patients.

	NonOp					Op				
	Mean	SD	SE	Δ	p	Mean	SD	SE	Δ	p
SF36 PCS Baseline/PreOp	42,28	9,80	0,34			36,55	9,23	0,37		
SF36 PCS 6 months	42,17	9,94	0,41	-0,12	0,83	40,28	8,64	0,40	3,73	0,00
SF36 PCS 1 year	42,27	10,32	0,47	-0,01	0,99	42,17	9,72	0,48	5,62	0,00
SF36 PCS 2 years	43,20	10,58	0,59	0,92	0,22	41,61	10,45	0,66	5,05	0,00
SRS22 subtotal Baseline/PreOp	3,43	0,73	0,03			2,83	0,68	0,03		
SRS22 subtotal 6 months	3,44	0,76	0,03	0,01	0,76	3,41	0,69	0,03	0,58	0,00
SRS22 subtotal 1 year	3,46	0,79	0,04	0,04	0,42	3,54	0,72	0,04	0,71	0,00
SRS22 subtotal 2 years	3,50	0,81	0,04	0,07	0,19	3,44	0,85	0,05	0,60	0,00
ODI Baseline	25,55	18,72	0,65			40,13	20,68	0,81		
ODI 6 months	24,32	18,31	0,75	-1,23	0,21	30,21	18,40	0,82	-9,92	0,00
ODI 1 year	24,20	18,60	0,84	-0,12	0,24	27,57	18,52	0,91	-12,55	0,00
ODI 2 years	22,37	17,99	1,02	-1,83	0,02	29,87	20,97	1,31	-10,26	0,00
SRS22 satisfaction Baseline/PreOp	3,71	1,02	0,04			3,07	1,07	0,06		
SRS22 satisfaction 6 months	3,59	1,04	0,05	-0,12	0,07	4,20	0,89	0,04	1,12	0,00
SRS22 satisfaction 1 year	3,64	1,06	0,05	-0,06	0,37	4,14	0,97	0,05	1,06	0,00
SRS22 satisfaction 2 years	3,75	1,01	0,06	0,04	0,60	4,00	1,05	0,07	0,92	0,00

96. Impact of Paraspinal Muscle Degeneration on Fatigue of Spinopelvic Compensatory Mechanism in Sagittal Plane Adult Spinal Deformity: Quantitative Assessment of MRI and Sagittal Parameters After 10 Minutes of Walking

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Summary
In ASD, compensatory mechanism to maintain adequate sagittal balance is based on para-spinal muscles (PSM). Patients were divided into two groups: "Decompensated sagittal deformity (DSD)" and "Compensated sagittal deformity (CSD)". DSD had profound degeneration of PSM by its volume at TL junction and quality at the lower lumbar spine. Fatigue in lumbopelvic compensation is dependent on PSM at the lower lumbar spine in CSD. Lumbar extensor strengthening exercise could be helpful for improving fatigue resistance to prevent decompensation in CSD.

Hypothesis
Sagittal decompensation by fatigue in "Compensated sagittal deformity" is related with para-spinal muscle status.

Design
Retrospective review of prospectively collected data

Introduction
In ASD, compensatory mechanism to maintain adequate sagittal balance is based on para-spinal muscles (PSM). However, there is limited understanding of how sagittal parameters and compensatory changes due to fatigue are affected by PSM.

Methods
Spinal sagittal parameters were measured on full-length standing radiographs before and after walking for 10 minutes in two groups: Compensated Sagittal Deformity (CSD: SVA≤4cm and PT>200) and Decompensated Sagittal Deformity (DSD: SVA>4cm and PT>200). The cross-sectional area of psoas at L3, PSM at T12 and L4 and its ratio with each vertebral body were measured in axial T2WI. The lean muscle mass (LM) and fatty infiltration (FI) into PSM was determined with pseudo-color mapping. The mean signal intensity (SI) of the muscle was measured using a histogram.

Results
145 patients (mean 68.1yrs) were included. Initial mean SVA was 1.8cm for CSD and 11cm for DSD (p<.01). After walking, significant deteriorations in SVA were observed by decreased PT and LL (p<.01) in CSD without significant change in TK, while SVA changes for DSD was correlated to worsening of all parameters (p<.01). PSM degeneration was more deteriorated in DSD. In CSD, correlation was observed between ΔLL-PSM(L4) (r=-.412, p=.046) and ΔPT-FI(L4) (r=.407, p=.048). However, weak correlation was observed in DSD. Regression for FI(L4) was predictive of ΔSVA (R2=.33, p=.003), ΔPT (R2=.166, p=.048) and regression for PSM(L4) was predictive of ΔLL (R2=.17, p=.046) in CSD.

Conclusion
DSD had profound degeneration of PSM by its volume at TL junction and quality at the lower lumbar spine. Fatigue in pelvic and lumbar compensation is dependent on PSM at the lower lumbar spine in CSD. However, fatigue resistance in DSD is less related with PSM. Lumbar extensor strengthening exercise could be helpful for improving fatigue resistance to prevent sagittal decompensation in CSD.

97. Both Bone and Muscle Quality Influence Reciprocal Change in the Thoracic Spine

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Summary
Bone and soft tissue quality both may play a role in post-operative spinal alignment. This study aims to investigate the relationship between thoracic reciprocal changes following ASD surgery and muscles/bone quality using CT-scan based measurements. This combined radiographic/CT-scan analysis revealed that larger muscles, greater fat infiltration, and lower bone quality were influenced post-operative reciprocal changes in the thoracic spine.

Hypothesis
Thoracic kyphosis and PJK are affected by poor muscle and bone quality.

Design
Retrospective review, single center.

Introduction
CT-scans are obtained in a calibrated environment that can calculate and identify specific tissues densities based on Hounsfield units (HU); this provides a unique opportunity to analyze both bony elements and soft tissues in a single study. This study aims to investigate the relationship between thoracic reciprocal changes in ASD surgery and muscles/bone quality using CT-scan based measurements.

Methods
Operative adult spinal deformity (ASD) pts, with at least 6 months FU, preop CT-scans, and pre/post scoliosis films were included. In addition to the classic radiographic spino-pelvic parameters, muscles and bone analysis was conducted at T2, T10, and L3 (3 slices per vertebra). Cross-sectional area (CSA) and fat (-100 to -50HU) percentages were calculated for the erector spinae. Vertebral bodies densities (excluding cortical margins) was

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expressed as the mean HU. Correlation analysis was conducted between alignment change and muscle/bone quality.

Results

61 pts met the inclusion criteria (58yo, 80%F, 25.8kg/m2) with a mean FU of 1Y. The average fat infiltration was 8% at T2, 6% at T10, and 11% at L3. There was a significant change in pre to post alignment (all p<0.001), in PI-LL (14°vs-3°), TPA (22°vs11°), and with a mean 9° increase in ΔTK (kyphosis), and a PJK of 10°. ΔTK significantly correlated with the CSA of the posterior muscles at T2 (r=0.546), indicating that the larger muscles were associated with an increase in TK. ΔPJK significantly correlated with the fat infiltration of the posterior muscles at L3 (r=0.388), suggesting that a greater fat infiltration was associated with a greater PJK. PJK patients with a UIV in UT spine had significantly smaller vertebral bodies density (150.5HU vs 214.8HU p=0.041)

Conclusion

This combined radiographic/CT-scan analysis revealed that larger muscles (e.g. more solicited pre-op due to compensation), greater fat infiltration, and lower bone quality were associated larger PJK/ changes in thoracic spine. These preliminary results warrant further focus on bone/muscle quality and sagittal alignment.

98. 5 Year Outcomes of Three Column Osteotomies for Correction of Adult Spinal Deformity in Elderly Patients

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Summary

Although three column osteotomies may improve sagittal balance in the elderly adult spinal deformity patients, few studies report on their long-term outcomes in this patient population. Over five years post-operatively, patients reported improved health related quality of life measures, despite a high revision rate (37%).

Hypothesis

Three column osteotomies significantly improve elderly patients' spinal alignment and quality of life at five years post-operatively.

Design

Retrospective analysis of prospectively collected data.

Introduction

Three column osteotomies may significantly improve sagittal balance, but it is unclear how this surgical technique affects long-term (> 5 year) outcomes in the elderly.

Methods

All adult patients treated with posterior spinal fusion for spinal deformity by a single surgeon from 2005 to 2012 were analyzed. Inclusion criteria age greater than 60 years and treatment with at least one three column osteotomy (Schwab 3-6) for deformity. Seventy-two patients fit the demographic criteria. 35 patients (49%) had clinical follow-up of at least 5 years. Paired student's t-tests were used to compare radiographic parameters and outcome scores.

Results

Mean age was 66.0 ± 5.1 years. The index procedure was a revision surgery in 20 (57%) cases. Median follow-up was 5.9 years (range: 5.0 - 11.8 years). Mean pre-operative thoracic kyphosis, lumbar lordosis, and sagittal vertical axis were 51.2±30.3˚, 31.3±21.6˚, and 14.5±8.9 cm. Schwab 3 or 4 osteotomies were used in 25 (71%) patients. Schwab 5 or 6 osteotomies were used in 11 (31%) of patients. Thirteen (37%) patients required revision surgery at a median of 2.2 years post-operatively (range: 0.1 - 4.7 years). At final radiographic follow-up, mean changes in post-operative lumbar lordosis and sagittal vertical axis were not significant [0.2±12.7˚ (p = 0.28), and -0.8±5.5 cm (p = 0.89), respectively]. Thoracic kyphosis had increased [5.0±16.8˚ (p = 0.002)]. Outcomes improved significantly at five years compared to pre-operatively for the following measures: Oswestry Disability Index (ODI), Scoliosis Research Society- 22 (SRS-22) function, pain, self-image, and satisfaction (p< 0.05).

Conclusion

Three-column osteotomies have a long-term durable effect on improving quality of life in elderly patients. Positive long-term outcomes must be weighed on short term complication risk.

99. Unaltered Upper Instrumented Vertebra Reduces Risk of Proximal Junctional Failure Following Surgery for Adult Spinal Deformity

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Summary

Patients undergoing revision surgical fusion or osteotomy distal to an unaltered upper instrumented vertebra (UIV) experienced a 0% rate of proximal junctional failure (PJF), compared to 13.8% of ASD patients undergoing fusion generating a new UIV (p=0.01). The lack of PJF occurred despite worse preoperative sagittal deformity and larger operative correction in unaltered UIV patients. This study suggests that the origin of PJF includes acute soft tissue injury and lack of adjacent bony remodeling as contributing factors.

Hypothesis

Patients with prior instrumented fusions undergoing distal extension or osteotomy have decreased rates of proximal junctional kyphosis (PJF)

Design

Retrospective cohort study with propensity matching of prospectively collected multicenter patient data

Introduction

PJF is a serious complication following ASD surgery. Patients undergoing caudal extension or osteotomy of prior fusion may be at decreased risk of PJF if the upper instrumented vertebra (UIV) is unaltered.

Methods

Prospective multicenter cohort of 754 adult patients undergoing thoracolumbar fusion for ASD were analyzed. 41 patients undergoing distal extension of or osteotomy through prior fusion with an unchanged UIV were identified. PJF was defined as either proximal junction (PJ) angle ≥ 28.0° and Δ PJ angle ≥21.6°) or by listhesis. Propensity score matching was performed for unaltered UIV patients and new UIV patients for age, BMI, number of levels fused, UIV, frailty score, ΔSVA, Δ PI-LL, and ΔTPA and were compared for rates of PJF.

Results

Patients with an unaltered UIV had a 0% rate of radiographic PJF, compared to 13.8% of those with a new UIV (p=0.012). Mean time to PJF was 11.2 months (range: 0.5-33.7). Prior to propensity matching, unaltered UIV patients had worse sagittal malalignment with a higher PI-LL (27.0 vs 16.6; p=0.003), and SVA (90.6mm vs 68.5mm; p=0.073) and underwent larger sagittal alignment correction (ΔSVA -55.6mm vs -43.1mm; p=0.049). After propensity matching, all radiographic and demographic parameters were similar (p>0.05), and PJF rates remained lower in the unaltered UIV patients compared to the new UIV patients (0% vs 8.5%; p=0.009)

Conclusion

Despite worse preoperative sagittal deformity and larger operative correction, patients undergoing distal extension of fusion with unaltered upper instrumented vertebra (UIV) experienced a 0% rate of proximal junctional failure, compared to 13.8% of ASD patients undergoing surgery with a new UIV (p=0.01), This study suggests that the etiology of PJF includes acute soft tissue trauma and lack of adjacent segment bony remodeling as contributing factors.

100. Cervical, Thoracic and Spinopelvic Compensation after Proximal Junctional Kyphosis – Does Location of PJK Matter?

Han Jo Kim, MD; Renaud Lafage, MS; Jonathan Charles Elysée, BS; Christopher Shaffrey, MD; Douglas C. Burton, MD; Christopher Ames, MD; Gregory Mundis, MD; Richard Hostin, MD; Shay Bess, MD; Eric O. Klineberg, MD; Justin Smith, MD, PhD; Peter Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

Summary

The location of PJK results in different compensation mechanisms of the cervical and thoracic spine. The Lower Thoracic (LT) group compensates with an increase in Pelvic Tilt (PT) and Cervical Lordosis (CL) while decreasing C2-T3 SVA. The Upper Thoracic (UT) group increases their CL to counter the increase

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in T1 Slope (T1S) but continues to have TS-CL mismatch with an elevated C2-7 SVA (cSVA).

Hypothesis
The location of PJK changes the alignment of the spine proximal to the PJK

Design
Retrospective review of prospective database

Introduction
Proximal Junctional Kyphosis (PJK) can occur at any segment along the spine and yet, compensation mechanisms at levels proximal to an area of PJK have not clearly been characterized. Understanding compensation mechanisms may help in determining optimal level selection when performing revision surgery for PJK.

Methods
PJK location was based on UIV location: LT (T8-L1) or UT (T1-7). Inclusion criteria were fusion > 5 Levels with the LIV being S1/Ilium. PJK was defined by Glattes criteria. Alignment parameters were compared between PJK patients separated by UIV group. A correlation analysis was made between PJK magnitude and global/cervical alignment within UIV group.

Results
There were 369 patients included in the analysis; mean age of 63, BMI 28 and 81% female, LT (n=193) vs. UT (n=176). The rate of radiographic PJK was 49% and higher in the LT group (55% vs. 42%, p =0.01). In the UT group, significant differences were noted in all cervical radiographic parameters (p<0.05) between PJK vs non-PJK patients, while in the LT group, only the T1S and C2-T3 SVA (CTS) were significantly different between PJK and non-PJK groups. In comparing UT vs. LT PJK patients, UT had more posterior global alignment (smaller TPA, SVA & larger PT) and larger anterior cervical alignment (greater cSVA, TS-CL mismatch, CTS) compared to LT. Correlation analysis of PJK angle magnitude and PJK location demonstrated a strong correlation with an increase in CL, T1S and CTS (r=0.59,0.44,0.55 respectively) in the UT group. In the LT group, PT increased with PJK angle (r=0.17) and no significant correlations were noted to SVA, cSVA or TS-CL.

Conclusion
PJK location results in different compensation mechanisms of the cervical and thoracic spine. The LT group compensates with an increase in PT and CL while decreasing CTS. The UT group increases their CL to counter the increased in T1S but continues to have TS-CL mismatch with an elevated cSVA.

Case example of patient recruiting different compensatory mechanism depending on PJK location: A) Upper thoracic PJK with maximum extension of CL B) Lower thoracic with increase PT, Flattening TK and increase CL

101. Effective Prevention of Proximal Junctional Failure (PJF) in Adult Spinal Deformity (ASD) Surgery Requires a Combination of Surgical Implant Prophylaxis and Avoidance of Overcorrection of Age Adjusted Sagittal Parameters

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Summary
Propensity score matched analysis of 625 ASD patients demonstrated isolated use of surgical implants to prevent PJF was less effective than combined prophylactic implants and avoidance of over correction of age adjusted sagittal alignment parameters. Patients receiving no implant prophylaxis and demonstrating sagittal plane overcorrection had highest incidence PJF incidence (24.2%), while patients receiving hook at UIV and remaining within age adjusted alignment parameters had the lowest incidence of PJF (5.1%). Future PJF preventive research should consider alignment and implants.

Hypothesis
Combination of surgical implants and avoidance of sagittal alignment overcorrection will most effectively reduce PJF.

Design
Propensity score matched, retrospective analysis of a multi-center prospective ASD database.

Introduction
PJF is a severe form of proximal junctional kyphosis (PJK). Efforts to prevent PJF have focused on use of different surgical implants. Less attention has been placed upon use of age adjusted alignment goals to prevent PJF.

Methods
ASD patients (≥5 levels fused, ≥1 year follow up) were evaluated for use of any PJF prophylactic implant (PROPH vs. NONE), specific type of implant (HOOK, CEMENT, TETHER), and for overcorrection of age adjusted sagittal alignment (OVER vs. ALIGN). Propensity score matched analysis (PSM) controlling for confounding variables for patients receiving implant prophylaxis was performed comparing the efficacy of prophylactic implants vs. age adjusted alignment to prevent PJF. PJF defined as radiographic threshold for proximal extension of posterior fusion for severe PJK as previously reported.

Results
625 of 834 eligible for study inclusion were evaluated. PSM analysis demonstrated PJF incidence was lower for PROPH (n=235; 11.3%) vs. NONE (n=390: 20.3%; p<0.05). Of all implants, HOOK at UIV (n=115) was the most efficacious prophylactic implant preventing PJF vs. NONE (7.0 vs. 20.3%, respectively; p<0.05). ALIGN (n=165) had lower incidence of PJF (13.2%) than OVER (n=225; 24.2%; p<0.05). The combination of PROPH+ALIGN (n=81) further reduced PJF (9.9%), and HOOK+ALIGN (n=39) had lowest rate of PJF (5.1%) while NONE+OVER (n=225), had highest rate of PJF (24.2%; p<0.05; Figure).

Conclusion
Optimal PJF reduction following ASD surgery requires combining prophylactic surgical implants with avoidance of overcorrection of sagittal alignment. Further research is needed to improve intraoperative reconciliation of desired spinal alignment, improvement of surgical implants and identification of ideal vertebral levels to include in the PJF prophylaxis.

PSM	No Prophylaxis	Any Prophylaxis	Hook	Cement	Tether	P Value
N (Total)=625	390	235	115	58	62	
Incidence of PJF; % (N)	20.3[1,2]	10.6[1]	7.0[2]	12.1	16.1	0.0018[1], 0.0009[2]
Timing of PJF (months)	11.3	11.1	8.9	13.3	11.0	>0.05
PI-LL Generational Alignment Over correction (%)	64.0	65.7	66.1	62.1	75.0	>0.05
Incidence of PJF; %Aligned:%Overcorrected	13.2[1]:24.2[1,2,3,4,5]	9.9[1]:11.0[2]	5.1[1]:7.9[3]	9.1:13.9	20.0:14.3	0.0056[1], 0.0011[2] 0.0078[1], 0.0071[2], 0.0020[3]

102. Selective Thoracic Fusion of Lenke 3, 4 Curves: Rule Breakers or New Rule Makers?

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Summary
New rules for performing a successful selective thoracic fusion in Lenke type 3, 4 lumbar modifier C curves are proposed.

Hypothesis
A Lenke type 3 or 4, lumbar modifier C curve pattern may have a selective thoracic fusion (breaking the Lenke rules) rather than fusing all structural curves.

Design
Retrospective review of data prospectively entered in a multi-center database

Introduction
The Lenke treatment algorithm rules are broken most often in type 3, 4 curves. Selective fusion is done in these "rule breaker" cases with frequent success. Lenke suggested that curves with MT:TL/L Cobb and apical vertebral translation (AVT) ratios >1.2 may be candidates.

Methods
AIS patients with PSF for Lenke curve types 3, 4 lumbar modifier C and minimum 2 year follow-up were queried for those fused selectively (to L2 or above) or non-selectively (entire lumbar Cobb). Radiographic measurements of pre- and 2-year post-op coronal, pre-op lumbar curve flexibility, coronal and sagittal global alignment were evaluated, as were the pre-op MT:TL/L Cobb and absolute AVT ratio.

Results
Data for 139 Lenke 3, 4 AIS patients was included. 38 patients had STF. Pre-op mean MT:TL/L Cobb was 1.36, absolute AVT 1.62, lumbar erect Cobb was 50°, mean bend was 32°, and mean % flexibility 35. Mean post-op 2 year erect Cobb was 25°, mean pre-op sagittal T10-L2 -7.21°, 2 year post-op -2.35°; mean pre-op coronal balance C7-CSVL -1.31°, 2 year post-op -1.94°. 101 patients had non-STF fusion. Pre-op mean MT:TL/L Cobb was 1.15, absolute AVT 0.94 lumbar erect Cobb was 58°, bend was 33°, mean % flexibility 42%, mean post-op 2 year erect Cobb was 19, mean pre-op sagittal T10-L2 0.11, 2 year postop -9.13°, mean pre-op coronal balance -1.86°, and 2 year post-op -0.725°. (Table 1) The differences in pre-op MT:TL/L Cobb and AVT between STF and non-STF were both significant at p<0.001.

Conclusion
Since Lenke treatment algorithm rules are broken 27% of the time performing STF in Lenke 3, 4 modifier C curves with good maintenance of sagittal and coronal global alignment at minimum 2 years post-op, perhaps new rules for when not to include the structural lumbar curve in the fusion are indicated. We propose that a MT:TL/L Cobb and AVT ratios >1.2 as suggested by Lenke be the new rules to indicate that Lenke type 3 and 4 curves may undergo successful STF.

	Selective Fusion (N=38)	Nonselective Fusion (N=101)
Pre-op mean MT:TL/L Cobb	1.36	1.15
Absolute AVT	1.62	0.94
Lumbar erect Cobb (°)	50	58
Mean bend (°)	32	33
Mean % flexibility	35	42
Mean post-op 2 yr erect Cobb (°)	25	19
Mean pre-op sagittal T10-L2 (°)	-7.21	0.11
Mean 2 yr post-op sagittal T10-L2 (°)	-2.35	-9.13
Mean pre-op coronal balance C7-CVSL (°)	-1.31	-1.86
Mean 2-yr post-op coronal balance C7-CVSL (°)	-1.94	-0.725

103. How to Determine Distal Fusion Level in the Major Thoracolumbar and Lumbar Adolescent Idiopathic Scoliosis Treated by Rod Derotation and Direct Vertebral Rotation

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Summary
Selection of lowest instrumented vertebra (LIV) is crucial when considering the management of adolescent idiopathic scoliosis (AIS) because it is highly associated with postoperative surgical outcomes. The prevalence of unsatisfactory results was 15.2% (7/46) when the curve was flexible with minor rotation. However, the prevalence of unsatisfactory results was significantly increased to 61.1% (11/18) when the curve was rigid with severe rotation. Unsatisfactory results had significant influence on the progression of compensatory (caudal) curve and LIV disc angle.

Hypothesis
Proper determination of distal fusion level is a very important factor in deformity correction, preservation of motion segments, and prevention of distal adding on phenomenon in the treatment of major thoracolumbar and lumbar (TL/L) AIS.

Design
A retrospective comparative study.

Introduction
The selection of distal fusion level remains debatable, and there has been no definitive criteria in AIS with major TL/L curve. Therefore, the present study aimed to analyze the exact distal fusion level in the treatment of major TL/L AIS using rod derotation (RD) with direct vertebral rotation (DVR) following pedicle screw instrumentation (PSI).

Methods
AIS patients with major TL/L curves (n=64) treated by PSI with RD and DVR methods with a minimum 2-year follow-up were divided into AL3 (flexible) and BL3 (rigid) according to the flexibility and rotation by preoperative bending radiographs: type A (L3 crosses CSVL (center sacral vertical line) with L3 rotation of less than grade II) and type B (L3 does not cross CSVL or L3 rotation is more than grade II).

Results
There was no significant difference in TL/L (major) curve between the AL3 and BL3 groups postoperatively (P = 0.933) and at the last follow-up (P = 0.144). Additionally, there was no significant difference in thoracic (minor) and compensatory (caudal) curve postoperatively (thoracic curve: P = 0.828, compensatory curve: P = 0.976); however, there was a significant difference in compensatory (caudal) curve at the last follow-up (P = 0.041). The overall prevalence of unsatisfactory results was 28.1% (18/64 patients), and the prevalence was 15.2% (7/46) in the AL3 group and 61.1% (11/18) in the BL3 group, which was significantly different (P < 0.05).

Conclusion
LIV would be selected at L3 (EV) when the curve is flexible; L3 crosses CSVL with a rotation of less than grade II in preoperative bending radiographs. However, if the curve is rigid, LIV should be extended to L4 (EV + 1) in order to prevent the adding-on phenomenon in the treatment of major TL/L AIS using RD and DVR following PSI.

104. Re-evaluating the "1.2 Ratio Rule" for Successful Selective Thoracic Fusion for C Lumbar Modifier Curves in Adolescent Idiopathic Scoliosis: Two- to Five-Year Follow-up of All Pedicle Screw Constructs

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Summary
Selective thoracic fusion can be successfully performed using all pedicle screw constructs for AIS curves with a C lumbar modifier even if the thoracic to lumbar (T:L) coronal Cobb and apical vertebral translation ratios are both less than 1.2. Contrary to previous recommendations using hook constructs, pedicle screw constructs allow surgeons to push the originally proposed T:L ratios for selective thoracic fusions while still maintaining long-term spinal balance.

Hypothesis
The use of all pedicle screw (APS) constructs allows for successful selective thoracic fusion (STF) for AIS patients with a C lumbar modifier when the pre-op Thoracic to Lumbar (T:L) coronal Cobb and apical vertebral translation (AVT) ratios are both < 1.2.

Design
Retrospective review of a prospectively collected multicenter database

Introduction
Previous work by Lenke et al stated the pre-op T:L coronal Cobb

and T:L AVT ratios should both be > 1.2 to avoid postoperative decompensation after STF for AIS with a C lumbar modifier using hook constructs. The present study replicates this previous work with APS constructs.

Methods

PSF with a lowest instrumented vertebra of L1 or above defined an STF. Coronal imbalance > 2cm indicated postoperative decompensation. Inclusion criteria of an STF for AIS with a C lumbar modifier using APS yielded 174 patients with 2-year and 75 patients with 5-year follow-up.

Results

Post-op decompensation was noted in 68/174 patients (39%) at 2 years and in 21/75 patients (28%) at 5 years post-op. Pre-op T:L Cobb and AVT ratios did not significantly differ in patients who were Decompensated (D) or Non-Decompensated (ND) at 2 and 5 years post-op. In the ND group, T:L Cobb was <1.2 in 37% of patients, T:L AVT was <1.2 in 22%, and both ratios were <1.2 in 13%. No pre-op or post-op radiographic parameters (coronal/sagittal Cobb, curve flexibility, apical translation, Risser sign, Lenke classification, or % correction) were predictive of decompensation at 2 or 5 years post-op with multivariate analysis.

Conclusion

Although the majority of patients with coronal balance did have T:L ratios > 1.2, there was no increased incidence of post-op coronal decompensation following STF of AIS patients with a C lumbar modifier using an APS construct when the T:L ratios of coronal Cobb (37% of pts) and AVT (22% of pts) were < 1.2. Additionally, this study found no pre-op T:L Cobb or AVT ratio cutoff that was predictive of post-op coronal decompensation 2-5 years after STF for AIS using APS, thus refuting this strict cutoff from a successful STF.

	Not Decompensated	Decompensated	P value for univariate analysis
Pre-op T:L Cobb ratio	1.28	1.24	0.4
Pre-op T:L AVT ratio	1.85	1.63	0.13
Pre-op Sagittal T5-T12	23°	24°	0.7
Pre-op Thoracic Flexibility	33%	28%	0.1
Pre-op Lumbar Flexibility	65%	55%	**0.001**
Pre-op Coronal Balance <2cm*	75% (n=73)	25% (n=25)	**0.005**
Pre-op Coronal Balance ≥2cm*	55% (n=47)	45% (n=39)	
Pre-op Lenke 1C or 2C	67% (n=93)	33% (n=46)	0.09
Pre-op Lenke 3C or 4C	52% (n=19)	48% (n=18)	
2yr PO Thoracic Coronal Cobb	22°	25°	**0.03**
2yrPO Thoracic % correction	58%	55%	0.3
2yr PO Lumbar Coronal Cobb	22°	26°	**0.002**
2yr PO Lumbar % correction	46%	40%	**0.01**
5yr PO Thoracic Coronal Cobb	24°	31°	**0.02**
5yr PO Thoracic % correction	52%	35%	**0.02**
5yr PO Lumbar Coronal Cobb	23°	29°	**0.02**
5yr PO Lumbar % correction	43%	29%	0.09
****NO significant parameters identified on multivariate analysis****			

2yr PO: 2 year postoperative
5yr PO: 5 year postoperative
*Coronal Balance: Distance C7 plumb line to Center Sacral Vertical Line

105. L4 Tilt at Skeletal Maturity Can Predict Lumbar Disc Degeneration and Low Back Pain in Adults Treated Non-Operatively for Adolescent Idiopathic Scoliosis with Thoracolumbar/Lumbar Curve: A Mean 25-Year Follow-up Study

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Summary

In adult patients treated non-operatively for adolescent idiopathic scoliosis (AIS) with thoracolumbar/lumbar (TL/L) curve, low back pain (LBP) and lumbar disc degeneration (LDD) were positively correlated with L4 tilt. L4 tilt >15° at skeletal maturity was a predictor for moderate to severe LBP and LDD in adulthood.

Hypothesis

Radiographic parameters at skeletal maturity may predict LBP and LDD in adulthood.

Design

Long-term follow-up study

Introduction

TL/L curves, even if mild to moderate, are enough to warrant future concerns regarding LBP and LDD; however, the risk factors at skeletal maturity remain unclear.

Methods

Subjects treated non-operatively for AIS with TL/L curve (Lenke's lumbar modifier C) at skeletal maturity and were aged ≥30 years at the time of the survey were included. Of 147 patients who met the criteria, 56 (55 women; age, 39.5±7.1 years) returned for a follow-up evaluation. The curve types included a double curve in 38 patients and a single in 18. Forty-eight patients also underwent lumbar MRI at the time of the survey. The average Pfirrmann scores from the L1/2 to L5/S1 discs was defined as the LDD score.

Results

The mean Cobb angle of the TL/L curve increased from 37.3°±7.5° to 47.8°±12.6°. At the time of the survey, the mean visual analogue scale (VAS) score for LBP, Oswestry disability index (ODI), and LDD score were 2.7±2.6 cm, 12.3±12.3%, and 3.2±0.4, respectively. L4 tilt at skeletal maturity was positively correlated with VAS, ODI, and LDD score (Table 1). In multivariate analyses, L4 tilt was an independent predictor for detecting VAS >3 cm, ODI >20%, and LDD score >3 (Table 2), with cutoff values of 16.5° (area under the curve [AUC], 0.70), 15.5° (AUC, 0.81), and 14.5° (AUC, 0.68), respectively. Moreover, LDD scores were positively correlated with VAS (rs = 0.46) and ODI (rs=0.40) ($p < 0.05$).

Conclusion

A great L4 tilt can induce LDD, causing LBP and disability in adulthood. For adolescent patients with a great L4 tilt (>15°), periodic follow-ups into adulthood should be conducted.

Table 1. Bivariable correlations

	VAS (n = 56)		ODI (n = 56)		LDD score (n = 48)	
	rs	P-value	rs	P-value	r/rs	P-value
C7 translation	0.12	0.36	0.09	0.51	r = -0.08	0.57
TL/L curve						
Cobb angle	0.26	0.054	0.11	0.40	r = 0.11	0.48
Apex (T12=0 to L5=5)	0.03	0.84	0.12	0.36	rs = 0.06	0.67
AVT	0.23	0.088	0.19	0.15	r = 0.28	0.058
AVR (Nash-More grade)	0.08	0.55	0.30	0.025*	rs = -0.15	0.30
L3 tilt	0.14	0.29	0.01	0.95	r = 0.20	0.17
L4 tilt	0.38	0.005*	0.29	0.029*	r = 0.35	0.016*
L3 shift	0.12	0.38	-0.05	0.74	rs = 0.03	0.82
L4 shift	0.16	0.23	0.15	0.26	rs = 0.11	0.45

Correlations were assessed using Pearson's (r) and Spearmann's correlation coefficient (rs). TL/L indicates thoracolumbar/lumbar; AVT, apical vertebral translation; AVR, apical vertebral rotation. *p <0.05.

Table 2. Multivariate analyses (logistic regression analyses)

	Independent factors	odds ratio	95%CI	P-value
VAS >3cm	L4 tilt	1.20	1.03-1.39	0.021*
ODI >20%	L4 tilt	1.25	1.04-1.50	0.018*
LDD >3	L4 tilt	1.21	1.02-1.43	0.028*

Factors with a p < 0.20 in the univariate analyses were included in the multivariate analysis.

106. Novel Ossification Markers from a Single AP of the Spine, Combined with Demographics, Accurately Predict Peak Height Velocity in Children

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Summary

We have developed an algorithm using a novel humeral head ossification system that can predict peak height velocity (PHV) accurately at scoliosis clinic visits. Since our method uses only information present on a routine spine x-ray along with demographics, we believe that it will significantly improve the evaluation of the child with scoliosis without increasing radiation exposure, time, or cost. Accurate prediction of PHV in patients with adolescent idiopathic scoliosis will allow for more accurate treatment decision-making by physicians.

Hypothesis

We hypothesize that our novel system of classifying the ossification of the humeral head, in combination with demographics, will allow for accurate computationally guided prediction of peak height velocity.

Design

We analyzed data from 254 children from a prospective, consecutively enrolled set of children who had at least 5 years of follow-up. We included 94 children who had yearly radiographs.

Introduction

Peak height velocity (PHV) is a valuable tool when managing idiopathic scoliosis. Here we evaluate the accuracy of PHV age prediction using combinations of chronological age, sex, height, the Risser sign, tri-radiate cartilage stage and a novel five-part maturity scheme we developed based on proximal humeral ossification patterns.

Methods

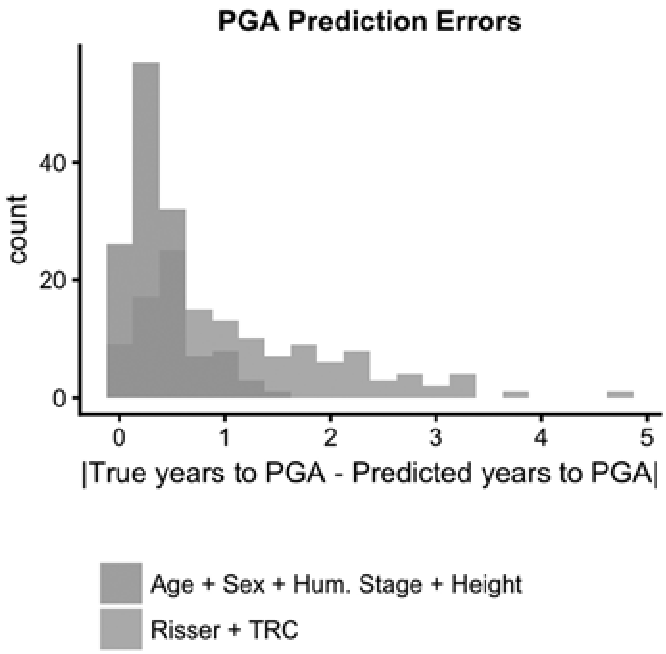
We analyzed 606 x-rays to create a novel humeral head classification scheme that was combined with age, sex, and standing height to predict the age of PHV. Linear regression models were trained to predict age of PHV using combinations of these variables. The age of PHV was predicted in separate models by using Risser stage and tri-radiate cartilage (TRC) scores. Predictive performance of the models was evaluated using 10-fold cross-validation. Performance and errors were averaged over all ten folds.

Results

A linear regression algorithm trained on age, sex, current standing height and humeral head stage successfully predicted PHV with a mean absolute error (MAE) of 0.42 years such that 67% of peak growth age (PGA) predictions were accurate to within half a year and 94% of PGA predictions were accurate to within a year. This algorithm outperformed linear regression models that were trained using a combination of Risser and triradiate closure signs (MAE 1.21, 29%, 53%). A model using demographic factors alone (MAE 0.51, 55%, 89%) was also strong.

Conclusion

The humeral head ossification pattern can be used in combination with age, sex and height to predict PHV accurately. Demographic factors alone also exhibited strong performance. Risser sign and triradiate closure were found to have low predictive accuracy.



107. Is Radiation-Free Ultrasound Accurate for Quantitative Assessment of Spinal Deformity in Adolescent Idiopathic Scoliosis (AIS): A Detailed Analysis with Radiography for 952 Patients

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Summary

After investigating 952 AIS patients, radiation-free ultrasound could be a viable option for measuring spinal deformity for curves with apices at T7 or lower, and for those with Cobb angle < 30°.

Podium Presentation Abstracts

Hypothesis
Ultrasound is accurate for measuring spinal deformity in AIS

Design
Prospective diagnostic accuracy study

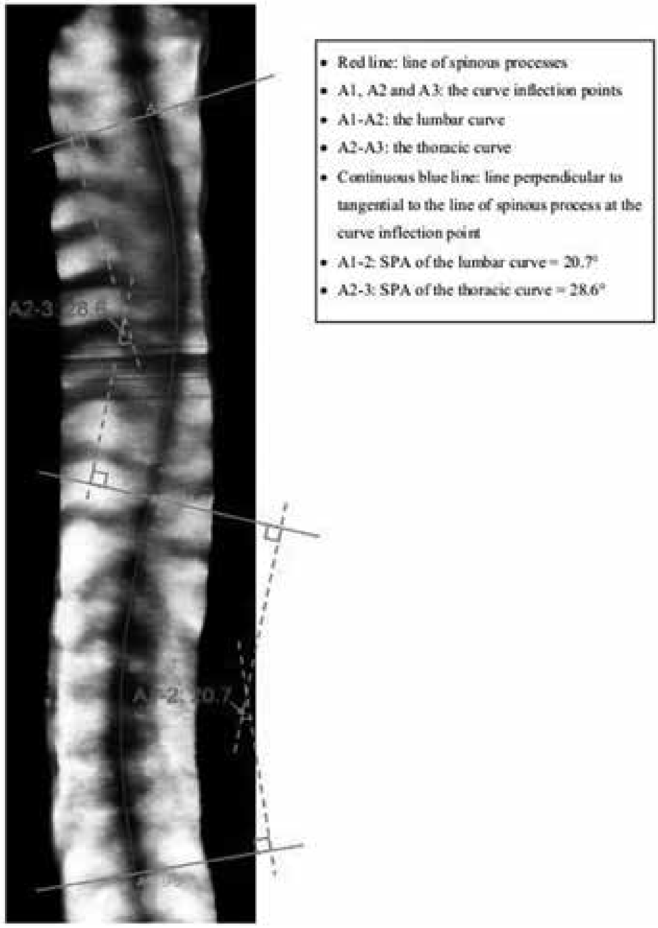
Introduction
As repeated x-ray can pose a health concern for AIS subjects, radiation-free ultrasound has recently been investigated for measuring spinal curvatures. Despite promising results are reported from previous pioneering studies, its role and accuracy in relation to curve severity and curve levels remain undefined.

Methods
AIS patients aged 8-40 years were recruited. Coronal Cobb angles (E_Cobb) were measured on standing posteroanterior EOS radiographs. Spinous process angles (SPA) were measured with an automatic algorithm from volume projection images obtained from ultrasound scanning of the spine (Fig 1). Intra-class correlation (ICC), linear regression and chi-square were used for analysis.

Results
952 AIS patients (75.7% female, mean age 16.7±3.0 years) were studied. The intra-and inter-rater reliability with ICC were respectively 0.988 and 0.949 for E_Cobb; 0.916 and 0.838 for SPA. Out of 1432 radiological curves (mean E_Cobb 29.3 ± 11.8°) detected by ultrasound, statistically significant correlation between E_Cobb and SPA was noted ($r=0.816$, $p<0.001$). Best correlation ($r=0.873$) was noted for upper spinal curves (USC, defined as curves with apices between T7 to T12.5). Correlation was 0.740 for lower spinal curves (LSC, apices at L1 or lower) and 0.629 for upper thoracic curves (UTC, apices at T6.5 or above). Conversion formulae to predict E_Cobb from SPA were [predicted E_Cobb = P_Cobb = 7.39 + 1.26 x SPA] for USC and [P_Cobb = 10.08 + 0.96 x SPA] for LSC. For curves with E_Cobb < 30°, the absolute difference between P_Cobb and E_Cobb was ≤ 5° in 66.6% and 62.4% of USC and LSC; while P_Cobb underestimated E_Cobb for greater than 5° in 6.0% and 7.2% of USC and LSC respectively.

Conclusion
Ultrasound gives satisfactory accuracy of measurement for curves with (a) apices at T7 or lower and (b) E_Cobb < 30°. Under this favorable situation, ultrasound can be considered in lieu of x-ray to reduce radiation exposure. (ClinicalTrials.gov-Identifier: NCT02581358)

Fig 1
A volume projection image of the spine showing the line of spinous processes with which the Spinous Process Angle (SPA) can be measured.



108. The Prevalence of Adding-On or Distal Junctional Kyphosis in Adolescent Idiopathic Scoliosis Treated By Anterior Spinal Fusion to L3 was Significantly Higher than By Posterior Spinal Fusion to L3

Seung-Jae Hyun, MD, PhD; Lawrence G. Lenke, MD; Yongjung J. Kim, MD; Keith Bridwell, MD; Kathleen Blanke, RN

Summary
We identify risk factors for distal AO or DJK in AIS treated by ASF and PSF to L3. Prevalence was 47.6% vs. 11.1%. More SV-3 on standing films, more proximal to NV, lesser total stability score, rigid L3-4 disc, more rotation and deviation of L3 and ASF were identified risk factors. We recommend PSF to achieve the greatest correction of both thoracic and lumbar curves as well as trunk shift and to prevent AO or DJK following to L3.

Hypothesis
ASF for AIS can reduce fusion levels, but can result in distal AO or DJK.

Design
Retrospective compararive study

Introduction

The purpose of this study was to compare and identify risk factors for distal adding on (AO) or distal junctional kyphosis (DJK) in adolescent idiopathic scoliosis (AIS) treated by anterior- (ASF) and posterior spinal fusion (PSF) to L3.

Methods

AIS patients undergoing ASF vs. PSF to L3 by 2 senior surgeons from 2000-2010 were analyzed. Distal AO and DJK were deemed poor radiographic results and defined as >3 cm of deviation from L3 to the center sacral vertical line (CSVL), or >10° angle at L3-4 on the AP or lateral xray at ultimate FU. New stable (SV) and neutral vertebra (NV) scores were defined in terms of gravity, rotational score. (Table 1) The total stability score was the sum of the SV and NV scores.

Results

20 of 42 (ASF group: 47.6%) and 8 of 72 (PSF group: 11.1%) patients showed the poor radiographic outcome. The other 22 and 64 patients of ASF and PSF group experienced the good radiographic outcome. Fused vertebrae (4.6 vs. 11.4), correction rate of main curve (48.6% vs. 67.6%), coronal reduction rate of L3 (19.8% vs. 33.0%) were significantly higher in PSF group ($p<0.01$). Multiple logistic regression results indicated that more SV-3 on standing and side bending films, more proximal to NV, lesser total stability score, rigid L3-4 disc, more rotation and deviation of L3 and ASF were identified risk factors for AO or DJK. Although there was significant improvement of the of SRS-22 average scores only in ASF and PSF groups, the ultimate scores of PSF group were significantly superior to ASF groups ($p=0.045$).

Conclusion

The prevalence of AO or DJK at ultimate FU for AIS with LIV at L3 was significantly higher in ASF group. Ultimate SRS-22 scores were significantly better in PSF group. If the LIV is L3, we recommend PSF to achieve the greatest correction of both thoracic and lumbar curves as well as trunk shift and to prevent AO or DJK following fusion to L3.

Table 1. Definition of gravity, rotational and total stability score

Gravity stability score		Rotational stability score		Total stability score	
SV	LIV at SV	NV	LIV at NV	TS-0 to -6	Summation of SV and NV score
SV-1	CSVL passes between medial pedicle borders of the LIV	NV-1	LIV is one vertebra proximal to NV		
SV-2	CSVL touches the LIV	NV-2	LIV is two vertebra proximal to NV		
SV-3	CSVL does not touch the LIV	NV-3	LIV is three vertebra proximal to NV		

SV, stable vertebra; NV, neutral vertebra.

109. Do Patients with "Less Than Ideal" Outcomes at 2 Years Continue to Have Suboptimal Outcomes in the Long-Term Following Surgery of Adolescent Idiopathic Scoliosis?

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Summary

Despite signs of suboptimal outcomes 2 years following surgical correction for adolescent idiopathic scoliosis, many cases can anticipate improvement in the clinical deformity and patient reported outcomes five years after surgery.

Hypothesis

A "less than ideal" outcome 2 years following surgery for adolescent idiopathic scoliosis (AIS) does not predict a "less than ideal" outcome at 5 years.

Design

Retrospective review of a prospectively collected, multicenter database

Introduction

Managing patients with "less than ideal" outcomes following scoliosis surgery can be challenging. The aim of this study was to report the rate of suboptimal outcomes at 5 years in patients who already were reported to have a "less than ideal" outcome 2 years after surgery for AIS.

Methods

A prospectively collected multicenter AIS database was reviewed for patients with a minimum 5 year follow-up after surgery. From this cohort, patients with "less than ideal" outcomes at their 2 year follow up were identified and re-evaluated, using the same indicators, for continued "less than ideal" outcomes at their 5 year follow up. A "less than ideal" outcome was defined as having one of the following: coronal imbalance >2cm, shoulder height asymmetry >2cm, or less than 2 standard deviations below the mean score on SRS survey. Reoperations rates were also evaluated to determine if they were greater in this group and affected outcomes at 5 year visit.

Results

Of 916 patients, 157 (17%) patients had coronal imbalance and 69 (8%) patients had shoulder asymmetry at 2 year follow-up (Table). At 5 years this improved to 53 (6%) and 11 patients (1%), respectively. Similar results were seen in patient reported outcomes between 2 to 5 years, with the greatest change in the satisfaction category where 41 patients showed improvement. The rate of reoperations from 2-6 years after surgery did not significantly impact the outcomes.

Conclusion

A "less than ideal" outcome 2 years after surgery for AIS does not predict a "less than ideal" outcome 5 years after surgery. Most patients demonstrate some improvement in clinical deformity and SRS scores. Anticipating the potential course following a "less than ideal" outcome can help surgeons manage and counsel their patients appropriately.

Table.

	"Less than ideal" Outcome	Patients at 2 yrs	Patients at 5 yrs
	Coronal Balance (C7-CSVL) >2cm	157 (17%)	53 (6%)
	Shoulder Height >2cm	69 (8%)	11 (1%)
SRS scores <2SD below mean	Pain	43 (5%)	15 (2%)
	Self-Image	32 (4%)	13 (1%)
	General function	39 (4%)	13 (1%)
	Mental health	34 (4%)	10 (1%)
	Satisfaction	52 (6%)	11 (1%)
	Total	34 (4%)	15 (2%)

Podium Presentation Abstracts

110. Predictive Factors for Postoperative Medial and Lateral Shoulder Imbalance Following Posterior Spinal Fusion (PSF) in Lenke 1 and 2 Adolescent Idiopathic Scoliosis (AIS) Patients

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Summary
Medial and lateral shoulder imbalance are distinct phenomenon. Preoperative T1 tilt (strong correlation) and Postoperative PT Cobb angle (moderate correlation) were independent factors for T1 tilt. Postop PT Cobb angle (weak correlation) was also an independent factor for Cervical Axis. We also found these factors to be significant when we stratified T1 tilt and CA to balanced/ imbalanced group. Preoperative MTSB angle, PT correction rate and MT/PT flexibility had weak correlation with post-operative RSH. No significant factors correlated with Clavicle Angle.

Hypothesis
The risk factors for postoperative medial and lateral shoulder imbalance in Lenke 1 and 2 AIS patients are different.

Design
Retrospective study

Introduction
PSI had been found to affect postoperative patient satisfaction and was reported to occur in 6.7% to 55.4% of AIS patients. Authors have reported that medial and lateral shoulder imbalance are distinct phenomenon.

Methods
This study was carried out in 2 tertiary institution in Malaysia and Japan between 2011 and 2015. 153 Lenke 1 and 2 AIS patients who underwent PSF were recruited. Medial shoulder imbalance was represented by T1 tilt and Cervical Axis (CA) whereas lateral shoulder imbalance was represented by Radiographic Shoulder Height (RSH) and Clavicle Angle (Cla-A).

Results
Using Multiple Linear Regression (MLR) model, there was a significant +ve relationship between preoperative T1 Tilt ($p < 0.001$, $r = 0.66$) and Follow Up PT Cobb ($p < 0.001$, $r = 0.42$) with postoperative T1 Tilt. There was a significant +ve relationship between postop PT Cobb ($p < 0.001$, $r = 0.32$) with postop CA. There was a significant +ve relationship between MT Flexibilty/ PT Flexibility ($p = 0.036$, $r = -0.16$) with postop RSH. There was a significant -ve relationship between Preop MT Cobb SB ($p = 0.006$, $r = -0.23$) and PT Correction Rate ($p = 0.041$, $r = -0.13$) with postop RSH. When T1 Tilt was stratified into balanced/ imbalanced group, the following parameters: Lenke Type, Preop PT Cobb, Preop MT Cobb, Preop PT side bending Cobb, Preop T1 and FU PT Cobb showed significant intergroup differences. When CA was stratified into balanced/ imbalanced group, the following parameters: Preop CA and FU PT Cobb showed significant intergroup differences. ($p < 0.05$) For RSH, only follow Up MT Cobb shown to have significant intergroup differences.

Conclusion
In conclusion, preop T1 tilt had strong and significant correlation to postop T1 tilt. Higher residual PT Cobb angle was also significantly correlated with postoperative T1 tilt and CA. Preop MTSB angle, PT correction rate and MT/PT flexibility had weak correlation with postop RSH. No significant factors was associated with Cla-A

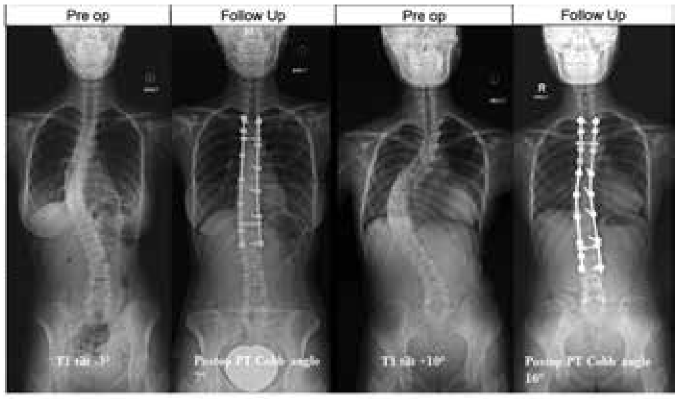


Figure: Two case examples illustrating the importance of pre-operative T1 tilt and postoperative PT Cobb angle as risk factors for postoperative medial shoulder imbalance

111. The Three-Dimensional Deformity in AIS Depends on the Type of Curvature

Ayman Assi, PhD; Mohammad Karam, MS; Wafa Skalli, PhD; Claudio Vergari, PhD; Ziad Bakouny, MS; Joeffroy Otayek, MS; Aren Joe Bizdikian, MS; Fares Yared, MS; Nour Khalil, BS; Khalil Emile Kharrat, MD; Gabi Kreichati, MD; Ismat Ghanem, MD, MBBS

Summary
It is still unknown how the 3D deformity differs between types of curvatures. 219 AIS (major thoracic: 109, thoracolumbar: 71, lumbar: 39) underwent full body biplanar X-rays with 3D calculation of major scoliotic curvature parameters. Over 90% of patients were characterized by high torsion, intervertebral rotation at junctions and hypokyphosis index. Patients with thoracic scoliosis, who were mostly thereafter treated surgically, had a more severe deformity in both the frontal and axial planes, compared to those with lumbar scoliosis.

Hypothesis
The scoliotic deformity in the 3 planes differs between the types of curvatures.

Design
Cross-sectional study

Introduction
Adolescent idiopathic scoliosis (AIS) is a deformity of the spine that occurs in the 3 planes. Three types of scoliosis are encountered, depending on the apex location of the major curve: thoracic (T), thoraco-lumbar (TL) or lumbar (L). It is still unknown how the deformity differs between types of curvature.

Methods
Patients with AIS, who underwent full body biplanar X-rays, were consecutively included. Parameters of the major scoliotic curvature were calculated in 3D: frontal Cobb angle, torsion

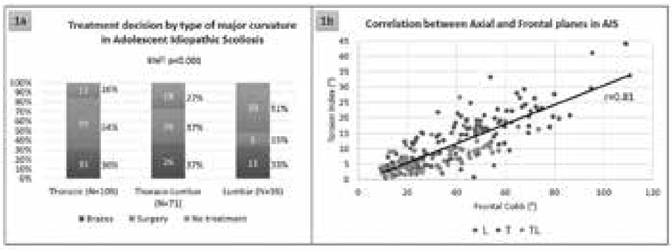
index (TI), hypokyphosis index (HI: loss of kyphosis or lordosis at the apex compared to controls) and intervertebral rotation at the junctional levels (IRJ). Post X-ray treatment decision was collected: no treatment (Cobb<25°), bracing, or surgery. Patients were divided into 3 groups depending on the type of curvature (T, TL, L). Between-group comparisons were performed while controlling for age.

Results

219 AIS were enrolled (183F; 14±2 years; T:109, TL:71, L:39). Frontal Cobb angle was higher in the T group compared to TL and L groups (T:44° vs TL:32° & L:26°; p<0.001). Similar HI (average:-2.1±4°) was found between groups. Both TI and IRJ were higher in the T group compared to TL and L groups: for TI, T:15° vs. TL:8° & L:6° (p<0.001) and for IRJ, T:9° vs. TL&L:6° (p<0.001). Thoracic scoliosis were mostly treated surgically compared to lumbar ones (fig.1a). Deformities were significantly correlated (p<0.001) between the frontal & sagittal (r=-0.27) and the sagittal and axial (r=0.46) planes. TI increased with increasing Cobb angle (r=0.81; fig.1b).

Conclusion

This is the first study to evaluate the deformity of different types of scoliosis in the 3 planes. Over 90% of patients were characterized by high torsion, intervertebral rotation at junctions and hypokyphosis index. Patients with thoracic scoliosis, which were mostly thereafter treated surgically, had a more severe deformity in the frontal and axial planes, compared to those with thoracolumbar and lumbar scoliosis. Increasing severity in the frontal plane relates to increasing severity in the sagittal and axial planes.



112. The Effect of Idiopathic Thoracic Scoliosis on the Tracheobronchial Tree

<u>*Enrique Garrido, MD, FRCS*</u>; James Farrell

Summary

There is a paucity of information on the relationship of the thoracic deformity produced by the scoliosis and the effect on the bronchial tree. 3D models of spine and airway lumen were reconstructed. Scoliosis, kyphosis and spine-airway proximity were correlated with airway narrowing and lung function. Loss of kyphosis causes the bronchus intermedius to come into close proximity with the spine narrowing its trifurcation. FEV1/FVC correlated negatively with airway narrowing implying an obstructive element to lung function in hypokyphosis.

Hypothesis

Hypokyphosis in right thoracic scoliosis causes right sided airway narrowing and increased airway resistance.

Design

Observational study: Matched Case-Control

Introduction

High prevalence of obstructive lung disease has been reported in patients undergoing surgical correction of thoracic scoliosis. Airway narrowing due to spine morphology is analysed as a contributing factor.

Methods

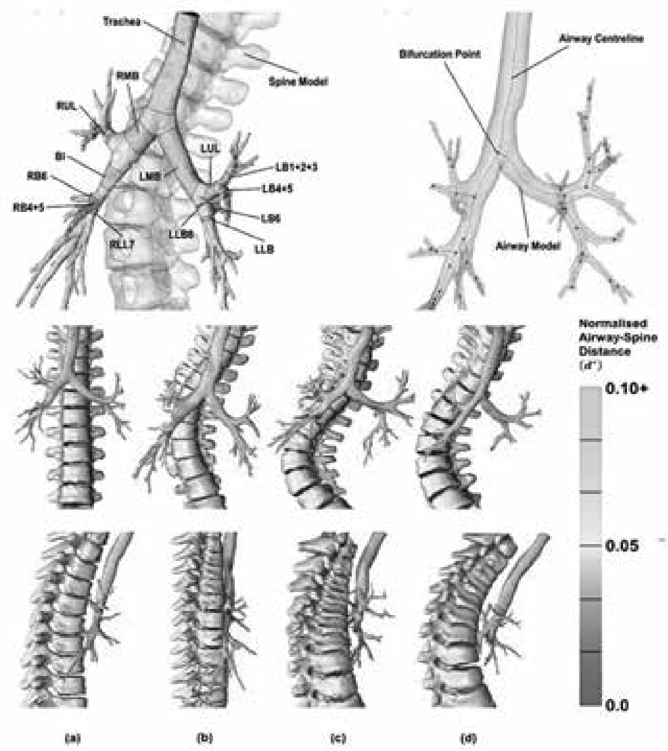
Preoperative surgical planning CTs of 34 patients with a main right thoracic scoliosis (age: 17.6±9.0) and a coronal thoracic cobb angle of 70.4 +/-19.8 STD were retrospectively analysed and compared to 15 non-scoliotic controls (age: 16.3±5.1). 3D models of spine and airway lumen were reconstructed. Matched for coronal thoracic cobb angle patients were divided into hypokyphosis (HypoS: <10°), normal kyphosis (NormS, ≥10° and <40°) and hyperkyphosis (HyperS: ≥40°) groups. Lumen area of bronchi, bifurcation angles, and minimum spine-airway distance were measured. Pulmonary function tests were correlated to scoliosis, kyphosis and lumen area.

Results

Loss of kyphosis led to proximity between bronchus intermedius (BI) and spine. HypoS (NormS) had lumen area reductions in the right main bronchus of 29% (19%), BI of 45% (23%), right middle lobar bronchus of 46% (32%) and right lower lobar bronchus (RLL7) of 66% (37%) respectively (P<0.05). The lower right superior segmental bronchus was reduced across all scoliotic groups (P<0.05). Airways were displaced caudal by 0.65±0.45 vertebra. Loss of kyphosis correlated negatively with FEV1/FVC, FVC/(FVC predicted) and FEV1/(FEV1 predicted) (P<0.01). Lumen area of trachea, right upper lobar bronchus, BI and RLL7 correlated negatively with FEV1/FVC. BI and RLL7 narrowing were strong predictors of FVC and FEV1 loss (P<0.001). Loss of one degree of thoracic kyphosis caused 0.61%, 0.72% and 0.22% loss in FVC, FEV1 and FEV1/FVC (P < 0.05).

Conclusion

Right-sided main stem airways are narrowed in HypoS and NormS. Loss of kyphosis leads to narrowing of BI and its trifurcation. FEV1/FVC correlated negatively with airway narrowing implying an obstructive element to lung function impairment in patients with scoliosis and hypokyphosis.



113. Negative Impacts of Postoperative Thoracic Hypokyphosis in Adolescent Idiopathic Scoliosis: A 10-Year Follow-up

<u>Ayato Nohara, MD</u>; Ryoji Tauchi, MD; Toshiki Saito, MD; Kazuki Kawakami, B.Kin; Tetsuya Ohara, MD; Noriaki Kawakami, MD

Summary

The effects of postop. thoracic hypokyphosis (HTK) in pts with adolescent idiopathic scoliosis (AIS), who underwent the correction of scoliosis with pedicle screw (PS) constructs were evaluated. These pts were compared with thoracic normokyphotic pts (NTK) (20°< and ≤40°). Postop. HTK in AIS pts revealed some negative effects on the cervical lordosis (CL) and pulmonary function test (PFT) during a 10-year FU period.

Hypothesis

Postop. HTK in pts with AIS negatively affects the sagittal alignment, PFT, and disc degeneration (DD) at unfused segments compared with that in pts with NTK.

Design

a retrospective cohort study

Introduction

Reductions in thoracic kyphosis (TK) post-operatively in collection with PS have been reported in short-term FU studies, no long-term study has yet been performed on this aspect. This study aimed to comparatively evaluate postop. HTK in AIS pts with respect to that in NTK pts to assess any potential issues developing over a long-term.

Methods

AIS pts with thoracic scoliosis and those who had received PS constructs with a min. FU period of 10 yrs was considered. All pts with X-ray & lumbar MRI, and PFTs were included. This study included 71 pts (2 males; 69 female, age at op. of 15.3 yrs). Lenke types consisted of type 1: 48, type 2: 12, type 3: 6. Sagittal modifiers were N = 49 pts, (-) = 16, and (+) = 4. Pts with postop. TK <15° were grouped under the HTK group and those with TK (20°< and ≤40°) were grouped under the NTK group; both the groups were then compared.

Results

The main curve of 71 pts was surgically corrected with a correction rate of 63.5% during the FU period. TK did not change through the surgical treatment period. Correlation was noted among preop. TK in CL, LL, PI, and %VC. The HTK and NTK groups consisted of 33 and 20 pts, respectively. The HTK group had a significantly lower preop. TK than the NTK group (p<0.001). CL was overall kyphotic in the HTK group at all intervals, whereas the NTK group had a more lordotic curve postop. compared with that preop. (p < 0.001). The %VC in the HTK group was relatively lower preoperatively compared with that in the NTK group (p=0.07), while it was significantly lower at 3 months and PO 10yrs (p=0.03, 0.016). DD was recorded in 21 pts (30.4%) at PO 10yrs, with no difference of occurrence observed between the two groups.

Conclusion

Postop. HTK in AIS pts has some negative effects on the cervical alignment and PFTs, as observed during a 10-year FU period. It is therefore suggested to not only obtain a good scoliosis correction but also to obtain a normal TK during surgical correction with PS.

		HTK	NTK	P value
Main curve	Preop	57.3°	52.0°	0.17
	Postop	18.8°	16.9°	0.2
	PO10y	20.1°	19.2°	0.445
TK	Preop	13.4°	29.7°	0.000
	Postop	9.4°	27.7°	0.000
	PO10y	13.1°	28.1°	0.000
CL	Preop	11.9°	7.4°	0.18
	Postop	8.8°	-0.2°	**0.009**
	PO10y	10.0°	-4.9°	**0.000**
LL	Preop	-53.2°	-57.0°	0.2
	Postop	-47.2°	-49.2°	0.42
	PO10y	-52.6°	-54.9°	0.38
%VC	Preop	78.5%	84.5%	0.07
	Postop	69.1%	83.0%	**0.03**
	PO10y	77.5%	87.1%	**0.016**

114. Radiological and Clinical Evaluation of the Use of Low and High Density Screw Systems in Scheurmann Kyphosis

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Summary

The use of low and high-density screw systems in spinal deformity surgery remains controversial . In our study ,It has been supported that the clinically same results can be obtained with less implant use in Scheurmann Kyphosis surgery.

Hypothesis

To determine how implant density affects clinical and radiological outcome in the treatment of Scheurmann Kyphosis.

Design

A retrospective multicenter study

Introduction

The use of low and high-density screw systems in spinal deformity surgery remains controversial.

Methods

149 Scheurmann kyphosis diagnosed patients who underwent posterior one stage correction surgery with a minimum follow up of 24 months. Radiographic outcomes included preoperative and 2 year postoperative sagittal cobb measurements, Risser stage and curve flexibility. We also assessed SRS-22 outcome measures before surgery and at the 2 year postoperative time point. Bivariate analysis was conducted between implant density and the following factors:percent correction of the kyphotic curve, number of osteotomy levels and other sagittal parameters. Patients were divided into two groups: the low-density (LD) group and the high density (HD) group defined by implant density for the kyphotic apex (1.3 screws per level). Independent sample t tests were used to compare demographic data as well as radiographic and clinical outcomes at baseline and at follow-up between the two groups.

Results

It was found that all the study groups were homogeneously distributed in the preoperative evaluations such as age, sex, duration of complaint, flexibility and riser stages. When the technical details of the surgical procedure were examined, the number of fused vertebrae (11.6 ± 1.1, 12.1 ± 1.7, p: 0.017), number of pedicle screws (15.4 ± 3.5, 23.5 ± 3.7, p: 0.0001) and osteotomy levels (2.8 ± 1.6; 3.9±1.9, p: 0.0001), statistically significant differences were found between low and high density screw groups (p <0.05). When the radiological evaluations were taken into consideration, there was no statistically significant difference between the values of T2-T12, T5-T12, T10-L2, and L1 -S1 Cobb angles.

Conclusion

Both radiologic and clinically similar results and limited number of complications were seen in both low and high density groups. It has been supported that the clinically same results can be obtained with less implant use in patients planned for Scheurmann kyphosis surgery.

Clinical and radiological measurements of patients according to screw density and time period

	Preop		Postop 1st m		Postop 2 yrs		
	Low	High	Low	High	Low	High	p
	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	
SRS22 Sub Total	3,3(3,1-4,5)	2,9 (2-22,3)			4,2 (3-4,9)	4,1 (2,5-4,8)	0,603
SRS22Function	3,8 (2,6-5)	4 (2,4-5)			4,3 (2-5)	4,2 (2,6-5)	0,465
SRS22 Pain	3,6(2,2-4,8)	3 (0,8-4,8)			4,2 (2,3-5)	3,8 (1,6-4,8)	0,082
SRS22 Self Image	3,2(1,3-4,4)	2,6 (1,4-5)			4,2(1-5)	4,2 (2,2-5)	0,021
SRS22 Mental Health	3,8(2,5-4,6)	3,2 (1,4-5)			4,6 (1,5-5)	4 (2,6-5)	0,508
Cobb/ T2-T12	79 (70-101)	79 (35-103)	46 (22-77)	48 (25-73)	46 (35-77)	49 (9-74)	0,290
Cobb/ T5-T12	65 (54-89)	67 (30-93)	40 (13-59)	35 (7-58)	38 (17-60)	36 (7-56)	0,469
Cobb/T10-L2	17 (1-45)	21 (-7-63)	10 (2-31)	10 (-20-32)	8 (0-39)	10 (-15-45)	0,091
Cobb/ L1(L1-S1)	59 (35-92)	67(-85-108)	48 (29-67)	43(-68-91)	48 (27-75)	40 (-38-82)	0,073

p: Repeated Measure Analysis – Greenhouse Geisser Test

Radiological Variables

	Low Density (n=37)			High Density (n=112)			
	n	Mean±SD	Median (Min-Max)	N	Mean±SD	Median (Min-Max)	p
Age	37	17,7±3,7	18(11-25)	112	18,1±4,9	16(7-38)	0,690
Time of complaint	37	4,8±2,70,8	4(1-11)	112	3,7±2,5	3(1-12)	**0,006**
Flexibility (fulcrum/hiperextension)	37	30,3±12,7	28(13-60)	112	33,7±19,3	30(8-75)	0,629
Risser	37	3,8±1,2	4(1-5)	112	4,4±1,1	5(0-5)	**0,001**
Number of Fused Vertebra	37	11,6±1,1	12(9-14)	112	12,1±1,7	12(7-15)	**0,017**
Number of Pedicle Screw	37	15,4±3,5	16(10-26)	112	23,5±3,7	24(12-29)	**0,0001**
Number of Osteotomy Level	37	2,8±1,6	3(0-5)	112	3,9±1,9	4(0-7)	**0,0001**

p: Mann Whitney U Test

115. A New Classification for Scheuermann's Kyphosis

David Bumpass, MD; Lawrence G. Lenke, MD; Michael P. Kelly, MD, MS; Ronald A. Lehman, MD; Richard McCarthy, MD; Michael Vitale, MD; Baron Lonner, MD

Summary

Despite being one of the most common spinal deformities, no classification for Scheuermann's kyphosis (SK) exists to highlight key components of the pathology, produce a common language, and guide surgical treatment. SK patients have previously been shown to have considerable variability in clinical and radiographic outcomes. We have developed a modular SK classification, and demonstrate its reliability to group SK patients into clinically-meaningful categories.

Hypothesis

We will develop a valid, clinically relevant, and reproducible classification to guide treatment of SK.

Design

Expert consensus/reliability study, using multicenter radiographic data.

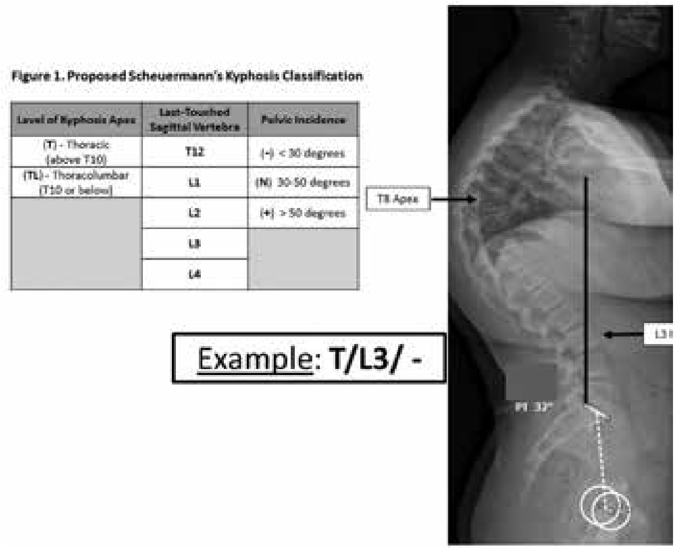
Introduction

Historically, SK patients have been broadly grouped as having a thoracic or thoracolumbar apex. Recent studies have reported that the SK population is actually markedly more complex. We propose a novel and simple SK classification that achieves more complete identification of SK subtypes, and can organize decision-making regarding deformity correction.

Methods
Using multiple rounds of nominal group technique, an established consensus-building methodology, 15 deformity surgeons identified 3 radiographic parameters most critical to characterize and treat a SK deformity: apex level, last-touched sagittal vertebra (LTSV), and pelvic incidence (PI). A classification system was then formulated and agreed upon (Fig 1). A multicenter radiographic database of 223 SK patients was used in a multivariate cluster analysis to evaluate whether these variables did indeed predict groupings within the SK population. To calculate interrater reliability, 7 surgeons classified a series of 28 SK patients on two occasions, and intraclass correlation coefficients (ICC) were calculated.

Results
Cluster analysis identified that the 3 classification variables did indeed predict distinct groupings within the SK patients (r=0.5, p<0.001). ICC values were 0.95 for apex level, 0.97 for LTSV, and 0.94 for PI, each representing excellent interrater agreement.

Conclusion
We propose a novel, modular, and simple classification for Scheuermann's kyphosis (SK). The 3 classification variables of apex level, LTSV, and PI identify distinct groupings within the SK population, and demonstrated near-perfect reliability. Classification formulation and reliability confirmation are essential steps towards establishing a much-needed common language for SK to predict outcomes and guide treatment.



116. Severe Hyperkyphosis Harms Aerobic Capacity and Maximal Exercise Tolerance in Patients with Scheuermann Disease

Carlos Barrios, MD, PhD; Jesus Burgos Flores, MD, PhD; Alejandro Lorente, PhD; Rocıo Tamarız-Martel Moreno, MD; Eduardo Hevia, MD; Luis Miguel Anton Rodrigalvarez, PhD; Rafael Lorente, PhD

Summary
Adolescents with mild or moderate thoracic hyperkyphosis due to Scheuermann disease do not exhibit significant restrictions in ventilatory parameters measured by conventional static spirometry and maximal exercise tolerance test as compared to healthy individuals matched in age. However, patients with severe hyperkyphosis (>70º) show a reduced aerobic and ventilatory capacity.

Hypothesis
Slight or moderate Scheuermann hyperkyphosis (SK) do not imply cardiorespiratory response to maximal exercise

Design
Prospective evaluation of non consecutive patients

Introduction
The evaluation of ventilatory functional restrictions during a maximal exercise tolerance test in patients with SK has never described. This study evaluates the respiratory functional capacity of patients with Scheuermann as compared to healthy adolescents matched in age.

Methods
41 adolescents with hyperkyphosis (mean, 70.9º±9.2º) due to SK were assessed by basal spirometry and dynamic ventilatory parameters during a maximal exercise tolerance test. Similar studies were performed in a control group of 20 healthy adolescents. Exercise test consisted of a ramp protocol on treadmill, and was completed to exhaustion to determine maximal oxygen uptake (VO2max) and ventilatory efficiency parameters.

Results
There were no differences between SK patients and healthy individuals in any of basal parameters (FVC, FEV1). The maximal aerobic power (VO2max) was greater in healthy controls than in hyperkyphotic patients (50.0 ± 6.7 vs 43.4 ± 11.3 mL/kg/minute; p<0.05). There was an inverse correlation between the increase in the magnitude of thoracic kyphosis and the deterioration of the maximal aerobic power. VO2max and VEmax were severely deteriorated in patients with more than 75º kyphosis. SK patients showed a shorter duration of the exercise test and less energy cost measured in METS (metabolic equivalents) as compared to healthy controls.

Conclusion
Patients with mild and moderate hyperkyphosis (<70º) do not exhibit cardiopulmonary restrictions in basal static conditions and during maximal exercise tolerance tests. Patients with more severe hyperkyphosis show a significant respiratory inefficiency together with lower ventilation capacity and lower VO2max.

117. Asymmetric Expression Of Wnt/Β-Catenin Pathway In AIS: Primary or Secondary to the Curve?

Lei-Lei Xu, PhD; Chao Xia, PhD; Fei Sheng, PhD; Bingchuan Xue, PhD; Xiaodong Qin, PhD; Weiguo Zhu, PhD; Yong Qiu, MD; Zezhang Zhu, MD

Summary
Asymmetric expression of 3 genes in the Wnt/β-catenin pathway was observed in the bilateral paraspinal muscles of adolescent idiopathic scoliosis (AIS) patients. By contrary, the expression of these genes was comparable in the paraspinal muscles of Cobb-angle matched congenital scoliosis (CS) patients. Such

asymmetric expression of genes in Wnt/B-catenin pathway is likely to be primary to the curve of AIS, and may play a role in the etiology of AIS.

Hypothesis
Asymmetric expression of Wnt/B-catenin pathway in the paraspinal muscle may be related with the risk of AIS.

Design
A case-control study

Introduction
Previous GWAS has highlighted the role of Wnt/B-catenin pathway in AIS. As a downstream gene of Wnt/B-catenin pathway, MyoD was reported to be related to the growth of muscle fiber type II. Interestingly, it has been well documented that there was remarkably asymmetric proportion of fiber type I/II between the concave and convex side of AIS. Moreover, the expression of MyoD was significantly correlated with the asymmetric proportion of fiber type I/II in AIS. This study aims to investigate whether there exists asymmetric expression of Wnt/B-catenin pathway in the concave and the convex side of AIS and to clarify its relationship with the development of spinal deformity

Methods
3 groups of subjects were included in this study. Group 1 was composed of 40 female AIS patients aged between 10 and 18 yrs. Group 2 was composed of 20 CS patients who were matched with AIS in terms of age, curve pattern and curve magnitude. Group 3 was composed of 24 adolescent female LDH patients with no spinal deformity. Paraspinal muscles were collected from all subjects during surgery. qPCR and western blot were used to determine the expression of 3 genes in Wnt/B-catenin pathway

Results
The mean age were 14.2 ± 2.4 yrs for AIS, 14.4 ± 2.1 yrs for CS and 14.9 ± 3.1 yrs for LDH, respectively. The mean Cobb angle was 48.5 ± 8.7 degrees for AIS and 49.2 ± 7.3 degrees for CS, respectively. AIS patients were found to have remarkably lower mRNA and protein expression of B-catenin, LBX1 and TNIK in the concave side than in the convex side at the apical region. By contrast, at the proximal region, the mRNA expression of these 3 genes were comparable. Moreover, no significant difference regarding mRNA expression was found between the concave side and the convex side of CS patients, or between the bilateral sides of LDH patients

Conclusion
There exists remarkably asymmetric expression of Wnt/B-catenin pathway at the apex of AIS. The asymmetric expression of susceptible genes is likely to be primary to the curve, and may play a role in the etiology of AIS

118. Blockade of Osteoclast-Mediated Bone Resorption with a RANKL Inhibitor Enhances Spinal Fusion in a Rat Model

Evalina Burger, MD; Nichole Shaw, BS; Christopher Erickson, BS; Peter Yarger, BS; Yangyi Yu, MD; Todd Baldini, MS; Christopher Kleck, MD; Vikas Patel, MD, BS, MA; Karin Payne, PhD

Summary
Osteoprotegerin (OPG) is a RANKL inhibitor that blocks osteoclast differentiation and activation, which in turn may lead to more matrix deposition. This study investigated whether administration of OPG after spinal fusion in a rat model leads to greater bone at the fusion site, and whether a timing-dependent dosing regimen would allow for a more targeted control.

Hypothesis
We hypothesize that administration of OPG after spinal fusion will inhibit osteoclasts and lead to more bone.

Design
Basic science

Introduction
Osteoprotegerin (OPG) blocks osteoclast differentiation and activation, making it a potential candidate to control bone remodeling and lead to more bone. The use of OPG as an enhancer of spinal fusion has not been studied previously. The goal of this study was to determine whether administration of OPG after spinal fusion in a rat model led to greater bone at the fusion site and whether a timing-dependent dosing regimen would allow for a more targeted control.

Methods
Forty-eight male Sprague-Dawley rats received a one-level posterolateral intertransverse fusion of L4-L5 with bone allograft. Rats were divided into 4 groups according to initiation of OPG or saline administration: (1) saline at Day 0, (2) OPG initiated at Day 0, (3) OPG initiated at Day 10, or (4) OPG initiated at Day 21 post-surgery. Rats received weekly subcutaneous injections of rat OPG-Fc (10 mg/kg) and were euthanized 6 weeks post-surgery. Quantitative microCT and histological analysis was performed. The percentage of trabecular bone surface lined with osteoclasts was measured. Statistics were performed using one-way ANOVA (SigmaStat) and $p<0.05$ considered significant.

Results
MicroCT analysis revealed a greater bone volume fraction and mean trabecular thickness in the groups that received OPG injections starting at Day 0 and 10 after surgery when compared to the groups receiving saline or OPG starting at Day 21 post-surgery (Fig.1). A smaller percentage of trabecular bone surface was lined with osteoclasts in all groups that received OPG when compared to the saline group. Initiation of OPG at Day 0 and 10 after surgery led to an even greater decrease when compared to OPG initiated at Day 21.

Conclusion
This study indicates success of OPG in inhibiting osteoclast bone resorption, which led to greater bone at the fusion site. It also demonstrates that early administration of OPG after spinal fusion is critical to enhance fusion mass. OPG is an attractive therapy to improve spinal fusion and warrants further investigation.

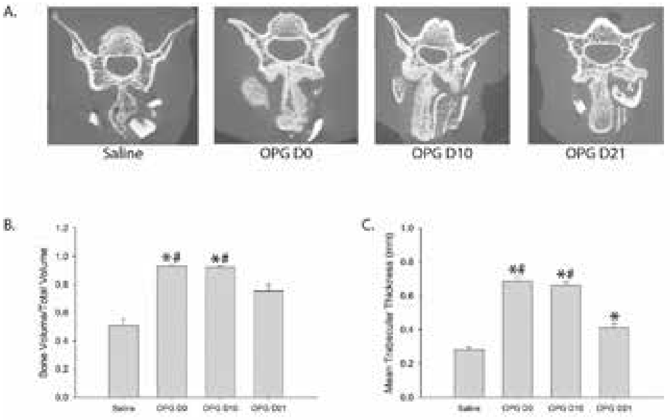


Figure 1. (A) Representative microCT images of the different treatment groups. (B) Bone volume fraction and (C) Mean trabecular thickness. *p<0.05 compared to Saline and #p<0.05 compared to OPG D21.

119. Differentially Expressed ceRNA Networks in Vitamin-A Deficiency Induced Congenital Scoliosis

Chong Chen, MD; Zheng Li, MD; Haining Tan, MD; Tianhua Rong, MD; Youxi Lin, MD; Xingye Li, MD; Jianxiong Shen, MD

Summary
Prenatal Vitamin-A Deficiency (VAD) associated with congenital scoliosis (CS) might due to a defect in retinoic acid signaling pathway during somitogenesis. Sequencing analysis of 13 rats embryo (9 in VAD group and 4 in control group) on 9 days involved in this study and then the competing endogenous RNA (ceRNA) networks of VAD-CS was constructed. This is the first research to comprehensively identify ceRNAs regulated network in somitogenesis and to demonstrate the different ncRNA expression patterns of VAD-CS.

Hypothesis
The ceRNAs regulated networks mis-modulation involved in VAD induced CS during somitogenesis.

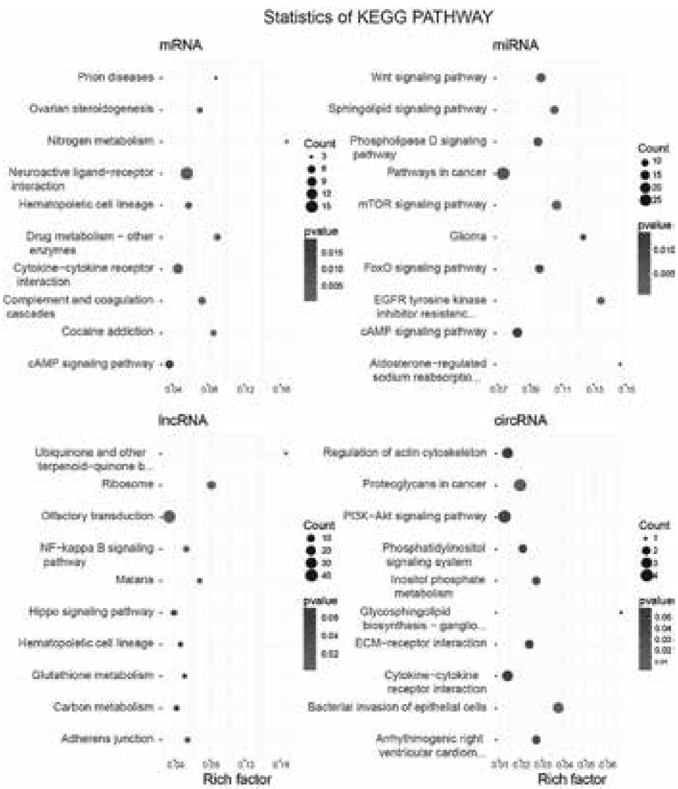
Design
Based on VAD induced CS (VAD-CS) rat model to identify and investigate ceRNAs networks' functions and relationships related to pathogenesis of CS.

Introduction
Congenital scoliosis occurs as a result of the anomalous development of vertebrae and is frequently associated with somitogenesis malformation. Although ncRNAs have recently been shown to play a role in CS pathogenesis, the competing endogenous RNA (ceRNA) regulated networks in CS remain largely unknown.

Methods
Sequencing analysis was performed to investigated the expression patterns of ncRNAs on 9 days rat embryo following the VAD-CS model (9 in VAD group and 4 in control group). Quantitative real-time polymerase chain reaction was performed to validate the expression of selected long non-coding RNAs (lncRNAs), microRNAs (miRNAs), circular RNAs (circRNAs), and mRNAs. Bioinformatics tools and databases were employed to explore the potential ceRNA functions and relationships and luciferase assay were performed to have a further identification.

Results
A total of 134 lncRNAs, 82 miRNAs, 125 circRNAs and 541 mRNAs were identified significantly. The most significantly involved pathways in VAD-CS pathogenesis were Wnt, PI3K-ATK, FoxO and mTOR signaling pathways. In addition, the lncRNA-miRNA-mRNA and circRNA-miRNA-mRNA networks of CS was constructed. The mechanism of gene expression regulated by ncRNA was revealed at the full transcriptome level via the regulated networks of the ceRNA. These results illustrate the relationship between ncRNA and mRNA in the pathogenic mechanism of CS.

Conclusion
This is the first study to comprehensively identify ceRNAs regulated network of the embryo somite development of VAD-CS and to demonstrate the involvement of different ncRNA expression patterns. This information will enable further research on the pathogenesis of CS and facilitate the development of novel CS therapeutics targeting ceRNAs.



120. Intra-Wound Application of Vancomycin Powder May Increase Gr (-) Wound Infections: A Case-Control Study

Prashant Adhikari, MS; Vugar Nabiyev, MD; Selim Ayhan, MD; Selcen Yuksel, PhD; Selcuk Palaoglu, MD, PhD; Emre Acaroglu, MD

Summary
To compare the surgical site infection rates in spinal surgery with or without topical intra-wound application of vancomy-

cin powder in addition to standard IV antibiotic prophylaxis, a retrospective case series review was performed. The results of the study demonstrated that topical intra-wound application of vancomycin powder does not reduce the risk of SSI in spinal surgery and may even increase the rate of Gr (-) infections.

Hypothesis
Application of intra-wound vancomycin powder before surgical closure may not reduce the surgical site infection (SSI) rate after spine surgery

Design
Retrospective case control study.

Introduction
SSI after spine surgery is a devastating condition with significant increases in health care costs, hospital stay and morbidities. Recent studies have suggested that application of intra-wound vancomycin powder before surgical closure may be a promising method for reducing the SSI rate after spine surgery. However, its use is controversial and the literature support on its efficacy is conflicting.

Methods
A total of 158 patients undergoing spinal surgery in a single hospital with the same surgical team, for indications other than infections and single level cervical or lumbar disc surgeries from January 2015 to December 2016 were included in the study. Of these, eighty-eight (55.7%) patients who were operated in 2016 and had received intra-wound vancomycin (V group) were compared to 70 (54.3%) who were operated in 2015 and did not have (No-V group). Data on demographics, surgical characteristics, possible risk factors for SSIs and the application of vancomycin powder were collected from the patients' files and electronic patient records. Infection rates were compared with Chi-square statistics.

Results
Groups were similar with respect to demographic and surgical characteristics. Out of 158 patients, 4 (2.5%) patients acquired SSI. There were 3 (3.4%) patients with SSI in the V group compared to 1 (1.4%) patient in the non-V group (p=0.43). All patients with SSI in both groups were found to have undergone more than three levels of instrumented fusion. The isolated microorganisms were Escherichia coli in two patients and Pseudomonas aeruginosa in one patient in the V group, whereasthe non-V patient grew Morganella morganii and Staphylococcus epidermidis.

Conclusion
Intra-wound application of vancomycin powder does not reduce the risk of SSI in spinal surgery. Moreover, it may also affect the underlying pathogens increasing the propensity for gram negative species.

121. Topical Vancomycin in Concentrations over 5 mg/ml is Toxic to Stem Cells

Chenghao Zhang, PhD, MBBS, MS; Eric Lewallen, PhD; A. Noelle Larson, MD; Andre van Wijnen, PhD; Thomas Boyce, MD; Robin Patel, MD; Todd Milbrandt, MD

Summary
High concentrations of topical vancomycin powder may have negative effect on surrounding cells, especially mesenchymal stem cells and osteoblasts. This work suggests a maximum dose for topical application in spine surgery so as to achieve bactericidal effects without deleterious effects on local tissues and fusion potential.

Hypothesis
Local application of vancomycin would have a negative effect on stem cell response in vitro.

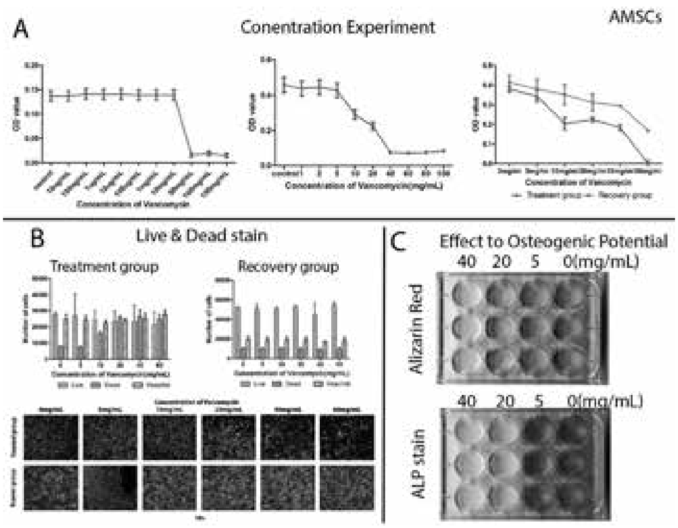
Design
Human adipose-derived stem cells were exposed to topical vancomycin and evaluated by assays of cellular function.

Introduction
High concentrations of topical vancomycin powder may have negative effect on surrounding cells, especially mesenchymal stem cells and osteoblasts.

Methods
Human adipose-derived stem cells (hAMSCs) were treated for 24 hours with vancomycin over 11 concentrations, ranging from 0 to 150 mg/mL. The recovery response was also investigated. Two groups were analyzed, an exposure group (E), exposed to vancomycin for 24 hours, and a recovery group (R), exposed to vancomycin for 1 hour and then recovered for 24 hours. Cellular number (MTS), activity (Live&Dead stain) and c-FOS, c-Jun, ATF4 and ATF6 gene expression were measured with qPCR. Osteogenic potential of the stem cells was also assessed with alizarin red and ALP staining.

Results
Cell death and decreased cellular proliferation was observed at vancomycin concentrations above 50 mg/mL ($p<0.05$, Figure 1A). The R group recovered after 1 hour at concentrations from 5 to 60 mg/mL (Figure 1A). Gene expression (qPCR) in the E group showed upregulation of stress genes (ATF4 and ATF6) and apoptosis genes (c-FOS and c-Jun), while expression of cell proliferation and ECM genes was decreased (Figure 1B). The osteogenic potential was downregulated with significantly less calcium deposition and ALP reaction as vancomycin concentrations increased. With vancomycin 20 mg/mL, there was no ALP synthesized, but cells produced calcium deposition (Figure 1C).

Conclusion
Vancomycin concentrations above 5 mg/mL caused negative effects on hAMSCs, with apoptosis occurring at 50 mg/mL. Gene expression and osteoblastic potential also were decreased at higher concentrations. Further work is needed to determine corresponding dose for topical spine application in humans, but high concentrations appear to be toxic to human cells.



122. The Impact of Prophylactic Intraoperative Vancomycin Powder on Microbial Profile, Antibiotic Regimen, Length of Stay, and Reoperation Rate in Elective Spine Surgery

Zachary Grabel, MD; Dale Segal, MD; Allison Boden, BA; Stephanie Boden; Andrew Milby, MD; John Heller, MD

Summary
There is growing concern that the microbial profile of surgical site infection (SSI) in the setting of prophylactic vancomycin powder may favor more resistant and uncommon organisms. In this series, prophylactic vancomycin powder was associated with a higher prevalence of gram negative and polymicrobial organisms in patients who ultimately developed post-operative SSI. However, this did not adversely affect the need for multiple reoperations, antibiotic regimen, or length of stay (LOS) for these patients.

Hypothesis
We hypothesized that prophylactic vancomycin powder is associated with a greater prevalence of gram negative and polymicrobial cultures in those who develop surgical site infection but this would not affect antibiotic regimen, reoperation rate or length of stay.

Design
Retrospective cohort.

Introduction
The purpose of this study was to demonstrate the impact of prophylactic intraoperative vancomycin powder on microbial profile, antibiotic regimen, length of stay (LOS), and reoperation rate in spine surgical site infection (SSI).

Methods
A retrospective review of patients who underwent posterior thoracic and/or lumbar spine surgery between 2010 and 2017 was conducted. Those undergoing surgical treatment of SSI were identified, and patients were divided into two groups - those who were treated with intra-operative vancomycin (treated) and those who were not (untreated). The organism profile for each group was compared. The average length of stay, reoperation rate, and number of patients requiring more than one antibiotic were calculated for each patient in both groups.

Results
There were 5,909 procedures performed. 115 SSIs were identified. Prophylactic vancomycin powder was used in the index procedure for 42 of those cases. 23.8% of cultures in the vancomycin group were polymicrobial and 16.7% were gram negative compared to 9.6% (p=0.039) and 4.1% (p=0.021) in the untreated group, respectively. In the vancomycin-treated group, 26.1% of patients underwent repeat irrigation and debridement compared to 38.4% in the untreated group (p=0.184). The percentage of patients in the treatment and untreated group who required more than one antibiotic was 26.0% and 26.1%, respectively (p=0.984).Mean LOS in the treatment group was 8.0 versus 7.9 for the untreated group (p=0.94)

Conclusion
In this series, prophylactic vancomycin powder was associated with a higher prevalence of gram negative and polymicrobial organisms in patients that ultimately developed post-operative SSI. However, this did not adversely affect the need for multiple reoperations, antibiotic regimen, or length of stay for these patients.

123. Using Lean/Six Sigma Reaches Target Zero for Surgical Site Infections (SSIs) in Pediatric Spinal Fusion Surgery for Over 100 Consecutive Cases

Karen Myung, MD, PhD; Brock Reiter, MD; Michael Kheir, MD

Summary
This study evaluates the use of Lean/Six Sigma (LSS) to reduce SSIs in pediatric spinal fusion surgery. We hypothesized that Lean/Six Sigma implementation can reduce the rate of spinal SSIs. Deployment of a Lean/Six Sigma endeavor reduces SSIs to zero for over 100 consecutive pediatric spinal fusion cases inclusive of all diagnoses, compared to a rate of 5% in the previous consecutive 100 cases in a single surgeon experience.

Hypothesis
Lean/Six Sigma deployment can significantly reduce the rate of pediatric spinal SSIs.

Design
A single-surgeon, single-institution comparative study was performed, with a prospective consecutive case cohort compared to a retrospective consecutive case cohort.

Introduction
Despite concerted efforts, SSIs remain a significant cause of morbidity and expense. Studies have taken a "kitchen sink" approach, yet report a "human factor" that poses as an uncontrolled variable. Lean/Six Sigma (LSS) approaches to quality and process improvement were philosophically designed to analyze the "human factors" in an effort to reduce such errors.

Methods
A LSS event to reduce pediatric spinal SSIs was conducted in September, 2015. Intraoperative tasks from room set-up to wheels-out were included in the process scope. LSS-based

changes were implemented. Data on 100 consecutive spinal fusion cases (Post-Lean group) were prospectively collected after the event, and were compared to retrospectively collected data on 100 consecutive spinal fusions that preceded the event (Pre-Lean group). No spinal fusion patients were excluded. The CDC definition for deep SSI was used. Student t and Pearson chi-square tests evaluated significance of differences.

Results
Process improvements were simple and without cost, and continue to include efforts to improve staff engagement and consistency. The demographics, surgical factors and comorbid conditions, including neuromuscular diseases, were similar between groups. 100-case SSI rates were 5% and 0% for the Pre-Lean and Post-Lean groups, respectively (p=0.024). No patients were lost to follow-up. Importantly, the current SSI rate remains zero at greater than 2-year follow-up.

Conclusion
Intuitively, surgeons understand that the “human factor” is relevant in SSIs. This study demonstrates the use of LSS to address the “human factor,” when the “kitchen sink” has already been implemented, reducing SSIs in pediatric spinal fusion surgery to zero. The implications on quality and costs are immense. Importantly, few examples of the use of LSS to successfully improve orthopedic surgery processes exist in the literature.

124. Single-Stage Implant Exchange Provides Less Correction Loss than Implant Removal Only Following Late Infections After Posterior Spinal Fusion for AIS

Derek Nhan, BS; Paul D. Sponseller, MD; Harry L. Shufflebarger, MD; Suken Shah, MD; Burt Yaszay, MD; Michelle Claire Marks, MS, PT; Peter Newton, MD; Harms Study Group

Summary
Late infections following posterior spinal fusion (PSF) for AIS represent a significant post-operative complication and are often an indication for revision. While removal of implants is frequently curative, single-stage implant exchange offers reduced loss of correction and improved sagittal profile, and equivalent re-infection risk and patient-reported outcomes (HRQL) at 2 years after revision. Implant removal only may require eventual revision to correct deformity progression and pain.

Hypothesis
Single-stage implant exchange (SSE) will have an equivalent re-infection rate compared to implant removal only (ROI), but will provide better deformity control and patient-reported outcomes for treatment of late infections.

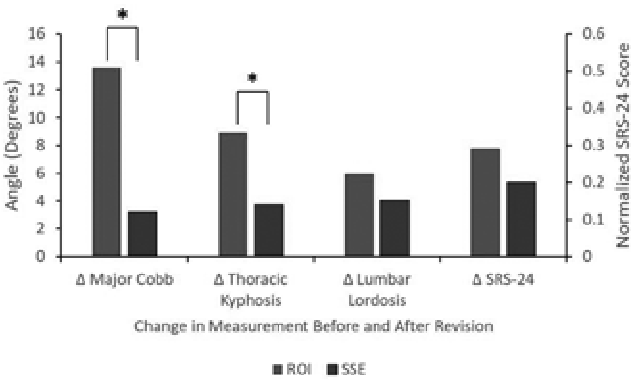
Design
Retrospective review of a prospective AIS registry

Introduction
Risk of late-developing (>1 yr) infections following spinal fusion for AIS is ~1.7-6.7% and represents the leading cause for late revision. While implant removal and short-term antibiotics are usually curative, deformity progression and less satisfactory outcomes may occur.

Methods
A multicenter AIS registry was queried for patients who underwent PSF and had late infections after their index surgery. Patients were sub-divided into either ROI or SSE. Radiographic (major Cobb, thoracic kyphosis, lumbar lordosis), surgical (EBL, op time), and HRQL outcomes at ≥ 2 yr follow-up after revision were compared.

Results
40 patients were included (mean age at index 15±2 yrs), who had late infections 2.4+/-1.1 yrs (range 1.2-4.4 yrs.) post-op. 24 patients were treated with ROI (mean age 18±3 yrs) while 16 had SSE (mean age 19±3 yrs). Organisms, when isolated, were mostly gram (+). Pre-revision measurements showed no group differences for major Cobb (p=0.631), thoracic kyphosis T2-T12 (p=0.182), or lumbar lordosis (p=0.421). At latest follow-up, however, loss of correction was significantly less in the SSE group (mean change in major Cobb +13.6° for ROI vs. +3.2° for SSE, p=0.04) & change in thoracic kyphosis (mean +8.9° for ROI vs. +3.7° for SSE, p=0.041). SRS-24 scores at 2 yrs were greater for SSE but did not reach significance (4.13 vs. 3.98, p=0.66), respectively. No difference was seen for SSE vs. ROI in op time (191 vs. 155 min, p=0.29), EBL (610 vs. 555 mL, p=0.96), or length of stay (8 vs. 5 days, p=0.21). All wounds healed and no patient had a subsequent infection after revision by 2 yrs follow-up. 2 ROI pts had re-instrumentation for curve progression.

Conclusion
For late infections after spinal fusion in AIS, SSE provides less correction loss vs. ROI and equivalent re-infection risk and HRQLs without a greater operative burden.



125. The Treatment of SSI in Severe Spinal Deformity Received PVCR: Hard Choices of Removing Implants

Jingming Xie, MD; Tao Li, MD; Yingsong Wang, MD; Ying Zhang, MD; Zhi Zhao, MD; Zhiyue Shi, MD; Ni Bi, MD

Summary
The study provides data and treatment strategy for the surgical site infection (SSI) after PVCR.

Hypothesis
The stability of the spine depend only on the anterior and posterior implants in PVCR, and the surgeon should face a distinct and more intractable SSI in PVCR.

Design

Retrospective study.

Introduction

Patients undergoing PVCR for severe spinal deformity have poor nutrition, longer operation time, more fusion levels with larger blood loss, those patients have a higher risk of SSI.

Methods

A large case cohort analysis of 158 severe spinal deformity underwent PVCR to access the incidence, identify risk factors and treatment for SSI. SSI was classified as type 1: not involved implants, type 2: involved posterior implants, type 3: type 2 + involved anterior resection space. Medical records were reviewed.

Results

Prophylactic antibiotics was administered pre-operatively and post-op 72 hours in all cases. SSI developed in 9(5.7%) cases: 4(2.5%) with type 1, 5(3.2%) with type 2, without type 3; acute SSI in 6, delayed in 3. Poor nutrition was an independent risk factor for all SSI and type 1 SSI (P = 0.035). Drain removal delayed (>4 days) was a risk factor for type 2 (P = 0.018). The escherichia coli was the most commonly identified organism. All SSI cases received antibiotic treatment. All type 1 SSI were cured by debridement/VSD. 4 type 2 were cured by repeated debridement/VSD/irrigation. 1 case developed delayed type 2 SSI, SSI recurred at 6 months after repeated debridement/VSD. Then, all implants were removed by traction to maintain the spinal stability. Four months later, implants were replaced again after SSI being controlled.

Conclusion

In PVCR, the treatment of refractory SSI is intractable, especially when the spine is not sufficiently stable. Removing implants is a tough but efficient choice sometimes. The new classification of SSI is more conducive to guide clinical decisions in osteotomy that require implants to provide spinal stabilization. Active prophylactic antibiotics is necessary to avoid type 3 SSI.

Patient No.	Age	Sex	Presenting Symptoms	Onset (Weeks)	No. Surgeries for Treatment	Intraoperative Findings	Culture Results	Antibiotics	Remarks
1	[illegible]	F	Drainage, Swelling	1	3	Type 2	Escherichia coli	Cefoperazone and Sulbactam 6 wk	Drainage removal delayed
2	[illegible]	F	Back pain, Drainage	2	3	Type 2	Escherichia coli	Cefoperazone and Sulbactam Levofloxacin 6 wk	Drainage removal delayed Poor Nutrition
3	[illegible]	M	Back pain, Drainage, Swelling, Fever	2	2	Type 2	Escherichia coli	Imipenem, Moxifloxacin 6 wk	Drainage removal delayed
4	22	F	Back pain, Swelling, Fever	47	8	Type 2	Enterobacter cloacae	Levofloxacin 12 wk	Drainage removal delayed
5	[illegible]	F	Swelling, Skin ulcer Fever	6	9	Type 2	MRSA	Vancomycin 6wk	
6	[illegible]	F	Back pain, Fever Swelling, Drainage	3	2	Type 1	Bacillus	Cefoperazone and Sulbactam 6 wk	Poor Nutrition
7	24	M	Swelling	1	2	Type 1	Negative	Cefazolin 2 wk	
8	[illegible]	M	Swelling, Drainage	[illegible]	2	Type 1	Staphylococcus aureus	Cefoperazone and Sulbactam 2 wk	Poor Nutrition
9	[illegible]	F	Drainage	8	2	Type 1	Negative	Cefazolin 2 wk	Poor Nutrition

126. Flat Bed Rest vs. Immediate Mobilization after Incidental Durotomy in Spine Surgery: Preliminary Results of a Randomized Controlled Trial

Mazda Farshad, MD; Alexander Aichmair, MD; Michael Betz, MD; José Spirig, MD; David Ephraim Bauer, MD

Summary

This is the only available randomized controlled trial with thirty–nine patients (mean age of 64 ±13 years) undergoing lumbar spinal surgery complicated by incidental durotomy and immediate repair consecutively randomized to either immediate postoperative mobilization (n=23) or flat bed rest for 48 hours (n=16). There was no benefit of prolonged bed rest other than a very slight difference in hospitalization in the favor of the early mobilization group.

Hypothesis

Prolonged bed rest is not advantageous to early mobilization after incidental dural lesions.

Design

Randomized controlled trial

Introduction

Incidental durotomy (ID) is a frequent complication during spinal surgery. Persisting leakage of cerebral spinal fluid (CSF) can occur even after ID-repair and requires revision surgery. Prolonged flat bed rest with intention to reduce hydrostatic pressure at the repair site is proposed but debated to reduce the occurrence of CSF leakage after ID-repair. A RCT is lacking comparing prolonged bed rest versus immediate mobilization after ID-repair.

Methods

Thirty–nine patients (mean age of 64 ±13 years) undergoing lumbar spinal surgery complicated by ID and immediate repair were consecutively randomized to either immediate postoperative mobilization (n=23) or flat bed rest for 48 hours (n=16). The adherence to the mobilization regimen was controlled with a motion tracking system. Indications for revision surgery were clinical symptoms, a semi quantitative analysis using glucose sticks and/or Beta transferrin confirming CSF leakage. The rate of revision surgery, medical complications, duration of hospitalization, as well as tear size were compared between groups.

Results

One patient in the bed rest group underwent revision surgery because of persistent CSF leakage while none of the patients in the early mobilization group required further surgical interventions. Two patients in the flat bed rest group experienced medical complications (pneumonia and cerebral ischemia). There was only a slight difference in duration of hospitalization (6 ± 2 vs. 8 ± 4 nights) and no differences in tear size (3.26 vs. 4.07 mm) in the early mobilization group compared to the bed rest group, respectively.

Conclusion

Preliminary results of the here presented only available randomized controlled trial indicate no benefit of prolonged bed rest in patients undergoing spine surgery complicated by ID. The study is being continued to minimize the potential of a sample size bias.

127. Revision Rate after Primary Adult Spinal Deformity Surgery

Frederik Pitter, MD; Martin Lindberg-Larsen, MD, PhD; Alma Pedersen, MD, PhD, DMSc; Benny Dahl, MD, PhD; Martin Gehrchen, MD, PhD

Summary

Revision rates following Adult Spinal Deformity (ASD) has been

reported from 7 to 26%. Complete follow-up over several years can be challenging but possible in Denmark due to the unique social security number system. We report revision rate of 20% within 2 years after primary ASD surgery. Implant failure was the most common reason for revision (24%), whereas infection caused revision in 12%. Higher comorbidity burden predisposed to revision, while younger patients seemed to have lower risk for revision.

Hypothesis
Revision rates after ASD surgery is significantly related to comorbidity.

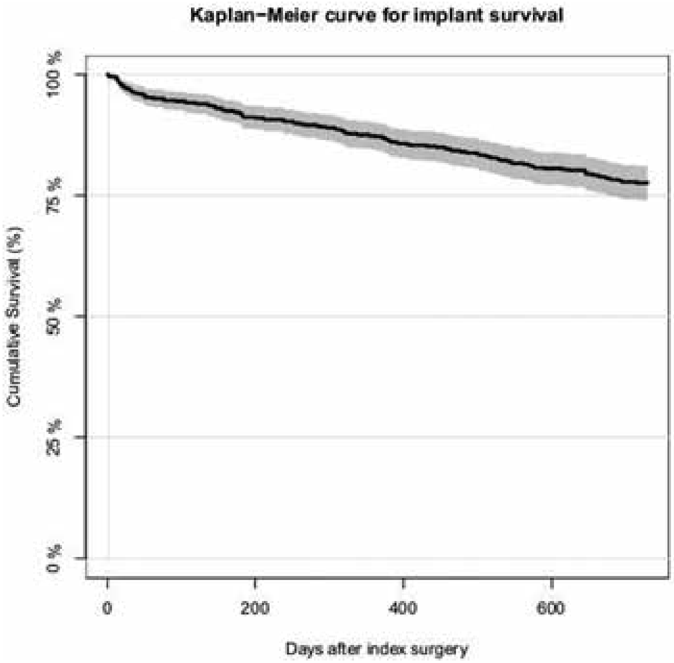
Design
Nationwide cohort study with 2-year follow-up on all patients.

Introduction
Revision rates following primary ASD surgery has been reported to vary between 7 and 26 %. Most studies report loss to follow-up as a considerable limitation. All citizens in Denmark receive a unique social security number, which is used on all contacts with the Danish Healthcare System. This allows a complete nationwide follow-up over time.

Methods
Patients ≥18 years of age, undergoing primary instrumented surgery for ASD in Denmark between January 1st 2006 and December 31st 2014 were identified by procedure and diagnosis codes in the Danish National Patient Registry (DNPR). Each patient was followed for 2 years. All spinal revision procedures were identified. Medical records were reviewed for revision surgeries to determine reason for revision and type of revision procedure. Overall comorbidity for each patient was summarized using the Charlson Comorbidity Index (CCI) score based on data from DNPR; low comorbidity (score of 0 (no record of diseases included in the CCI)); moderate comorbidity (score of 1-2); and severe comorbidity (score of ≥3).

Results
A total of 790 patients were identified, and 19.9% of these were revised during the two-year follow-up. 7.2% of patients were revised more than once. Median time to first revision was 285 days (Interquartile range 105 – 507). The most common reason for revision was implant failure (23.9%), followed by implant dislodgement (14.5%) and infection (11.8%). A total of 46.2% of infections occurred within 90 days postoperatively. Infections were deep in 61.5% of patients. Risk of revision was increased in patients with CCI 1-2 (OR=1.7, 95% CI 1.0-2.7)) and in patients with CCI ≥3 (OR = 2.4, 95%CI 1.2-5.0) when analyzed in a multiple logistic regression model.

Conclusion
We report a 20% revision rate after ASD surgery on a nationwide basis with complete 2 years follow-up. A high burden of comorbidity was associated with increased the risk of revision after primary surgical treatment of ASD.



128. Intra-Operative Neuromonitoring for Pediatric Deformity: A 12 Year Experience From a Single Institution.

John Vorhies, MD; Kali Tileston, MD; Lawrence Rinsky, MD; Leslie Lee, MD; Scheherazade Le, MD; S. Charles Cho, MD; Viet Nguyen, MD

Summary
In a review of 605 pediatric spinal deformity using intraoperative neurophysiologic monitoring (IONM) between 2003 and 2015 we found a 5.8% rate of alerts and a 1.3% rate of clinical neurologic deficits. No transient IONM alert resulted in a permanent deficit. IONM was 100% sensitive and 95% specific for a clinical deficit. A persistent IONM alert has a 57% positive predictive value for a clinical deficit.

Hypothesis
Intra-Operative Neuromonitoring (IONM) alerts predict clinical neurologic deficits

Design
retrospective cohort study

Introduction
Multimodal IONM has been established as an effective means to prevent neurologic injury during surgical treatment of pediatric spinal deformity. Here we present a 12 year experience from a single institution to evaluate the efficacy of IONM to predict postoperative neurologic deficits.

Methods
A retrospective review of 605 pediatric spinal deformity cases using IONM between 2003 and 2015 at a single institution. Intraoperative changes were identified and compared to postoperative clinical deficits. IONM changes were classified as transient (resolving by end of case) or persistent (not resolving by end of case).

Results

A total of 35/605 cases (5.8%) had IONM alerts; 21 (60%) were transient and 14 (40%) were persistent. Of the patients with transient changes, none developed clinical neurologic deficits. Of the patients with persistent changes, 8 (57%) had clinical postoperative deficits while 6 (43%) did not. None of the cases without IONM alerts developed new deficits. In our experience IONM is 100% sensitive and 95% specific for postoperative clinical neurologic deficits and has a 100% negative predictive value. Any IONM alert has a 23% positive predictive value for a clinical neurologic deficits and A persistent IONM alert has a 57% positive predictive value for a clinical deficit.

Conclusion

IONM is an important tool to prevent iatrogenic neurologic injury during pediatric spinal deformity surgery. Persistent IONM alerts are predictive of clinical deficits.

Table 1: Intraoperative Neurophysiologic Monitoring

Intraoperative neurophysiologic monitoring (IONM) changes compared to postoperative clinical neurologic deficits

	#	Deficits	%	No Deficits	%	
	605	8	1%	597	99%	
IONM Changes	35 (5.8%)	8 8 persistent 0 transient	23%	27 6 persistent 21 transient	77%	PPV 23%
No IONM Changes	570	0	0%	570	100%	NPV 100%
		100% Sensitivity		95% Specificity		

129. Minimally Invasive Versus Standard Surgery in Idiopathic Scoliosis Patients: A Comparative Study

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Summary

This is the largest study comparing the surgical outcomes of MISS and PSF. The perioperative and radiographic benefits of MISS as shown in this study suggest that we should reevaluate the surgical approach offered to AIS patients.

Hypothesis

MISS has superior perioperative benefits

Design

Multicenter ambispective

Introduction

Minimally invasive scoliosis surgery (MISS), in smaller studies, has been shown to have significant benefits over standard posterior spinal fusion (PSF) in adolescent idiopathic scoliosis (AIS). This study seeks to compare the two procedures in a large group of patients.

Methods

Retrospective review of a multi-institutional prospective database was performed. Radiographic, clinical, and operative data were collected for MISS patients (3/08-7/17) and PSF (1/13 to 7/17).

Results

303 patients met the inclusion criteria: 150 were MISS and 153 were PSF. There were no significant differences in preoperative Cobb angle (MISS: 55.0° vs. PSF: 54.1°, p =0.798) or kyphosis (25° vs. 26°, p =0.342). MISS patients were significantly older. (15.3 vs. 14.7, p < 0.001), but PSF patients had a significantly higher BMI (21.6 vs. 19.8, p<0.001). The two most frequent Lenke types in PSF were Lenke 1 and 3, and in MISS were Lenke 1 and 2. Operative time (minutes) was significantly higher in MISS (317.5 vs. 266.0, p =0.040), but fixation points were significantly lower (20 vs 22, p <0.001). Blood loss was significantly lower in MISS (300 vs 500, p<0.001). Transfusion rate was significantly lower in MISS (n=6 vs n=28, p <0.001) as was length of stay (days) (4.9 vs 5.3, p = 0.025). Cobb correction was comparable between MISS and PSF (68.2% vs 67.3%, p = 0.760), however percent increase in thoracic kyphosis was significantly higher in MISS (14.6% vs -8.6%, p <0.001). Complication rate was higher in PSF (9.2% vs 8.7%), but not significant (p = 0.883). In PSF, there were 5 transient signal losses, 3 acute infections, 2 seromas, 1 C. difficile colitis, 1 intraoperative pneumothorax, and 1 proximal junctional kyphosis requiring revision. In MISS, there were 7 infections (6 delayed, 1 acute), 2 hardware-related revisions, 2 suture granuloma requiring revision, 1 DVT, and 1 pneumothorax.

Conclusion

This is the largest study comparing the surgical outcomes of MISS and PSF. MISS patients seem to benefit from less blood loss, lower transfusion risk and shorter hospital stay with similar Cobb correction.

130. Neurologic Injury in Complex Adult Spinal Deformity Surgery: Multilevel Oblique Lumbar Interbody Fusion (MOLIF) Using Hyperlordotic Porous Metal Cages Versus Pedicle Subtraction Osteotomy (PSO)

Darren F. Lui, MBBS, FRCS; Haiming Yu, MD; Jan Herzog; Joseph S. Butler, PhD FRCS; Karan Malhotra, FRCS; Susanne Selvadurai, BSc(Hons); Sean Molloy, MBBS, FRCS, MSc (eng)

Summary

Scoli RISK 1 trial shows that a true propsective trial regarding neurological injury in adult deformity surgery is higher than previously reported. The use of PSO as a technique is well established but known to carry morbidity particularly neurological. The use of MOLIF approach and multi level hyperlordotic cages restores sagittal balance as good as PSO but with less neurological injury.

Hypothesis

Staged oblique lumbar interbody has reduced neurological deficit in CASD compared to PSO

Design

Retrospective analysis of prospectively collected data

Introduction

Complex Adult Spinal Deformity (CASD) represents a challenging cohort of patients. The Scoli-RISK-1 study of adults under-

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going correction for adult spinal deformity (ASD) has shown a 22.18% perioperative risk of neurological injury in the perioperative period. Restoration of sagittal parameters is associated with good outcome in ASD. Pedicle subtraction osteotomies (PSO) is an important technique for sagittal balance in ASD but is associated with significant morbidity. The multilevel oblique lumbar interbody fusion (MOLIF) approach allows access through an extensile single incision from L1 to S1 and staged multilevel MOLIF may obviate PSO.

Methods

Single surgeon series 2007 to 2015. Prospectively collected data. Scoli-RISK-1 criteria were refined to only include fixed or fused spines otherwise requiring a PSO. Roentograms examined preoperatively and 1 year post-operatively. Primary outcome measure was the motor decline in American Spinal Injury Association (ASIA) at hospital discharge, six weeks and 6 month, 1 year and 2 years. PROMS, Demographics, blood loss, operative time, spinopelvic parameters measured and Spinal Cord Monitoring (SCM) events were recorded.

Results

68 consecutive patients. 34 each. Group 1(MOLIF) mean age 62.9 and Group 2(PSO) mean age of 66.76. gender MOLIF: 64.7% female versus PSO 76.5%. Body Mass Index(BMI) Group 1(MOLIF) 28.05 and Group 2 (PSO) 27.17. Group 1(MOLIF) neurological injury 2.94% at discharge but resolved by 6 weeks. Group 2 (PSO) 5 neurological deficits (14.7%) with no recovery by 6m-2y. SCM events: Group 1(MOLIF) 2.94% versus Group 2(PSO) 8.88%

Conclusion

A multistage MOLIF approach followed by PSF is safer than PSO in CASD with stiff spines. MOLIF showed a lower perioperative neurological injury rate compared to PSO indicating a safer operative technique whilst achieving superior spinopelvic harmony.

131. Is Achieving Optimal Spinopelvic Parameters Necessary to Obtain Substantial Clinical Benefit: Analysis of Patients Who Underwent Circumferential MIS or Hybrid Surgery With Open Posterior Instrumentation

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Summary

This study evaluated whether achieving optimal spinopelvic alignment (AL) was necessary to obtain MCID or SCB for ODI. 153 patients were divided into those that achieved AL and those who did not (MAL). There was no difference in the proportion of AL or MAL patients who achieved MCID or SCB. On multivariate analysis, achieving AL was not associated with obtaining MCID or SCB for ODI. Previously reported AL parameters may need modification to account for factors such as age.

Hypothesis

Achieving optimal spinopelvic parameters is necessary to attain meaningful improvement in adult spinal deformity (ASD) patients.

Design

Multicenter retrospective review

Introduction

It has been proposed that achieving optimal spinopelvic alignment is needed to attain clinical improvement. This study assessed whether obtaining optimal spinopelvic alignment was necessary to achieve a minimal clinically important difference (MCID) or substantial clinical benefit (SCB).

Methods

Inclusion criteria were age ≥18 years, and one of the following: coronal cobb>20°, SVA>5cm, PT>20°, PI-LL >10°. Patients underwent circumferential MIS or hybrid surgery and had 2-year minimum follow-up. Based on optimal spinopelvic parameters (PI-LL ±10°, PT<20°, SVA<5cm), patients were divided into aligned (AL) or mal-aligned (MAL) groups. MCID and SCB were defined as a 12.8 and 18.5 ODI improvement, respectively.

Results

153 patients were identified (74 AL and 149 MAL). Although baseline SVA was similar, PI-LL (9.9° vs 17.7°, p=0.002) and PT (19° vs 24.7°, p=0.001) significantly differed between AL and MAL groups, respectively (Table 1). As expected postoperatively, the AL and MAL groups differed significantly in PI-LL (-0.9° vs 13.1°, p<0.001), PT (14° vs 25.5°, p=0.001), SVA (11.8mm vs 48.3 mm, p<0.001), respectively. There was no difference in the proportion of AL or MAL patients who achieved MCID (52.75 vs 61.1%, p>0.05) or SCB (40.5% vs 46.3%, p>0.05), respectively. On multivariate analysis controlling for surgical and demographic differences, achieving optimal spinopelvic parameters was not associated with achieving MCID (OR 0.645, 0.31-1.33, 95%CI) or SCB (OR 0.644, 0.31-1.35, 95%CI) ODI.

Conclusion

Achieving optimal spinopelvic alignment did not appear to be a predictor for obtaining a MCID or SCB. Since spinopelvic parameters are correlated with clinical outcomes, our findings suggest that other factors such as age may influence the radiographic thresholds (SVA, PT, PI-LL) needed to achieve meaningful improvement.

Table 1.

	Aligned	Malaligned	p
N	74	149	
Age	60.2	61.9	0.236
BMI	27.4	27.7	0.79
Follow-up	35.0	40.9	0.012
MIS	51 (68.9%)	82 (55.0%)	0.047
Staged	27 (36.5%)	78 (52.3%)	0.025
Levels Instrumented	4.9	6.5	<0.001
IBF Levels	2.8	3.3	0.007
Total OR Time	427.6	524.0	0.002
Total EBL	604.5	992.3	0.001
Total LOS	6.6	8.1	0.004
Preop Back Pain	6.7	7.0	0.374
Preop Leg Pain	6.1	5.5	0.091
Preop ODI	49.8	52.1	0.475
Preop Max Cobb	36.4	32.8	0.224
Preop SS	32.2	29.8	0.182
Preop PT	19.0	24.7	0.001
Preop PI	50.8	54.7	0.021
Preop PI-LL	9.9	17.7	0.002
Preop LL	41.6	36.8	0.106
Preop SVA	30.9	48.7	0.503
Postop Back Pain	3.6	3.8	0.899
Postop Leg Pain	2.5	2.5	0.825
Postop ODI	30.7	33.1	0.484
Postop Max Cobb	23.2	16.1	0.45
Postop SS	31.6	29.6	<0.001
Postop PT	14.0	25.5	0.001
Postop PI	45.0	55.3	<0.001
Postop PI-LL	-0.9	13.1	<0.001
Postop LL	46.7	42.0	0.087
Postop SVA	11.8	48.3	<0.001
Δ Back Pain	-3.1	3.1	0.631
Δ Leg Pain	3.6	-3.1	0.411
Δ ODI	-18.9	-19.2	0.606

132. Assessment of T1 Slope Minus Cervical Lordosis and C2-7 Sagittal Vertical Axis Criteria of a Cervical Spine Deformity Classification System Using a Long-term Follow-Up Data After Multilevel Posterior Cervical Fusion Surgery

Seung-Jae Hyun, MD, PhD; Sanghyun Han, MD; Jong-Hwa Park, MD

Summary

A previous research proposed a cervical spine deformity (CSD) classification. However, C2-C7 SVA and TS-CL cut-off values were based on expert opinion. We investigated the validity of a CSD classification system. Regression models predicted a threshold C2-C7 SVA (value of 40.8 mm and 70.6 mm) and TS-CL (value of 20° and 25°) correlated with moderate and severe disability based on the NDI, respectively. The cut-off value C2-C7 SVA and TS-CL modifier of the CSD classification can be revised accordingly.

Hypothesis

CSD classification can be revised using a long-term follow-up data.

Design

A retrospective study with a minimum 5-year follow-up.

Introduction

Recently, a previous research proposed a cervical spine deformity (CSD) classification using a modified Delphi approach. However, C2-C7 SVA and TS-CL cut-off values for moderate and severe disability were based on expert opinion. This study aims to investigate the validity of the CSD classification system using a long-term follow-up data after multilevel posterior cervical fusion surgery in terms of C2-C7 SVA and TS-CL modifiers. Particularly, C2-C7 SVA- and TS-CL cut-off values for moderate and severe disability by NDI score were investigated.

Methods

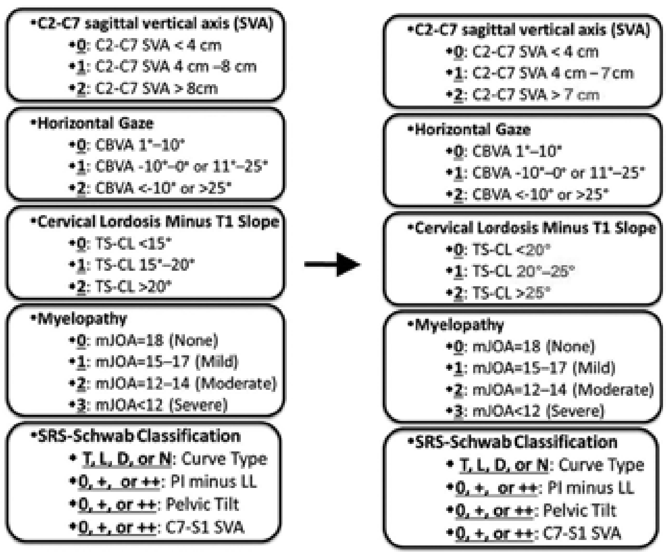
From 2007-2012, 30 consecutive patients with a minimum 5-year follow-up having multilevel (3 levels or more) posterior cervical fusion for cervical stenosis, myelopathy, and deformities met inclusion criteria. Radiographic measurements included: C0-C2 lordosis, C2-C7 lordosis, C2-C7 sagittal vertical axis (SVA), T1 slope, and T1 slope minus cervical lordosis (TS-CL). Pearson correlation coefficients were calculated between pairs of radiographic measures and health-related quality-of-life.

Results

Average follow-up period was 7.3 years. C2-C7 SVA positively correlated with neck disability index (NDI) scores (r = 0.554). Regression models predicted a threshold C2-C7 SVA value of 40.8 mm and 70.6 mm correlated with moderate and severe disability based on the NDI score, respectively. The TS CL also correlated positively with C2-C7 SVA and NDI scores (r = 0.841 and r=0.625, respectively). Results of the regression analyses indicated that a C2-C7 SVA value of 40 mm and 70 mm corresponded to a TS CL value of 20° and 25°, respectively.

Conclusion

Regression models predicted a threshold C2-C7 SVA (value of 40.8 mm and 70.6 mm) and TS-CL (value of 20° and 25°) correlated with moderate and severe disability based on the NDI, respectively. The cut-off value C2-C7 SVA and TS-CL modifier of the CSD classification can be revised accordingly.



133. Postoperative Recovery Kinetics: A Comparison of Primary and Revision Procedures for Cervical Deformity

Frank Segreto, BS; Peter Passias, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin Smith, MD, PhD; Breton G. Line, BS; Robert K. Eastlack, MD; Justin Scheer, MD; Dean Chou, MD; Nicholas Frangella, BS; Brian Neuman, MD; Themistocles Protopsaltis, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher Shaffrey, MD; Christopher Ames, MD; International Spine Study Group

Summary
Recovery profiles for cervical deformity(CD) patients undergoing primary(P) and revision(R) procedures are poorly understood. Utilizing a novel area-under-the-curve normalization methodology, our analysis establishes objective recovery benchmarks for 3M, 6M, 1Y and 2Y followup (f/u) timepoints for primary and revision patients. Primary and revision patients both exhibited postoperatively improved disability scores and relief of neurologic symptoms. Revision patients exhibited a significantly worse recovery of myelopathy symptoms relative to primary patients at 1Y, but this difference diminished by 2Y f/u.

Hypothesis
P and R CD patients have unique recovery profiles

Design
Retrospective review of a prospective CD database

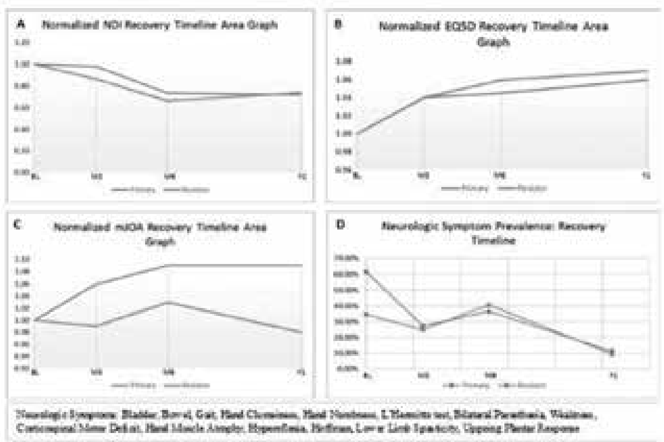
Introduction
The recovery profiles in CD patients undergoing P and R procedures are poorly understood.

Methods
CD patients (CL>10°, cervical scoliosis>10°, cSVA>4cm, TS-CL >10°, or CBVA>25°) with baseline(BL) and 1Y mJOA, NDI, and EQ5D scores were included. Occurrence of any neurologic symptom(Fig 1.) and HRQL scores were compared among P and R. A novel area-under-the-curve(AUC) normalization method generated normalized HRQL scores at BL and all f/u intervals(3M, 6M, 1Y). AUC was calculated for each f/u, and total area was divided by cumulative f/u length, generating one number describing overall recovery (Integrated Health State-IHS). Sub-analysis identified recovery patterns through 2Y f/u.

Results
76 patients were included (44 P, 32 R). Age:61.7, BMI:28.8, Gender:61.8%F, CCI:0.97, 94.6% White, all p>0.05 between groups. Surgical approaches were 49.7% posterior, 31.6% combined, 19.7% anterior; levels fused: 8.3 posterior, 3.4 anterior; EBL: 824.8.1ccs; op-time: 551.0min; all p>0.05 between groups. At BL, 61.4% of P and 34.4% of R were neurologically symptomatic(p=0.020). R remained less neurologically symptomatic until 3M, where P and R exhibited similar symptom rates through 1Y f/u (P:11.4% vs. R:9.4%)(p>0.05). BL HRQL analysis found no differences between P and R (NDI, mJOA, EQ5D all p>0.05). Standard analysis found P to exhibit BL to 1Y NDI (45.3 vs 31.6), EQ5D (0.741 vs 0.784) and mJOA (13.41 vs 14.34) improvements, while R had BL to 1Y NDI (52.3 vs 39.6) and EQ5D (0.729 vs 0.777) improvement, all p<0.05. After HRQL normalization, Y1 mJOA differences were found(P:1.09 vs R:0.980, p=0.027). R trended towards worse IHS mJOA scores (P:0.157 vs R:-0.001). 2Y f/u sub-analysis included 41 patients. All results were consistent through 2Y f/u, except mJOA differences subsided by 2Y f/u (P: 1.07 vs R:1.06, p>0.05).

Conclusion
Both P and R exhibited improved postoperative disability scores and relief of neurologic symptoms. R exhibited significantly worse myelopathy (mJOA) recovery compared to P at 1Y f/u, but this difference diminished by 2Y f/u.

Figure 1: Recovery Kinetics of NDI, EQ5D, mJOA, and Neurologic Symptoms among Primary and Revision Patients through 1Y



134. Development of a Novel Cervical Deformity Surgical Invasiveness Index

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Summary
This study created a cervical deformity specific invasiveness index using surgical and radiographic parameters. Extended length of stay, operative time, and high blood loss were strongly predicted by the newly developed CD invasiveness index, incorporating surgical factors and radiographic parameters clinically relevant for patients undergoing cervical deformity corrective surgery.

Hypothesis
Established metrics of assessing surgical invasiveness and patient risk aren't applicable to a CD population.

Design
Retrospective review

Introduction
There has been a surgical invasiveness index for general spine surgery and adult spinal deformity, but a CD index has not been developed.

Methods

CD was defined as at least one of the following: C2-C7 Cobb>10°, CL>10°, cSVA>4cm, CBVA>25°. Consensus from experienced spine and neurosurgeons selected weightings for each variable that went into the invasiveness index. Linear regression was used to predict operative time, EBL, and length of stay using the newly developed CD-specific invasiveness index, controlling for age, sex, and Charlson Comorbidity Index score. Binary logistic regression predicted high operative time (>338 minutes), high EBL (>600 cc), or high length of stay (>5 days) based on the median values of operative time, EBL and length of stay. Significance was set at P<0.05.

Results

85 CD patients were included(61.35±10.7 years, 65.9% female). The new CD index included: revision status, ACDF, corpectomy, levels fused, implants, posterior decompression, Smith-Peterson osteotomy, three column osteotomy, fusion to upper cervical spine, absolute change in TS-CL, cSVA, T4-T12 thoracic kyphosis and SVA from baseline to 1-year follow-up (Table 1). The newly developed CD invasiveness index was a significant independent predictor of estimated blood loss (R2=0.132, P=0.042). This CD-specific index was also a significant independent predictor of operative time (R2=0.171, P=0.004). CD-specific invasiveness index strongly predicted a hospital length of stay greater than 5 days (R2=0.310, P<0.001), high blood loss (R2=0.170, P=0.011), and extended operative time (R2=0.207, P=0.031).

Conclusion

Extended length of stay, operative time, and high blood loss were strongly predicted by the newly developed CD invasiveness index, incorporating surgical factors and radiographic parameters clinically relevant for patients undergoing cervical deformity corrective surgery.

Table 1. Surgical and radiographic components used to calculate the cervical deformity invasiveness score.

Surgical Factors	*Points Assigned*
ACDF	2 points per level
Corpectomy	4 points per level
Levels Fused	1 point per level
Implants	1 point per implant
Posterior Decompression	2 points per level
Smith-Peterson Osteotomy	2 points per level
Three-Column Osteotomy	8 points per level
Fusion to upper cervical spine	2 points
Revision Status	3 points
Radiographic Factors	
Absolute change in cSVA	0.5 point per 1mm change
Absolute change in TS-CL	0.5 point per 1° change
Absolute change in Thoracic Kyphosis	0.5 point per 1° change
Absolute change in SVA	0.5 point per 1mm change

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135. Indicators for Non-Routine Discharge Following Cervical Deformity-Corrective Surgery: Radiographic, Surgical, and Patient-Related Predictors

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Summary

In a population of 138 patients undergoing cervical deformity (CD)-corrective surgery, complications, radiographic alignment, surgical, and patient-related factors all had a significant influence on discharge location. Specifically, severe preoperative cervical and upper-cervical malalignment, age >59 years, fusions >8 levels, and estimated blood loss (EBL) >900cc were among the factors identified as influential in predicting non-routine discharge, defined as discharge to inpatient rehab or a skilled nursing facility.

Hypothesis

Patient and surgical factors affect discharge location after CD correction

Design

Retrospective review

Introduction

Non-routine discharge is associated with higher cost of care. Increasing prevalence of CD-corrective surgery and emphasis on value-based healthcare necessitates identification of indicators for non-routine discharge in surgical CD patients

Methods

Patients>18yr with discharge and baseline(BL) radiographic data. Non-routine discharge defined: inpatient rehab or skilled nursing facility. Conditional Inference Decision Trees identified predictors of non-routine discharge, and cut-off points at which predictors have a global effect. A Conditional Variable Importance Table used non-replacement sampling set of 3000 Conditional Inference trees to identify influential patient/surgical factors. Binary logistic regression indicated effect size of influential factors at significant cut-off points

Results

Of 138 patients(61yr,63%F) undergoing surgery for CD(8±5 lvls;49% posterior approach, 16% anterior, 35% combined), 29% experienced non-routine discharge. Table 1 shows non-routine discharge predictors. BL cervical/upper-cervical malalignment was the greatest predictor of non-routine discharge:C1 slope>14°, C2 slope>57°, TS-CL>57°. Patient-related predictors of non-routine discharge included BL gait impairment, age>59yr and apex of CD primary driver>C7. EBL>900cc and presence of any neuro complication also predicted non-home discharge. The only surgical predictor of non-routine discharge was fusion>8 lvl. There was no relationship between non-home discharge and reop within 6 months or 1 year(both P>0.05) of index procedure. Despite no differences in BL EQ-5D(P=0.946), non-routine discharge patients had inferior 1-year postop EQ-5D scores(non-routine:0.75, home:0.79,P=0.044).

Conclusion

Preop cervical malalignment was a top predictor of non-routine discharge in surgical CD patients. Age, driver of deformity, and >8 level fusion also predicted non-routine discharge, and should be taken into account to improve resource allocation and patient counseling.

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Importance	Variable	Sig.	O.R.	95% C.I.for EXP(B)	
				Lower	Upper
1	BL C1 Slope ≥ 14°	P<0.001	8.35	3.07	22.71
2	Gait Impairment	P<0.001	5.29	2.25	12.42
3	BL C2 Slope ≥ 57°	P<0.001	6.95	2.64	18.33
4	BL TS-CL ≥57°	P<0.001	5.89	2.19	15.85
5	Number of Complications ≥ 2	P<0.001	4.16	1.87	9.22
6	Postoperative LOS ≥ 6 days	P<0.001	3.99	1.79	8.91
7	BL SWAL Communication Score ≤ 52	P=0.005	4.22	1.55	11.50
8	Age ≥ 59 years	P=0.003	4.25	1.63	11.05
9	EBL ≥ 900 cc	P=0.001	3.56	1.65	7.67
10	Apex of Primary Driver ≥ C7	P=0.001	3.90	1.78	8.56
11	BL C2-S1 ≤ -22°	P=0.001	4.75	1.92	11.74
12	Levels Fused ≥ 8	P=0.001	4.03	1.81	8.98
13	Stay in SICU	P=0.001	5.35	1.93	14.82
14	C0 Slope ≥ -0.66°	P<0.001	4.15	1.86	9.26
15	cSVA ≥ 40 mm	P<0.001	4.63	1.97	10.87
16	Any Neuro Complication	P=0.018	2.76	1.19	6.41
17	T2-T12 Kyphosis ≤ -51°	P=0.001	3.85	1.78	8.35
18	McGregor's Slope ≥ 1.9°	P=0.002	4.08	1.68	9.91

136. Continuous-Incremental-Heavy Halo-Gravity Traction Combined with Posterior-Only Approach for Cervical Kyphosis Correction in Patients with Neurofibromatosis-1

Hongqi Zhang, MD; Zhenhai Zhou, PhD

Summary

Few studies have recommended anterior fusion alone or posterior fusion alone for cervical kyphosis associated with NF-1 because of some reasons, such as fusion failure, pseudoarthrosis and correction loss in follow-up. In this study, we evaluated the safety and effectiveness of Continuous-Incremental-Heavy Halo gravity traction(CIH-HGT) combined with posterior-only(PO) approach in the treatment of cervical kyphosis in patients with NF-1.

Hypothesis

A satisfied correction result, and successful bone fusion can be achieved via CIH-HGT combined PO approach. CIH-HGT combined PO approach can be another consideration for cervical kyphosis correction in patients with NF-1.

Design

A retrospective study

Introduction

Surgical management of cervical kyphosis in patients with NF-1 is challenging surgical problem. In the present, anterior-only(AO), posterior-only(PO) and combined anterior-posterior(AP) spinal fusion were common strategies for management of cervical kyphosis in patients with NF-1. However, the choice of surgical strategy and application of HGT remain controversial.

Methods

19 patients with cervical kyphosis due to NF-1 were reviewed retrospectively between January 2010 and January 2016. They were 8 males and 11 females (average age at the time of surgery 15 years, range 7-26 years). All the cases underwent CIH-HGT combined with posterior instrumentation and fusion surgery. Correction result, neurologic status and complications were analyzed. The deformity evaluation was performed on the anterior/posterior and lateral cervical radiographs. The neurological function evaluation was based on the JOA scores.

Results

In this study, 92% total correction was achieved via CIH-HGT combined with PO approach. Cobb angle decreased from initial 63.0 ± 21.0 degrees to postoperative 10.8 ± 4.0 degrees, P<0.01. Traction correction rate was 44% (63.0 ± 21.0 vs. 35.1 ± 11.2) and surgical correction rate was 48%(35.1 ± 11.2 vs. 10.8±4.0). JOA scores were improved from preoperative 13.6±1.6 to postoperative 16.0±1.0, P<0.01. Neurological status was also improved. There was no correction loss and the neurological status was stable in mean 3.7 years follow-up(10.8±4.0 vs. 10.3 ± 5.6). The incidence of complications was 36.8%(7/19). 6 patients underwent local complications and 1 patient underwent a second surgery.

Conclusion

CIH-HGT combined PO approach is safe and effective method for cervical kyphosis correction in patients with NF-1. Good correction, successful bone fusion can be achieved via this procedure, even improvement of neurological deficits

137. Incidence and Risk Factors for Instrumentation-Related Complications After Scoliosis Surgery in Pediatric Patients with NF-1

Ziming Yao, MD, PhD; Xuejun Zhang, MD

Summary

We studied the incidence of instrumentation-related complications (IRC) in surgical treatment for neurofibromatosis type 1 (NF-1) dystrophic scoliosis and compared the radiographic and clinical data between patients with or without IRC. The results revealed that 17/59 (28.8%) patients suffered IRCs and age less than 9 years, kyphosis more than 50° and application of growing-rod are three risk factors for IRC after surgical treatment of NF-1 dystrophic scoliosis.

Hypothesis

The incidence of IRC in pediatric patients surgically treated for NF-1 dystrophic scoliosis is high, and the risk factors include clinical and radiographic parameters.

Design

Retrospective cohort study.

Introduction

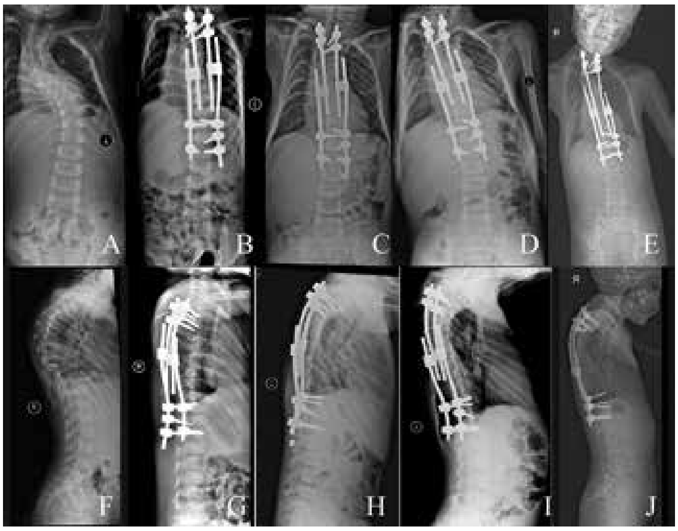
Although pedicle screw based surgical management including growing rods technique and definitive fusion has been widely used for surgical correction of NF-1 dystrophic scoliosis and achieved well corrective outcomes, these procedures could lead to a high incicence of IRC and the risk factors for ICR have not been reported.

Methods

With a minimum of 3 years' follow-up, data of 59 pediatric NF-1 patients who had been surgically treated for dystrophic scoliosis were retrospectively reviewed. All of their clinical and radiographic data were collected. We evaluated potential risk factors, including age, sex, curve type, preoperative Cobb angle, kyphosis angle and spinal length, surgical procedure and fused level. The univariate analysis andmultivariate logistic regression analysis were performed to identify the risk factors associated with IRC.

Results
17 (28.8%) patients suffered 19 IRCs, including 7 cases of curve progression, 3 cases of screw dislodgement, 3 cases of adding-on phenomenon, 2 cases of rod breakage, 2 cases of PJK, 1 case of cap loosing and 1 case of pedicle cutting. The univariate logistic regression analysis revealed age<9, kyphosis≥50°, and application of growing-rod technique as the significant risk factors (P<0.05). Binomial logistic regression analysis demonstrated 2 independent risk factors of IRC, including kyphosis≥50º (OR: 8.23; P=0.025) and application of growing-rod technique (OR: 8.75; P=0.032).

Conclusion
17/59 (28.8%) patients suffered IRCs and age less than 9 years, kyphosis more than 50º and application of growing-rodare three risk factors for IRC after surgical treatment of NF-1 dystrophic scoliosis. Identification of these risk factors aids in stratifying pre-operative risk to reduce IRC incidence. In addition, the results could be used in counseling patients and their families during the consent process.



138. Two Staged Posterior Surgeries for Severe Idiopathic Scoliosis Using a Magnetically Controlled Growing Rod

Mario Di Silvestre, MD; Tiziana Greggi, MD; Konstantinos Martikos, MD; Francesco Vommaro, MD; Gianluca Colella, MD

Summary
Recently pedicle-screw constructs reaffirmed the role of posterior only fusion in severe adolescent idiopathic scoliosis (AIS). The use of pre-operative halo traction is burdened by complications and often proves to be not very effective. The aim of the study is to evaluate the use of a temporary magnetically controlled growing rod, in a two-staged posterior surgery. The procedure has the disadvantages of performing two surgeries, and being expensive, but it certainly represents a safer technique, reducing possible neurological complications.

Hypothesis
Two staged posterior surgery for the treatment of severe scoliosis

Design
Retrospective study

Introduction
The aim of the study is to evaluate the use of a temporary magnetically controlled growing rod, in a two-staged posterior surgery for the surgical treatment of severe adolescent idiopathic scoliosis.

Methods
We included in the study 15 consecutive patients reviewed at a mean follow-up of 2.5 years (min 2.2 - max 2.0). All patients had a severe thoracic AIS over 90° (Lenke type 1 or 2). The mean angular value of scoliosis was 99 ° (min 95 °, max 125 °) with a mean flexibility index of 30%. No case presented neurological deficits. In all patients, a first posterior surgery was performed: pedicle screws and aggressive Ponte osteotomies were performed, and a temporary magnetically controlled growing rod implanted. In the following days (on average 18) the rod was lengthened by means of a solenoid applied to the skin. Finally, a second posterior surgery was carried out to remove the magnetically controlled rod, arriving to definitive correction with rods and fusion. The density of the pedicle screws was 83% on average (min 77-max 91%). A thoracoplasty for a better aesthetic effect was associated in 8 cases.

Results
At follow-up, the mean final correction of scoliosis was 68.4% with an average corrective loss of -1.9 °. The translation of the last instrumented vertebra averaged -1.00 cm, and the average tilt correction was of -19 ° in the coronal plane. A pleural effusion was recorded in 3 of the 8 cases undergoing thoracoplasty and required a thoracentesis between 4th and 6th postoperative days. Neurological complications did not occur, but there was a severe and acute decrease of MEPs in 2 cases, then resolved intraoperatively.

Conclusion
The use of of a temporary magnetically controlled growing rod (in a two-staged posterior surgery) resulted effective and well tolerated, and it permitted to replace the halo-traction period before the posterior correction of a severe scoliosis. The procedure has the disadvantages of performing two surgeries, and being expensive, but it certainly represents a safer technique, reducing possible neurological complications.

139. Postoperative Pulmonary Complications in Complex Paediatric Spine Deformity: A Retrospective Review of Consecutive Patients at SRS GOP Site in Ghana

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Summary
The rates of pulmonary complications after spinal surgery have been reported to range from 0.9% - 5%. In underserved regions

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spine deformity pts usually report late, and are often malnourished with poor pulmonary function. The surgeries are usually associated with longer operative time, and often require 3 column osteotomies, thoracoplasties with significant blood loss. Risk of embolization of marrow material into the lung, ventilation-association lung injury and transfusion-associated lung injury further increase the risk of pulmonary complications.

Hypothesis
Pre-op and surgical factors may increase the incidence and risk of pulmonary complications

Design
Retrospective review of prospective cohort

Introduction
Pulmonary complications are important cause of morbidity and mortality in patients following spinal surgeries.But there is paucity of literature on the incidence and risk factors of post op pulmonary complications following complex spine deformity surgery in underserved regions.

Methods
276 complex spine pts aged 3-25yrs consecutively treated at an SRS GOP site in Ghana were retrospectively reviewed using information from electronic records and filed folders. Data was analyzed using STATA 14 software. During analysis , pts were labelled into two groups: Grp 1: patients with pulm. complications vs Grp 2: patients with no pulmonary complications. Comparative analysis for risk factors included independent t-test , chi square test for independence. Multivariate logistic regression analysis was performed to evaluate the strength of the association.

Results
The incidence proportion of pulmonary complication was 17/276 (6.1%) (Grp 1) and 259 pts (Grp 2) had no events. There were 8M/9F for Grp 1 vs 100M/159F Grp 2, p=0.48. BMI was similar in each group(17.2 vs 18.4km-2,p=0.15), avg preop kyphosis (90.6 vs 88.7deg ,p=0.87.), avg Pre-op Scoliosis (95 vs 88.5deg,p=0.43). Pre-Op FVC was significantly lower in Grp 1 vs Grp2(45.3 vs 62.0%,p=0.02),Pre-Op FEV1 were 41.9% vs 63.1,p<0.001. EBL,OR time and Surgery Levels were similar in both Grps.Thoracoplasty was preformed in 41.18% vs 21.57%,p=0.06, SPO 47.06% vs 42.31%,p=0.038 and VCR 5.88% vs 20.31%,p=0.145,respectively.Multivariate logistic regression shows that every unit increase in pre-Op FVC(%) decreases the odds of pulmonary complication by 5% (OR=0.95, 95% CI 0.90 to 0.99, p=0.035).

Conclusion
Incidence of pulmonary complications observed among this series is comparable to reported series. Pre-Op FVC was found to be an independent predictor of pulmonary complications. The observed case fatality rate of 17% following pulmonary complications highlights the need for thorough pre-op evaluation to identify high risk patients.

Pulmonary Complications		Outcomes	
Event	frequency	Recovered	Died
ARDS	1	0	1
Pulmonary Failure	1	1	0
left lobar pneumonia	2	2	0
pleural effusion	1	1	0
Pneumothorax	1	1	0
pulmonary embolism	1	1	0
pulmonary oedema	2	2	0
Reintubation	3	2	1
Pulmonary Distress	1	0	1
Tracheostomy	4	4	0
Total	17	14	3

140. Halo Gravity Traction Can Mitigate Pre-Operative Risk Factors and Surgical Complications in Severe Spinal Deformity

Sravisht Iyer, MD; Oheneba Boachie-Adjei, MD; Rufai Mahmud, MD; Irene Wulff, MD; Henry Ofori Duah, RN; Henry Osei Tutu, BS; Kwadwo Poku Yankey, MD; Harry Akoto, MB ChB; FOCOS Spine Research Group

Summary
Pre-operative Halo Gravity Traction (HGT) can improve the pre-operative risk profile when treating patients with severe spinal deformity by decreasing curve magnitude (CM) and reducing the need for three column osteotomies (3CO). HGT also provides time to medically optimize patients for surgery, e.g., improve body mass index (BMI). These pre-operative risk factors can be quantified using the FOCOS score (FS). Patients who respond to HGT with a reduction FS have a substantially lower risk of surgical complications.

Hypothesis
Patients who respond to HGT with a reduction in FOCOS score will be less likely to incur surgical complications.

Design
Retrospective Review of Prospective Cohort

Introduction
The use of HGT for large deformities can greatly improve CM. The impact of these changes on procedure choice, preoperative risk factors and surgical complications has not been described.

Methods
Patients treated with HGT before undergoing primary surgery were included. HGT used traction up-to 50% body weight for 6 weeks to 8 months. The FOCOS Score (FS), a previously-described risk stratification score, was used to quantify operative risk. FS was calculated using patient-factors (PtF; ASIA, BMI, Etiology), procedure-factors (PcF; osteotomy planned, # of levels fused, etc.) and curve magnitude (CM). Scores ranged from 0-100 with higher scores indicating increased risk (max 20 for PtF, 40 for PcF and 40 for CM). FS was calculated before and after HGT to see how changes in FS affected complication rates.

Results
96 patients were included. Halo-related complications occurred in 34% of patients; most were pin-site infections (79%) managed with Pin site change and oral antibiotics. Halo revision was required in 8.3%. Pre-op coronal and sagittal CM averaged

128°. Coronal CM improved by 32% and sagittal CM by 31% following HGT. Average FS improved from 87 to 69 after HGT. CM, PcF and PtF all improved (p<0.05). The greatest changes were in CM (38 to 30) and PcF (36 to 26). Prior to HGT, a 3CO was planned in 87/96 patients (91%). This dropped to 36/96 patients (38%) after HGT. Patients who had a reduction in FS>=10pts following HGT were four times less likely to have a surgical complication (9.9% v 40%, OR 4.1, 95% CI: 1.7-9.5, p<0.001). Multivariate regression showed that change in FS was an independent predictor of decreased surgical complications (p=.009).

Conclusion
Halo-related complications occur in 34% of patients but most can be managed medically without abandoning its application. Pre-op HGT can reduce FS and surgical risk by improving CM, lowering 3CO use and improving BMI. A reduction in FS following HGT predicts a lower rate of surgical complications,

141. MIMO Adherence Study: Preliminary Results of a Randomized Controlled Trial

<u>Stefan Parent, MD, PhD</u>; A. Noelle Larson, MD; Soraya Barchi, BS; Hubert Labelle, MD, FRCS(C); David W. Polly, MD; Minimize Implants Maximize Outcomes Study Group

Summary
There is a significant heterogeneity in the number of pedicle screws used in the treatment of adolescent idiopathic scoliosis (AIS). While some surgeons recommend fewer screws, with implant densities as low as 1.04 screws per level, the optimum configuration of screw placement for the treatment of AIS has not been established. Preliminary analysis of the MIMO trial shows a high-level of surgeon adherence to randomization assignment, with most crossovers due to surgeons using too few implants in the high-density group.

Hypothesis
Our null hypothesis was that randomization assignment would be respected by the treating surgeon, i.e. there would not be crossover in the allocation groups.

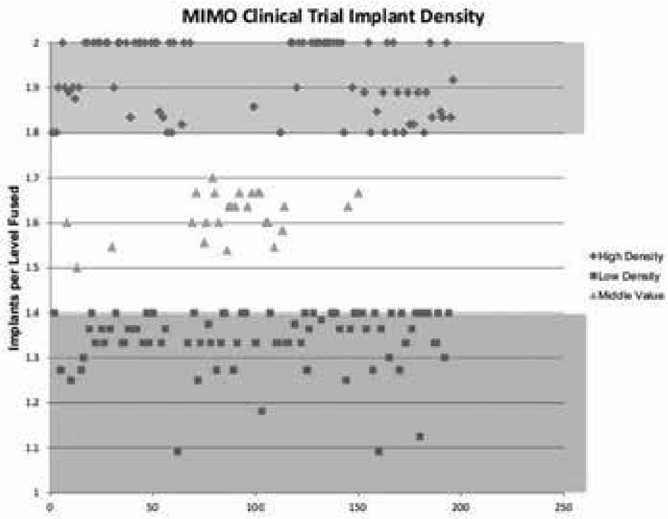
Design
Prospective randomized controlled trial.

Introduction
The optimal implant density, or the number of screws per level, remains unknown in the treatment of AIS. Our objective was to analyze implant distribution in surgically instrumented Lenke 1 patients and evaluate adherence to the randomization assignment in the Minimize Implants Maximize Outcomes Clinical trial (MIMO) protocol.

Methods
A total of 189 AIS patients with Lenke 1A curve, who underwent instrumented spinal fusion were prospectively recruited and randomized into 2 groups (high or ≥1.8 implants per level fused vs low-density ≤ 1.4). Implant density was assessed for the instrumented spine on upright 3-months postoperative radiographs by 2 observers blinded to the randomization.

Results
The upright 3-months postoperative radiographs of 189 AIS patients, aged 10 to 18 years, were analyzed. The mean implant density was 1.63± 0.28 implants per level fused (1.09 to 2.25); 89 patients had a high-density (HD) configuration (≥1.8 implants/level) and 74 patients had a low-density (LD) configuration (≤1.4 implants/level). Furthermore, 26 patients had implant density between 1.4 and 1.8. After controlling for the initial randomization, there were 102 patients randomized to HD while 87 were randomized to LD. When evaluating the number of anchor points, 25 patients randomized to HD did not reach the HD threshold while only 7 patients crossed-over from LD to HD. Therefore, 83% did respect the randomization whereas 17% deviated from the protocol.

Conclusion
Overall, adherence to the MIMO protocol was high, and study data can be analyzed as intention-to-treat. Interestingly, non adherence to the protocol was due to surgeons assigned to the high-density group using too few screws.



142. Impact of Frailty and Comorbidities on Surgical Outcomes and Complications in Adult Spinal Disorders

<u>Mitsuru Yagi, MD, PhD</u>; Nobuyuki Fujita, MD; Eijiro Okada, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD; Yoshiyuki Yato, MD, PhD; Takashi Asazuma, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD; Keio Spine Research Group

Summary
Retrospective review of surgically treated 156 ASD, 152 DS, and 173 LSCS with 2 yrs F/U showed that ASDs were relatively frail and had more comorbidities. Surgical outcomes and complication worsened as the mFI and CCI increased in ASD, whereas favorable outcomes and acceptable complication rates were achieved in others regardless of increased frailty and CCI. Careful patient selection and preoperative treatment of comorbidities may decrease surgical complications and improve clinical outcomes for the surgical treatment of ASD.

Hypothesis
The impact of the severity of frailty and comorbidities on postoperative HRQoLs and complication rates may differ according to the type of spinal disorder.

Design
Retrospective review of surgically treated 481 adult patients with spinal disorders.

Introduction
Elective surgeries for spinal disorders improve clinical outcomes but also have high complication rates. The purpose of this study was to elucidate the effect of frailty and comorbidities on postoperative HRQoL and complication rates.

Methods
We retrospectively reviewed the results of consecutive elective spine surgeries for 156 adult spinal deformity (ASDs:65±9yrs), 152 degenerative spondylolisthesis (DSs:64±10yrs), or 173 lumbar spinal canal stenosis (LSCSs:71±9yrs) with followed at least 2 years. Modified Frailty Index (mFI) and Charlson Comorbidity Index (CCI) were determined from baseline demographics. We compared the prevalence and the influence of mFI and CCI on postoperative outcomes and complication rates.

Results
The mFI and CCI were significantly worse in ASD than in others (mFI: ASD 0.09±0.12, DS 0.06±0.06, LSCS 0.04±0.05, p<.01. CCI: ASD 2.1±1.6, DS 1.4±0.7, LSCS 1.6±0.9, <.01). Postoperative HRQoL deteriorated as mFI worsened in ASD (nofrail: ODI 26±11, SRS 3.7±0.7; prefrail: ODI 32±12, SRS 3.6±0.6; frail: ODI 42±15, SRS 3.2±0.7). In DS and LSCS, however, SF-36 PCS and MCS improved regardless of mFI and CCI. The 2-year major complications rate increased with frailty (36%, 58%, and 81%) in ASD, but not in others.

Conclusion
ASDs were more frail and had more comorbidities than the other populations. In ASD, postsurgical outcomes and complication rates deteriorated as frailty and CCI increased, whereas surgery produced favorable outcomes and acceptable complication rates in DS and LSCS regardless of frailty and CCI. Careful patient selection and treatment of comorbidities prior to surgery may decrease complications and improve outcomes for the surgical treatment of ASD.

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143. Outcomes and Mechanical Complications by Roussouly-Type in Adult Spinal Deformity: A Single-Center Study

Pooria Salari, MD; Hong Joo Moon, MD, PhD; Lawrence G. Lenke, MD; Munish C. Gupta, MD; Michael P. Kelly, MD, MS

Summary
Restoration of sagittal contours may minimize the rate of mechanical complications in adult spinal deformity surgery. A single-center cohort found no difference among Roussouly types for pseudarthrosis. Type 4 (high PI, high LL) had higher Proximal Junction Kyphosis (PJK) and revision rate for PJK. Patients with restored Roussouly-types had higher self-image and satisfaction scores at 2 years follow up.

Hypothesis
Mechanical complications will be more prevalent and outcomes worse in Roussouly Type 3 and 4 (high pelvic incidence [PI]) adult spinal deformity (ASD) cases.

Design
spective cohort

Introduction
Recent work suggests that under correction of high PI cases may be associated with higher risk of proximal junction kyphosis (PJK), proximal junctional failure (PJF) and pseudarthrosis. The Roussouly classification described sagittal plane morphologies according to sacral slope. Whether the different Roussouly types (RT) have differing modes of failure or outcomes is unknown.

Methods
Retrospective study of 526 ASD patients treated with min. 5-level surgery to the sacrum/ilium at a single institution, min. 2yr follow up. RT was determined using preoperative lateral standing radiographs. Mechanical complications including pseudarthrosis, PJK/PJF, and reoperations recorded. Scoliosis Research Society-22r and Oswestry Disability Index scores were compared from baseline to last follow up.

Results
456 (87%) were female, mean age 57±0.5 yrs, mean f/u 56(24-154) mths. (181, 35%) Idiopathic scoliosis and (171, 33%) fixed sagittal plane deformity, 270 (51%) revision surgeries. RT 2 (252, 48%) and 4 (208, 40%) were most common. Rate of pseudarthrosis and revision for pseudarthrosis was not statistically different in different RT. PJK was more common in RT-4. RT 4 was associated with the highest revision rate for PJK (p=0.04). Postoperatively (321,60%) were restored to their RT. Mechanical complications were not different between restored and non-restored RT. Patient with restored RT had a higher self-image and satisfaction scores at 2 years follow up (P<0.05). (Table-1).

Conclusion
RT 4 sagittal profiles (High PI, High Thoracic Kyphosis) were associated with the highest rate of revision for PJK. Pseudarthoris rates were not different amongst groups, despite the varying lordosis requirements. Patient with restored RT had higher self-image and satisfaction scores.

Table-1: Outcomes and Mechanical complications by Roussouly -Type

Roussouly Type		1	2	3	4	P value
Rod Fracture		0	[illegible]	8/95(8.5%)	47/95(49.5%)	0.142
PJK	6 wks Postop	0	52/105(49%)	9/105(8.5%)	44/105(42%)	0.43
	Latest F/U	1/169(0.6%)	82/169(48.5%)	21/169(12.5%)	65/169(38.5%)	0.9
Revision Rate (per 100 person*year)	PJK	0	0.35 (0.13,0.94)	0	1.2 (0.7, 2.1)	0.042*
	Rod Fracture	0	1.3 (0.82, 2.27)	1.47 (0.55,3.9)	2 (1.2, 3.18)	0.62

Roussouly Type		1	2	3	4		Restored	Not Restored	P value
ODI	Preop	26.4±4.1	40±16.5	43.4±17	42±17.4	0.16	40±16	42±17	0.6
	Postop	21.5±11.8	24.5±17.2	21.2±17.6	25.4±16.9	0.25	25±17	23.8±16	0.4
	Latest F/U	12±9.8	25.6±18.9	24±10.8	27±19.7	0.32	26±20	26.6±18	0.7
SRS-22									
Pain	Preop	2.7±6	2.7±0.8	2.5±0.7	2.3±0.9	0.17	2.4±0.8	2.6±0.8	0.6
	2 year	4.1±0.3	3.7±0.9	3.7±0.9	3.5±0.5	0.14	3.7±1	3.6±1	0.5
	Latest F/U	4.4±0.2	3.6±1	3.6±1	3.4±1	0.16	3.5±1	3.5±0.9	0.5
Function	Preop	3.1±0.46	2.8±0.8	2.6±0.8	2.8±0.85	0.2	2.8±0.8	2.7±0.8	0.3
	2 year	4±0.8	3.5±0.8	3.5±0.8	3.4±0.8	0.6	3.4±0.8	3.6±0.7	0.3
	Latest F/U	4±0.8	3.5±0.8	3.5±0.8	3.5±0.85	0.6	3.5±0.9	3.6±0.8	0.4
Self-image	Preop	2.4±0.8	2.7±0.7	2.5±0.7	2.3±0.7	0.13	2.6±0.7	2.5±0.7	0.7
	2 year	3.6±0.8	3.7±0.8	3.7±0.8	3.6±0.9	0.18	**3.8±0.9**	**3.5±0.8**	**0.04***
	Latest F/U	4.1±0.2	3.5±0.9	3.6±1	3.4±0.8	0.3	3.4±0.9	3.5±0.8	0.5
Mental Health	Preop	3.4±0.3	3.5±0.8	3.2±0.9	3.3±0.9	0.13	3.4±0.9	3.4±0.9	0.7
	2 year	4.5±0.7	4±0.8	3.9±0.9	4±0.8	0.48	4±0.8	4.1±0.8	0.11
	Latest F/U	4.75±0.3	4±0.8	4±0.9	4±0.9	0.42	**3.9±0.9**	**4.1±0.8**	**0.04***
Satisfaction	Preop	2.5±1.5	2.9±1	2.6±1.1	2.8±1	0.2	2.7±1	2.9±1	0.11
	2 year	4.2±0.2	4.2±0.8	**4.5±0.7**	4.2±0.9	**0.05***	**4.3±0.8**	**4.1±0.8**	**0.02***
	Latest F/U	3.8±0.5	4±0.9	4.2±0.8	3.9±0.8	0.24	4±0.9	3.9±0.8	0.3
Total	Preop	2.9±0.3	2.9±0.6	2.7±0.6	2.8±0.7	0.08	2.9±0.7	2.8±0.6	0.6
	2 year	4±0.3	3.7±0.7	3.7±0.7	3.7±0.7	0.4	3.8±0.7	3.7±0.7	0.5
	Latest F/U	4±0.3	3.6±0.7	3.6±0.7	3.6±0.7	0.4	3.6±0.8	3.6±0.7	0.5

144. Reciprocal Change of Sagittal Profile in Unfused Spinal Segments and Lower Extremities after Complex Adult Spinal Deformity Surgery: A Full-Body Radiographic Analysis

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Summary

This radiographic analysis using a full-body X-ray assessed the sagittal alignment and the reciprocal changes in unfused segments and lower extremities after thoracolumbar corrective surgery in patients with adult spinal deformity (ASD). Postoperatively, there was a decrease in TPA, and preoperative pathologic compensatory mechanisms in the cervical spine and lower extremities were partially improved. The reciprocal changes in the lower extremities significantly impacted the posterior shift of Cranial SVA, achieving one of the ultimate goals of corrective surgery.

Hypothesis

The pathologic compensatory mechanisms in the cervical spine and lower extremities spontaneously improve after adequate thoracolumbar corrective surgery in ASD.

Design

Single-center cohort study

Introduction

Reciprocal changes of pathologic compensatory mechanisms in unfused spinal segments occur after ASD surgery. However, few studies have described these reciprocal changes in the unfused segments and lower extremities simultaneously.

Methods

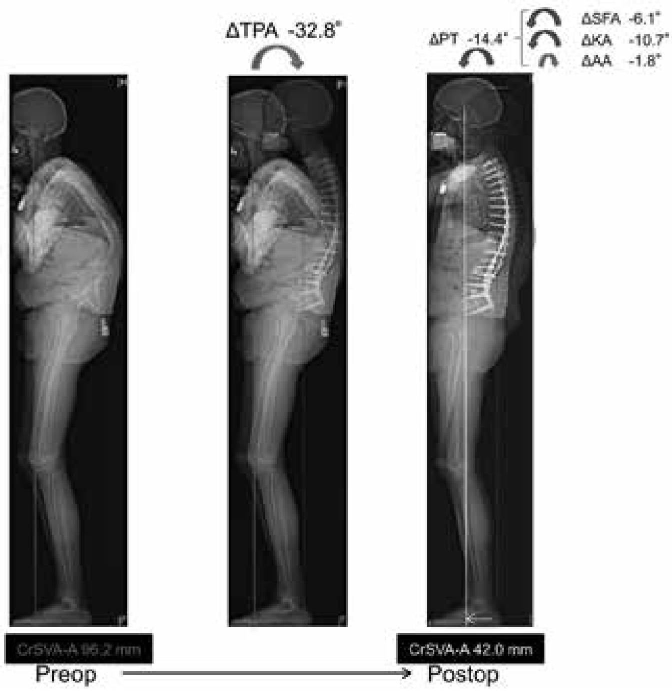
This study included ASD patients with >5 fused levels, who underwent pre- and postoperative full body X-ray with biplanar imaging system. The baseline compensatory status was assessed by comparing two groups preoperatively subdivided according to T1 pelvic angle (TPA) (alignment-maintained group: TPA <20 and malalignment group: TPA> 20). The correlation between the iatrogenic change (ΔTPA), reciprocal changes in the cervical spine and lower extremities, and the cranial sagittal vertical axis-hip/ankle change were analyzed.

Results

84 patients met criteria. More than 75% of these patients underwent proximal thoracic-to-sacrum fusion. At the baseline, patients in the malalignment group showed greater C2-7 lordosis (C2-7L), sacrofemoral angle (SFA), and knee flexion angle (KA) than those in the alignment-maintained group (P<0.05). These compensatory recruitments were partially restored after adequate corrective surgery. Linear correlations were observed between ΔTPA and ΔC2-7L, ΔSFA, and ΔKA (r =0.485, 0.438, and 0.686, respectively). The multivariate regression analysis revealed that ΔTPA, ΔSFA, ΔKA and ΔAA independently impacted ΔCrSVA-A (Figure), while ΔTPA and ΔSFA predicted ΔCrSVA-H.

Conclusion

With surgical correction, there was a significant decrease in TPA, resulting in partial restoration of the compensatory mechanisms in the cervical spine and lower extremities. Reciprocal changes in the lower extremities significantly impacted the shift of the CrSVA-H/A. A preoperative clinical evaluation of the lower limb joints, as well as a full-body radiographic evaluation, is paramount to appreciate optimal global sagittal balance in corrective surgery.



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145. 3D Printed Patient Specific Drill Guides for Pedicle Screw Insertion: A Retrospective Cohort Study

Rajiv K. Sethi, MD; Sumeet Garg, MD; Jean-Christophe A. Leveque, MD; Joseph DeWitt, MD, DO; Jacob Schulz, MD; George Frey, MD; Dominick Tuason, MD; Ninh Doan, MD, PhD; Kellen Nold, PA-C; Alyssa Senz, MS

Summary
Over a two-year period, clinical data was collected to evaluate the efficacy of 3D printed, patient specific drill guides for pedicle screw placement in posterior spinal fusion surgeries (PSFs) for the treatment of varying pathologies, complexities, and age groups. It was found that the guides were a safe and accurate treatment option for such patients.

Hypothesis
3D printed drill guides can be used to safely place pedicle screws in patients of all ages with various spinal pathologies.

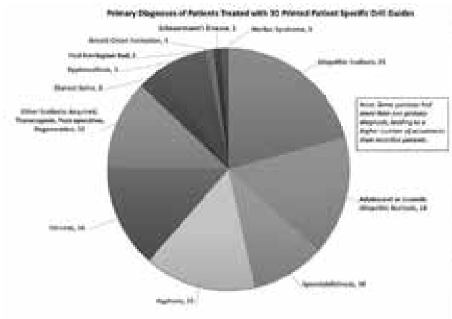
Design
Retrospective cohort study.

Introduction
Currently, pedicle screws are placed using freehand technique, fluoroscopic guidance, and intra-operative navigation, the latter of which contain a steep learning curve (Rivkin et al, 2014). 3D printed patient specific drill guides may serve as a solution that provides accuracy and greater safety than traditional forms of navigation.

Methods
3D printed patient specific drill guides were made for 107 patients using fine cut (1.25mm or less) pre-operative CT scans. Screw trajectories were planned and guides were designed using CAD software in advance of surgery. The guides were used by 27 spine surgeons with varying degrees of experience. Of the 107 cases, diagnostic data and implant related complications were collected from the operating surgeons for 83 patients. The resulting data is presented.

Results
Among the 83 patients, ages ranged from 5-83yrs (mean 52, median 61). 18 were pediatric, 32 were over the age of 65. Guided levels spanned from T1 to the sacrum/ilium. Mean levels per case was 10. In total, 841 levels were instrumented. Diagnoses treated include idiopathic scoliosis (n=21), juvenile and adolescent idiopathic scoliosis (n= 16), spondylolisthesis (n=10), kyphosis (n=15), stenosis (n=14), and other complex conditions (see Figure 1). All cases were completed with a 1.2% occurrence of implant related complications, unrelated to the use of the patient specific guides (one occurrence of dislodged transverse process hooks).

Conclusion
In this retrospective study, it was found that the 3D printed patient specific drill guides served as a safe treatment solution across a wide array of age groups, conditions, and surgeon experiences. In Rivkin et al, 266 patients were treated using intra-operative cone beam tomography navigation. 4 patients (1.5%) required revision due to misplaced pedicle screws. None of the patients treated with the 3D printed drill guides required revision due to misplaced pedicle screws.



146. 90 Day Return to Emergency Department (ED) Post-Spinal Deformity Surgery: Frequent Causes and Risk Factors

Vishal Sarwahi, MBBS; Stephen Wendolowski, BS; Jesse M. Galina, BS; Shashank Gandhi, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
Return to the ED continues to be a quality measure in healthcare. The purpose of this study was to describe one institution's experience with visits to the ED following spinal deformity surgery. 12.4% of patients returned to ED within 90 days mostly with medical complaints – nearly half by 30 days. There were no risk factors identified, however, a majority of complaints appear to be preventable.

Hypothesis
Postoperative ED visits within 90 days are preventable.

Design
Ambispective study

Introduction
Return to the hospital after surgery is frequently being used as a quality metric. The purpose of this study is to evaluate the reasons and risk factors for ED visits less than 90 days.

Methods
A review of spinal deformity surgeries between 2011-2017 was performed. Radiographic, operative, and hospital stay data was collected. Median and interquartile range (IQR) was with Wilcoxon-Signed Rank and Kruskal-Wallis tests. Patients who returned to the ED for any reason within 90 days were analyzed. ED visits were categorized as medical and surgical. Medical visits included but not limited to fever, pain, and seizures. Surgical visits included but not limited to wound infection, and surgical site infection.

Results
258 patients were included: 210 idiopathic scoliosis, 37 neuromuscular, 6 Scheurmann's kyphosis, 3 spondylolisthesis (grade 4), and 2 other. 32 patients (12.4%) returned to the ED within 90 days. 23 (72%) returned with medical-related complaints: pain (n=9), fever (n=5), constipation (n=4), spasm/seizures(n=2), syncope (n=1), fall (n=1) and dysnea(n=1). 9 (28%) returned

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with surgical-related complaints: drainage from incision (n=5), wound infection (n=3), and baclofen pump failure (n=1). 46.8% (n=15) returned to the ED within 30 days. There was no significant difference in age (14.9 vs 14.4 years, p=0.41), BMI (21 vs 20.7,p=0.40) preoperative Cobb (55.6 vs 52.1, p=0.71), preoperative kyphosis (25 vs 29.5,p=0.86), and levels fused (12 vs 13,=0.19) between those did not return to the ED and those who did. Blood loss (500 vs 550ml,p=0.90), surgical time (286.5 vs 266.5,p=0.37), and length of stay (5 vs 5,p=0.39) were also similar between the two cohorts. Neuromuscular distribution was also similar (13% vs 25%).

Conclusion

12.4% of patients returned to ED within 90 days mostly with medical complaints – nearly half by 30 days. Although no risk factors were found in this study, the findings present an opportunity to better improve discharge planning and care coordination.

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147. Association Between Non-Modifiable Demographic Factors and Press Ganey Satisfaction Scores in Spine Surgery Clinics

Bradley Johnson, MD; Dennis Vasquez-Montes, MS; Aaron Buckland, MBBS, FRACS; John A. Bendo, MD; Jeffrey Goldstein, MD; Thomas Errico, MD; Charla Fischer, MD

Summary

Patient satisfaction is an important metric in value-based care systems and the Press Ganey survey is the most widely used metric to measure patient satisfaction. In this retrospective analysis of Press Ganey surveys from 1400 spine surgery patients, we demonstrate that independent, non-modifiable demographic factors such as age, education level, survey mode, and insurance type significantly influence satisfaction scores.

Hypothesis

Non-modifiable demographic factors influence spine patient satisfaction scores on the Press Ganey survey.

Design

Retrospective survey analysis

Introduction

Patient satisfaction is an important metric in value-based care systems. The Press Ganey Associates survey is the most widely used instrument for measuring patient satisfaction. Understanding the factors that influence these surveys may help to better utilize survey results and direct interventions to increase patient satisfaction.

Methods

Press Ganey CG-CAHPS surveys administered to ambulatory spine surgery clinic patients within a large tertiary care network from 05/2016 to 09/2017 were retrospectively reviewed. Mean comparison testing was performed to measure associations between patient demographics and survey responses to "overall provider rating" and "recommend this provider office" questions. Mean difference to achieve significance was set at $\alpha<0.05$. A multivariate analysis was performed to determine independent factors.

Results

1,400 survey responses from the offices of 11 orthopedic spine surgeons were included. Patients aged 18 to 34 had significantly lower responses to the "overall doctor rating" question than older patients (p<0.001), and increasing patient age was correlated with improving ratings. Highest education level was inversely correlated with satisfaction scores, with patients who attained graduate level education giving the lowest satisfaction scores (p=0.001). Those with commercial insurance had significantly lower ratings to "recommend this provider" (p=0.042) and "overall doctor rating" (p=0.022) than other insurance types. Patients administered the survey on paper had significantly lower ratings than those administered the survey online (p=0.006). Doctor ratings were significantly higher when the gender and ethnicity of the patient matched the gender and ethnicity of the provider (p=0.021).

Conclusion

This study demonstrates that independent, non-modifiable factors such as age, education level, survey mode, and insurance type influence satisfaction. It also suggests that patients may be more satisfied when they align with the gender and ethnicity of the provider.

Variables		Overall Doctor Rating 0-10			Recommend Provider		
		Mean	N	p-val	Mean	N	p-val
Age Group	0 to 17 Years	97.3 ± 9.3	83	0.000	93.0 ± 21.0	83	0.000
	18 to 34 Years	85.8 ± 26.2	103		81.0 ± 33.5	103	
	35 to 49 Years	91.6 ± 21.1	251		88.5 ± 29.0	252	
	50 to 64 Years	95.6 ± 14.1	499		93.0 ± 21.0	496	
	65 to 79 Years	96.7 ± 12.4	406		94.0 ± 20.0	407	
	Over 80 Years	97.3 ± 6.3	46		96.5 ± 12.5	46	
Gender	Male	94.0 ± 16.9	781	0.148	91.0 ± 24.5	781	0.207
	Female	95.3 ± 15.3	605		92.5 ± 22.5	606	
Education	8th grade or less	97.4 ± 6.7	13	0.001	91.5 ± 19.5	12	0.000
	Some high school	97.2 ± 13.6	24		96.0 ± 20.5	24	
	High school graduate	98.0 ± 9.2	195		97.0 ± 14.5	192	
	Some college	95.8 ± 15.1	366		94.0 ± 20.5	365	
	4 year college degree	93.3 ± 18.6	319		89.5 ± 26.5	320	
	More than 4 year college degree	92.7 ± 18.1	454		88.5 ± 26.5	456	
Insurance	Worker's Compensation	94.1 ± 18.8	58	0.022	93.5 ± 21.5	55	0.042
	No insurance	98.4 ± 4.9	58		96.5 ± 12.5	59	
	Commercial	93.6 ± 18.0	853		90.0 ± 26.0	854	
	Medicaid	95.1 ± 14.3	89		94.0 ± 21.0	89	
	Medicare	96.4 ± 12.3	330		94.0 ± 20.0	330	
Ethnicity	Hispanic	95.8 ± 14.9	134	0.441	94.5 ± 19.0	134	0.242
	Not Hispanic	94.7 ± 16.1			92.0 ± 23.5		
	Caucasian	95.3 ± 15.0	1043	0.006	93.0 ± 22.5	1042	0.013
	Not Caucasian	92.2 ± 19.6			88.5 ± 27.5		
	African American	96.1 ± 13.9	111	0.309	95.5 ± 17.5	111	0.023
	Not African American	94.4 ± 16.4			91.5 ± 24.0		
	Asian	86.6 ± 25.1	78	0.004	83.5 ± 31.0	78	0.014
	Not Asian	95.1 ± 15.4			92.0 ± 23.0		
Same Gender & Ethnicity	Same Gender and Ethnicity	96.1 ± 13.7	384	0.021	94.0 ± 20.5	384	0.023
	Different Gender and Ethnicity	94.0 ± 17.1			91.0 ± 25.0		
Mode	Internet	94.1 ± 16.9	1195	0.000	91.0 ± 24.5	1194	0.006
	Paper	97.4 ± 10.9	193		95.0 ± 16.5	193	

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Notes

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The Scoliosis Research Society gratefully acknowledges OrthoPediatrics for their support of the Annual Meeting Beverage Breaks and Welcome Reception.

The Goldstein Award is presented to the best clinical research poster at the Annual Meeting. The Moe Award is presented to the best basic research poster at the Annual Meeting. The Program Committee selects the nominees based on abstracts and selects the winners based on final posters.

200. 3D Validation of the New Sagittal Classification for AIS

Mareille Post, BS; Stephane Verdun, PhD; Silvestre Clement, MD; Davide Sassi, MD; Pierre Roussouly, MD; Kariman Abelin Genevois, MD, PhD

Summary

New sagittal classification differentiating three patterns in AIS has been tested by 3D radiographic analysis. Concordance was high for spino pelvic parameters and thoracic kyphosis especially T4T12 angle. T10L2 was the most variable parameter. However 91% of the cases were similarly classified in the sagittal classification by 2D and 3D analysis. This comparative analysis validates the use of the new sagittal classification in both 2D and 3D. However 3D analysis is more accurate to define sagittal alignement when Cobb > 55º

Hypothesis

New 2D sagittal classification of AIS validation based on 3D analysis of the spine.

Design

Comparative 2D versus 3D radiographic analysis

Introduction

In order to improve surgical planning of sagittal correction in AIS, we proposed a new sagittal classification (presented SRS meeting 2017). The main criticism is related to the fact that 2D lateral view results from the projection of the 3D deformity. Therefore, there is a need to validate the new sagittal classification using 3D radiograph analyzing software.

Methods

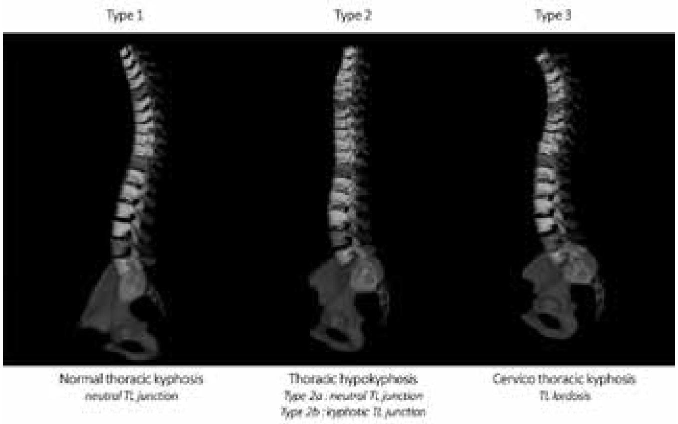
We performed a radiographic analysis in a cohort of 94 AIS patients (mean age 15,5 years) candidate for surgery with biplanar stereoradiography (prospective data). 2D measurements were performed with data management software and provided frontal and sagittal spinopelvic parameters (T1-T12, T4-T12, T10-L2, L1-S1, PI, SS, PT). Utilizing 3D radiograph analyzing software, a 3D model of the spine was constructed, providing 3D calculated frontal (cobb angle, apical rotation) and sagittal parameters. Each case was categorized according to Lenke and sagittal classification.

Results

According to Lenke, 72% of these patients were type 1/2, 13% type 3 and 15% type 5/6. Concordance between 2D and 3D parameters was high for spino pelvic parameters and thoracic angles. Mean error for thoracic kyphosis was 3° for T1T12 and 1° for T4T12. Mean error for L1S1 was 5°. We found more variation for T10L2 angle when Cobb angle > 55 and/or rotation > 21 degrees. However 91% of the cases were similarly classified in the sagittal classification in 2D and 3D.

Conclusion

This comparative analysis validates the use of the new sagittal classification in both 2D and 3D. 3D analysis emphasizes the clinical relevance of the new sagittal classification and helps to define more accurately the sagittal pattern in AIS. 2D analysis may underestimate thoraco lumbar junction behavior especially when lordotic. However the position of the inflexion point may help on 2D analysis to differentiate type 1 (normal kyphosis) from type 3 (cervico thoracic kyphosis). Type 2 (thoracic hypokyphosis) are well-characterized by either 2D and 3D analysis.



201. A Critical Thoracic Kyphosis is Required to Prevent Sagittal Plane Deterioration in Selective Thoracic Fusions in Lenke I and II AIS

Dominique A. Rothenfluh, MD, PhD; Alexandra Stratton, MD, FRCS(C); Colin Nnadi, MBBS, FRCS; Nicolas Beresford-Cleary, FRCS, BEng

Summary

Analysing the postoperative sagittal profiles of Lenke type I and II curves reveals a critical thoracic kyphosis of 23º which seems to be required to maintain or improve the SVA postoperatively in selective thoracic fusions. In thoracolumbar fusions with LIV at L2 or below, sagittal parameters are maintained at 2y follow up regardless of the thoracic kyphosis.

Hypothesis

It is hypothesized that restoration of thoracic hypokyphosis in AIS maintains a better postoperative sagittal profile and balance.

Design

Retrospective radiographic comparative study

Introduction

The quantitative analysis of the sagittal plane in adolescent idiopathic scoliosis (AIS) has only recently gained more attention. It has been reported before that undercorrection of thoracic hypokyphosis may be associated with reduced lumbar lordosis which in turn may have adverse effects on the global sagittal balance.

Methods

86/154 pts with 2y followup presented with Lenke type I and II. All patients had AIS correction with a side-loading pedicle

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screw system without special attention to the sagittal plane. Patient factors such as age, Risser grade, lowest and upper instrumented vertebra (LIV/UIV), lumbar modifier were recorded. Coronal Cobb and sagittal parameters (SP) were measured using Surgimap. Statistical analysis according to distributions and multiple linear and logistic regressions were performed using STATA for Mac v13.

Results

42 pts had STF and 44 TLF. Comparing the sagittal plane in STF vs.TLF, at 2 years there was a difference in the SVA (TLF -4.8±28.7mm vs. STF 13.1±28.4mm, p=0.01). A multiple regression analysis against SVA revealed LIV (p=0.015) and lumbar modifier C (p=0.014) as significant contributors (r-square=0.22, p=0.03). Logistic regression against postoperative change in SVA vs. thoracic kyphosis allowed calculation of a critical thoracic kyphosis of 23º (spec 0.70, sens 0.63). Saggital parameters remained significantly improved to preop at 2 years if thoracic kyphosis was above 23º (preop vs. 2y: SVA p=0.039, thoracic kyphosis (TK) p=0.006, lumbar lordosis (LL) p=0.036).

Conclusion

TLF with LIV at L2-L4 is significantly associated with a maintained SVA at 2 years, whereas STF and a lumbar modifier of C were associated with an increased SVA at 2y. In TLF sagittal parameters were maintained regardless of the amount of thoracic kyphosis. STF with correction of the thoracic hypokyphosis above 23º resulted in a maintained improvement of all sagittal parameters after 2y.

202. A High Preoperative Psycho-somatic Symptom Profile Predicts Persistent Pain at One Year After Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

Ying Li, MD; Sejal Virani, MD; Monica Weber, RN; Shoba Malviya, MD; Alan Tait, PhD; Michelle Caird, MD; Frances Farley, MD; Terri Voepel-Lewis, PhD

Summary

Patients with higher preoperative psycho-somatic symptoms, including depression, fatigue, pain interference, neuropathic pain, and pain catastrophizing characteristics, may be at risk for persistent pain and analgesic use at 1 year after posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS).

Hypothesis

A high preoperative pain and symptom profile predicts ongoing pain and analgesic use 1 year after PSF.

Design

Prospective cohort study.

Introduction

We previously reported that 30% of AIS patients undergoing PSF had a preoperative behavioral pain vulnerable profile that was associated with ongoing pain and analgesic use at 6 months postoperatively. The purpose of this study was to examine whether this high symptom profile predicts persistent pain and analgesic use at 1 year after PSF.

Methods

Patients aged 10-17 years were surveyed preoperatively and at 1 year after PSF. Baseline self-reported measures included pain intensity (0-10 scale), pain location (body map), neuropathic pain (painDETECT), catastrophizing, fatigue, depression, anxiety, and pain interference (PROMIS short forms). Perioperative and postoperative analgesics were recorded. Patients were re-surveyed at 1 year regarding pain intensity, pain interference, and analgesic use.

Results

95 adolescents (75% female) completed the study. Cluster analysis identified 3 baseline symptom profiles differentiated by pain interference, depression, fatigue, pain catastrophizing scores, and to a lesser extent, painDETECT and anxiety (Table 1). The number of painful body sites significantly correlated with symptom profile (rho=0.347, p<0.01). Compared to the low-medium symptom groups combined, the high symptom profile group had more females (95% vs. 68%, p=0.019) but was not different in hospital opioid use (0.013 vs. 0.011 MME/kg/hr, p=0.66). The high profile group reported more pain interference (10.13 vs. 3.95, p=0.003) and was more likely to be taking analgesics at 1 year (100% vs. 50%, p<0.001) compared to the low-medium symptom group. Controlled for hospital morphine consumption and pain scores, cluster membership predicted pain intensity and interference at 1 year (Table 2).

Conclusion

AIS patients with higher preoperative psycho-somatic symptoms may be at risk for ongoing pain and analgesic use 1 year after PSF. Identifying such symptomatology prior to surgery may help to strategize early interventions that could mitigate persistent postoperative pain.

Table 1. Differentiation of preoperative symptom clusters

	Low Symptom	Medium Symptom	High Symptom
PROMIS Pain Interference	1.44 ± 2.00	8.70 ± 4.10	16.15±6.05
PROMIS Depression	1.28±2.55	4.45±5.16	17.33 ± 6.11
PROMIS Fatigue	1.97 ± 2.66	9.42±6.56	19.3 ± 6.12
Catastrophizing	3.00 ± 3.53	12.73 ±8.36	25.55 ± 11.13
PainDETECT	1.42 ± 2.10	6.36 ± 5.73	8.55 ± 4.72 (NS vs Medium)
PROMIS Anxiety	8.44 ± 8.59	12.64 ± 8.67 (NS vs Low)	15.55 ± 7.40 (NS vs Medium)

All comparisons significant (p<0.015) with the exceptions indicated (NS)

Table 2. Profile membership and one year pain outcomes

Profiles	Pain Intensity*	Pain Interference*	Analgesic Use (Yes)**
Low Symptom	1.80 [0.99, 2.60]	1.92 [-0.24, 4.08]	47%
Medium Symptom	2.77 [1.91, 3.63]	6.13 [3.86, 8.39]	54%
High Symptom	5.14 [3.99, 6.29]	10.27 [7.22, 13.31]	100%

*Univariate ANOVA, estimated marginal means controlled for in-hospital morphine use and pain intensity, [95% Confidence Interval]; p ≤ 0.033 for High vs Low and Medium Profiles
**Chi-square, p≤0.001 for High vs Low and Medium Profiles

203. A Low-Frequency Missense Variant in SLC39A8 Associated with Idiopathic Scoliosis†

Matthew Dobbs, MD

Summary

Our association of AIS pathogenesis with altered manganese homeostasis opens up the possibility of dietary intervention to prevent scoliosis progression.

Hypothesis

We hypothesize that genetic factors responsible for scoliosis curve progression may be independent from those associated with its initiation.

Design
Whole-exome sequencing.

Introduction
The genetic factors predictive of severe adolescent idiopathic scoliosis (AIS) are largely unknown.

Methods
To identify genetic variants associated with severe AIS, we performed a genome-wide association study of common exonic variants using whole exome sequence data of 457 severe AIS cases and 987 controls.

Results
A nonsynonymous missense SNP in the heavy metal ion transporter SLC39A8 (p.Ala391Thr, rs13107325) was associated with severe AIS at exome-wide significance (P = 1.60 x 10-7; odds ratio (OR) = 2.01 (CI=1.54-2.62)). This pleiotropic SLC39A8 missense variant was previously associated with a variety of human traits, including blood pressure, body-mass index and cholesterol and manganese level. We replicated the association of this SNP with AIS in a second cohort (857 cases and 1095 controls) resulting in a combined P = 3.64 × 10–25; OR = 1.89. Clinically, rs13107325 was associated with greater spinal curvature, decreased height, increased BMI and lower plasma manganese level in our AIS cohort. Functional studies demonstrate reduced manganese influx mediated by the SLC39A8 p.Ala391Thr variant compared to WT expressed in vitro. Furthermore, slc39a8 null zebrafish had abnormal fin folds, impaired growth, and abnormal movement compared to wild-type zebrafish.

Conclusion
Our association of AIS pathogenesis with altered manganese homeostasis opens up the possibility of dietary intervention to prevent scoliosis progression.

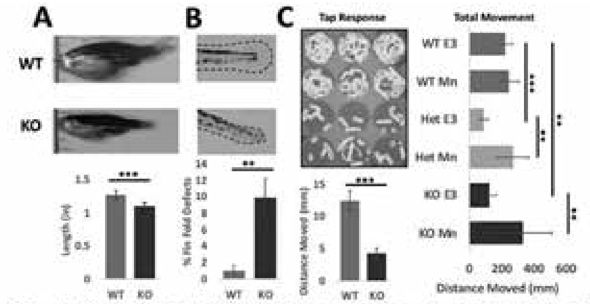

Figure 1. Growth and Movement Deficits in slc39a8 -/- zebrafish. A) Size difference between female WT (top) and female slc39a8 -/- fish (bottom) B) Fin-fold defects in slc39a8 -/- zebrafish compared to normal wild-type fin-folds C) Movement differences at 4 dpf between wild type and slc39a8 -/- zebrafish exposed to water containing either no Mn (E3) or 200mM Mn for 24 hours prior to measurement. Zebrafish were monitored for movement for 25 min without disturbing (Total Movement) followed by a tap (Tap Response). Tap response was measured in facility water (contains sea salt). For tap response, movement was visualized during the 10 sec after the tap as a heat map of position while moving above 5mm/s. *** p<0.001. ** p<0.01

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204. A Study Group's Experience and Practice Trends in Adult Spinal Deformity Surgery Over the Course of 9 Years: An Analysis of 1041 Patients

Micheal Raad, MD; Brian Neuman, MD; Munish C. Gupta, MD; Hamid Hassanzadeh, MD; Virginie Lafage, PhD; Peter Passias, MD; Themistocles Protopsaltis, MD; D. Kojo Hamilton, MD; Christopher Shaffrey, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Shay Bess, MD; Richard Hostin, MD; Christopher Ames, MD; Khaled M. Kebaish, MD, FRCS(C); International Spine Study Group

Summary
Our results show that with time, the study group's patient population steadily shifted towards becoming older, having prior surgeries as well as having worse radiographic deformities. This was not accompanied by similarly rising probability of performing three-column osteotomies or long fusions.

Hypothesis
We hypothesize that a study group's trends in the surgical treatment of adult spinal deformity changes substantially over time.

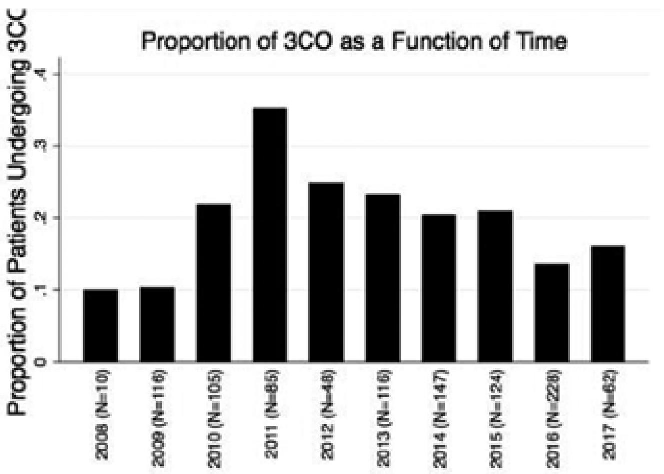
Design
Retrospective analysis of prospective data.

Introduction
The increasing popularity of new surgical procedures is often accompanied by a surge in research and studies reporting on their postoperative outcomes. Thus, some inadvertently fall out of favor creating visible trends. The aim of this study is to look at practice trends in ASD surgery over the course of 9 years, particularly three-column osteotomies and long posterior fusions.

Methods
This is a retrospective analysis of a prospective ASD surgical database with 43 contributing surgeons. Regular meetings are held 4-5 times/year. Temporal trends in patient factors, radiographic deformity, performance of three column osteotomies (3CO) and long fusions (>12 instrumented vertebra) were analyzed. Trends were visually inspected for linearity or inflection points using Lowess Smoother Plots and were subsequently confirmed using Spline or logistic regression analysis as appropriate.

Results
1041 patients (Years 2008 to 2017) met inclusion criteria. Average age steadily increased by a mean of 1.2 years annually (p<0.01). The proportion of revision cases also steadily increased (OR=1.07/year, p<0.02). Similarly rising, were baseline sagittal vertical axis (4cm/2009 – 8 cm/2017, p<0.01), pelvic tilt (22°/2009 – 26°/2017, p=0.03) and pelvic incidence minus lumbar lordosis (10°/2009 to 20°/2017, p<0.01). Interestingly, the proportion of 3CO increased up until the beginning of 2012 (p<0.01), peaking at 35% in 2011 and declining thereafter (p<0.01) Figure1. The rate of long fusions (>12 instrumented vertebrae) performed was steady up until the beginning of 2013 (p=0.52) after which it started to steadily decline (p<0.01).

Conclusion
Our results show that the complexity of the study group's patient population increased steadily over time. The performance of 3CO increased up until 2012 and declined thereafter, highlighting the possible role a study group's research and conclusions might have on its member practices.



205. A Unique 3-D Printed Patient-Specific Brace for Adolescent Idiopathic Scoliosis Proof of Concept and Comparison to the Boston Brace

Baron Lonner, MD; Andrea Castillo, BS; Isabelle Rauch, ABC Certified Orthotist ; Yuan Ren, PhD; Vasantha Murthy, MD

Summary
Bracing success is predicated on obtaining adequate in-brace correction and patient compliance which is impacted by comfort and appearance of the brace. In a first-of-its-kind 3D-printed brace (3DP) a thin, lightweight, well-conforming brace with porous vents throughout The unique 3DP provides comparable curve correction at first brace check for thoracic curves and improved correction of TL curves compared to the BB.

Hypothesis
The 3-D printed brace (3DP) will demonstrate initial in-brace curve correction comparable to the Boston brace (BB).

Design
Retrospective matched analysis

Introduction
In AIS, thoracolumbosacral bracing with a rigid orthosis is indicated for treatment of the skeletally immature patient with progressive curvature between 20 to 45 degrees . Bracing success is predicated on obtaining adequate in-brace correction and patient compliance which is impacted by comfort and appearance of the brace. In a first-of-its-kind 3DP created through surface topographical scanning of the patient, software modification of the design, and a unique 3-D printing manufacturing process, a thin, lightweight, well-conforming brace with porous vents throughout has been developed. The purpose of this study is to assess the ability of the 3DP to correct the primary curvature in AIS compared to the BB.

Methods
17 consecutive 3DP patients and BB patients were matched based on gender, primary curve magnitude, and location. Initial in-brace curve correction and percent correction were calculated and compared using paired t-test.

Results
Average age, curve magnitude, and curve location as well as skeletal maturity were similar between groups. 88.2% of patients were female. 28/34 patients were Risser stage ≤2. Both the 3DP and the BB showed significant curve correction in patients with main thoracic and thoracolumbar curves (3DP p= >0.0001, p= 0.000371742 and BB p= >0.0001, p=0.000304186).

Conclusion
The 3DP, a lightweight, conforming, and widely-vented orthosis provides comparable curve correction at first brace check compared to the BB. Proof of concept has been provided for this unique brace.

	3DP	BB	p value
Age	12.5	13	= 0.277
Gender	88.2% Female	88.2% Female	n/a
Risser Stage	≤2 (17); >2 (0)	≤2 (11); >2 (6)	=0.018
Main Curve n (%)	MT=6 (35%) TL=5 (30%); Double Curve= 6 (35%)	MT=6 (35%) TL=5 (30%); Double Curve= 6 (35%)	n/a
Overall Pre-Brace Cobb (°)	24.45°	26.35°	=0.887
Overall In-Brace Cobb (°)	13.4°	16.4°	=0.230
Overall Curve Correction (%)	45.4%	39.76%	=0.233
Thoracic Curve Correction (%)	40.2%	33.1%	=0.259
Thoracolumbar Curve Correction(%)	55.1%	52.2%	=0.703

206. Abolition of Sagittal T7-T10 Dynamics During Forced Ventilation in Lenke 1A AIS Patients as Compared to Healthy Subjects. An Underlying Factor of the Respiratory Limitation in AIS.*

Carlos Barrios, MD, PhD; Jesus Burgos Flores, MD, PhD; Luis Miguel Anton Rodrigalvarez, PhD; Eduardo Hevia, MD

Summary
As compared to healthy controls, Lenke 1A AIS patients show a stiffness of the thoracic spine during deep breathing, with an almost complete abolition of T7-T10 sagittal range of motion. T7-T10 stiffness, a crucial segment for deep breathing, could be an underlying cause of the ventilatory limitations described in AIS patients

Hypothesis
The decline of T7-T10 dynamics related to the stiffness of the apex region in Lenke 1A curves could harm the respiratory function of AIS patients.

Design
Case-control cross-sectional study

Introduction
An active participation in the respiratory function has been attributed to the thoracic spine, particularly to the T7-T10 segment. The apex region in Lenke 1A AIS curves usually involves the T7-T10 region. The objective of this study is to analyze the dynamics of the thoracic spine during deep breathing in AIS patients and in healthy matched controls.

Methods
34 AIS patients (31 girls, Cobb angle, 54.7±7.8°; Risser 1.5±1.1) and 20 healthy volunteers (16 girls) matched in age (13.8 versus 14.4 yr. mean age) participated in the study. In AIS curves, the apex was located in T8 (23) and T9 (11). Conventional sagittal radiographs of the whole spine were performed at maximal inspiration and expiration. The ROM of each spinal thoracic functional segment (T1-T7, T7-T10, T10-T12), the global T1–T12 and the T12-L1 ROM were measured. Forced vital capacity (FVC) and expiratory volume (FEV1) were also recorded.

Results
In healthy subjects, the mean T1–T12 ROM during forced breathing was 16.7°±3.7° (95%CI: 14.8-18.8), reflecting the flexibility of the thoracic spine (33.7%). AIS patients showed only a T1-T12 ROM of 1.1°±1.5° (95%CI: 0.4-1.8; p<0.001) indicating a sagittal stiffness of thoracic spine (4.6%). A wide T7–T10 ROM (15.3º±2.9°) was found in healthy controls (89.8% of the T1–T12 ROM). AIS patients showed only 0,4º±2.9º ROM at T7-T10. The T10-T12 segment was stable during deep breathing in both AIS and healthy controls (mean, 0.73º versus 0.68º). There was an increase of lumbar lordosis during expiration in both groups (AIS, 6.7º±7.2° ROM; healthy controls, 8.6º±3.2° ROM). AIS patients showed significantly lower FVC and FEV1 values than healthy controls.

Conclusion
Lenke 1A AIS patients show a restriction of the thoracic spine motion with an almost complete abolition of T7-T10 ROM. T7-T10 stiffness could explain the ventilatory limitations found in AIS patients.

207. Alignment Targets, Curve Proportion and Mechanical Loading: Preliminary Analysis of an Ideal Shape Toward Reducing Proximal Junctional Kyphosis

Renaud Lafage, MS; Frank J. Schwab, MD; Han Jo Kim, MD; Justin Smith, MD, PhD; Breton G. Line, BS; Christopher Shaffrey, MD; Douglas C. Burton, MD; Christopher Ames, MD; Gregory Mundis, MD; Richard Hostin, MD; Shay Bess, MD; Eric O. Klineberg, MD; Peter Passias, MD; Virginie Lafage, PhD; International Spine Study Group

Summary
Spinal alignment analysis is biased by the ability of the spine to compensate. Using a validated model to virtually remove the PJK and its compensation, this study investigates the combined effect of offsets from alignment targets, theoretical kyphosis, and mechanical loading on PJK. Patients who develop PJK or PJK-R following a complete fusion of the lumbar spine have an over correction versus age alignment goals, under correction of TK (flattening), and under loading of the UIV

Hypothesis
Mechanical loading and alignment differ in PJK patients

Design
Retrospective review of prospective data

Introduction
With increased focal deformity (PJK), patients recruit compensatory mechanisms; therefore any comparison of post-operative alignment is biased by these mechanisms. Using a validated model to virtually remove the PJK and its resultant compensation, this study investigated the combined effects of mechanical loading and alignment on PJK.

Methods
Pts with a compete fusion of the lumbar spine and 2yr follow-up were included and categorized into non-PJK, PJK or PJK-R (i.e. revision for PJK). Alignment targets were derived from recent publication on age-alignment objectives, theoretical values of thoracic kyphosis based on lordosis, and normative mechanical loading at each vertebra. Using virtual alignment, distance from alignment targets was compared across PJK groups and a sub-stratification by UIV position was conducted (UT vs. LT). Multilinear logistic regression was conducted to identify independent predictor of PJK and/or PJK-R.

Results
Of the 373 pts that met inclusion criteria (62.7 yo±9.9; 81%F), 172 (46.1%) with PJK, and 21 (5.6%) with PJK-R 2yr after surgery. As PJK severity increases, the global alignment becomes more posterior with a gradual over correction in terms of PT, PI-LL, and SVA (all p<0.005). In addition, PJK pts had a larger undercorrection from the theoretical TK predicted by their fused lumbar alignment (-3.7° vs 7.5° vs 13.4°) and a smaller bending moment offset at the UIV (UT: 0.64 vs 2.02 vs 1.98 ; LT: -0.85 vs 2.22 vs 1.83) (all p<0.001). Multivariate analysis demonstrated that PI-LL and bending moment difference were independent predictors of PJK/PJK-R in UT group and PT and bending moment difference for LT group.

Conclusion
By virtually removing the effect of PJK on compensatory mechanisms, and focusing on the difference from accepted alignment goals we found spinopelvic over correction, under correction of TK (flattening), and under loading of the UIV were associated with PJK and PJK-R. These differences are underreported when compensation bias is not accounted for.

Table 1: ANOVA between PJK groups. Grey cell: no significant difference between PJK severity

		PT (°)	PI-LL (°)	T4-T12 (°)	TPA (°)	SVA mm	Moment UIV (UT) N/m	Moment UIV (LT) N/m
Pre-op	No PJK	25.6 ± 10.3	19.5 ± 18.5	-41.8 ± 17.0	25.3 ± 12.5	78.8 ± 73.3	—	—
	PJK	26.7 ± 10.3	22.2 ± 20	-30.2 ± 17.4	26.5 ± 12.9	82.5 ± 72.9	—	—
	PJK-R	27 ± 8.7	16.4 ± 19.3	-36.2 ± 17.1	25 ± 10.8	70.1 ± 73.3	—	—
	p	0.593	0.242	0.28	0.664	0.738		
2-year post-op / pre-revision	No PJK	22.6 ± 9.9	5.7 ± 16.1	-41.8 ± 15.3	19.1 ± 11.1	36.8 ± 56.5	5.37 ± 2.8	11.34 ± 6.4
	PJK	22.6 ± 10.4	1.4 ± 18.8	-47.5 ± 16.2	18.3 ± 10.7	31.2 ± 51.6	6.97 ± 2.7	14.48 ± 5.5
	PJK-R	22 ± 6.2	-4.9 ± 9.4	-57.4 ± 13.7	17.4 ± 7	31.8 ± 48.6	5.68 ± 1.2	17.15 ± 7.8
	p	0.97	0.006	<0.001	0.835	0.609	0.002	<0.001
Virtual alignment	No PJK	22.9 ± 9.5	5.7 ± 16.1	-38.9 ± 14.9	18.3 ± 11.4	23.1 ± 50.9	4.35 ± 2.6	8.64 ± 6
	PJK	19.7 ± 8.2	3.4 ± 20.6	-31.5 ± 28.2	13.9 ± 10.5	1.2 ± 53.5	2.87 ± 2.7	5.95 ± 4.9
	PJK-R	16.1 ± 6.1	-4.9 ± 9.4	-37.5 ± 11.3	10.3 ± 6.5	-4.5 ± 38.8	1.44 ± 2.2	6.16 ± 4.5
	p	<0.001	0.035	0.009	<0.001	<0.001	0.001	0.004
Virtual offset with targets	No PJK	-0.9 ± 9.7	0.2 ± 16.7	3.7 ± 25.9	0.6 ± 12	13.4 ± 53.5	0.64 ± 2.2	-0.85 ± 5.3
	PJK	3.4 ± 8.5	4.3 ± 21.1	-7.5 ± 32.2	6.8 ± 11.2	42.5 ± 55.5	2.02 ± 2.2	2.22 ± 4.4
	PJK-R	7.6 ± 6.6	13.5 ± 9.9	-13.4 ± 17.3	11.2 ± 7.3	51.8 ± 40	1.98 ± 2.8	1.83 ± 4.2
	p	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001

208. All Lordosis is not Equal: Response to Thoracic Fusion in the Unfused Lumbar Spine of AIS Leads to Differences in Relative Contribution to Lordosis from the Disc and Bone*

Saba Pasha, PhD; John M. Flynn, MD; Patrick Cahill, MD

Summary
We compared the local morphological differences in the vertebral body and intervertebral disc in the unfused spine between 62 AIS at 2-year after STF and 20 non-scoliotic controls. We determined although the lumbar lordosis is not significantly different between the AIS at 2-year follow-up and the control group, the contribution of the bony lordosis to the total lumbar lordosis curve in post-operative AIS is significantly higher (56%) than this contribution in the non-scoliotic controls (15%).

Hypothesis
The contribution of the bony lordosis and disc sagittal wedging to the total lumbar lordosis is significantly different between the age-matched non-scoliotic controls and AIS at two-year post-STF.

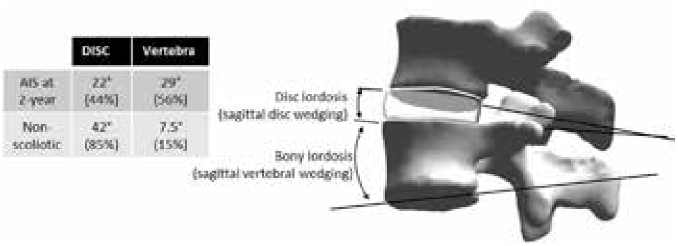
Design
Prospective cohort

Introduction
Spontaneous lumbar curve correction after selective thoracic fusion has been reported in AIS. The differences in the contribution of the vertebrae and discs to the total lumbar lordosis between the non-scoliotic controls and 2-year post-operative AIS have not been quantified. We aimed to quantify the contribution of the vertebral and disc sagittal wedging to the total lordosis pre-operatively and at two-year after posterior spinal fusion in AIS and compare it to a group of non-scoliotic controls.

Methods
62 Lenke 1 AIS, fused between T3-L1, with bi-planar low dose stereoradiography and minimum two-year follow-up were selected. 20 non-scoliotic adolescents were added as the control group. 3D reconstruction of the spine was used to measure the sagittal disc and vertebral wedging and the global L1-L5 lordosis at pre-op, first erect, and two-year follow-up and for the non-scoliotic control group.

Results
There was no significant change in lumbar lordosis between the pre-op and 2 year follow-up, $p>0.05$. There was a significant increase in vertebral sagittal wedging between pre- and 2year follow-up at L1-L3, $p<0.05$. The decrease in the sagittal disc wedging was significant between pre and FE and between FE and 2-year follow-up at L1-L3, $p<0.05$. The lumbar lordosis at two-year follow-up was composed of 56% of bony lordosis and 44% of sagittal disc wedging while in controls only 15% of the lordosis comes from the bony vertebral wedging and the other 85% is due to the disc sagittal wedging.

Conclusion
While the spinal fusion has been mainly looked at normalizing the global lordosis magnitude, the local changes in the unfused spine have been overlooked. Post-operative difference in lumbar lordosis between the non-scoliotic controls and unfused lumbar spine at 2-year post-STF includes a decrease in sagittal disc wedging an increased in vertebral wedging.



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209. Analysis of Axial Rotation and Gravity-Induced Axial Torque in Idiopathic Scoliosis by Barycentremetry.

Thomas Thenard, PhD; Claudio Vergari, PhD; Thibault Hernandez, MD; Raphael Vialle, MD, PhD; Wafa Skalli, PhD

Summary
Axial torque in the scoliotic spine could be an important parameter to understand the biomechanical aspects of scoliosis progression. Barycentremetry allows obtaining this parameter from biplanar radiographies and the reconstruction of the spine and of the external envelope. Results show that torques were maximal at the junctional levels, corresponding to high intervertebral axial rotations. This result underline the importance of junctional levels to understand the biomechanics of scoliosis progression.

Hypothesis
Analysis of gravity-induced axial torque on the spine may provide an insight on the biomechanical mechanism of scoliosis progression.

Design
Prospective and retrospective data collection and analysis.

Introduction
Adolescent Idiopathic Scoliosis (AIS) is a 3D deformation of the trunk, and its progression mechanism is not yet fully understood. Gravity loads applied to an asymmetrical spine may generate torque on the discs and growing vertebrae, and therefore yield axial rotations which may lead to scoliosis progression. The aim of this study was to analyse the gravity-induced torque along the scoliotic spine.

Methods
80 subjects were included: 27 healthy subjects (average age: 13 years (SD: 2.1)) and 53 AIS patients (average age: 14 years (SD: 1.7), average Cobb angle: 32° (SD: 16.2)). They underwent biplanar radiography and their spine and external envelope were reconstructed using validated methods. Barycentremetry yielded mass and center of mass location (COM) of the body segment above each vertebra. From COM and mass, torques around the spine axis were estimated at each vertebral level. The Intervertebral Axial Rotation (IAR) was also computed from 3D reconstruction. Correlations were analysed with Spearman test ($p<0.05$).

Results
On the AIS population, torque was maximal at the junctional levels, with average values of 2.9 Nm (SD: 2.1), and it was minimal at the apex with 0.5 Nm (SD: 0.5). IAR followed the same trend, mean 7.3 ° (SD: 3.6) at junctions and 1° (SD: 0.8) at the

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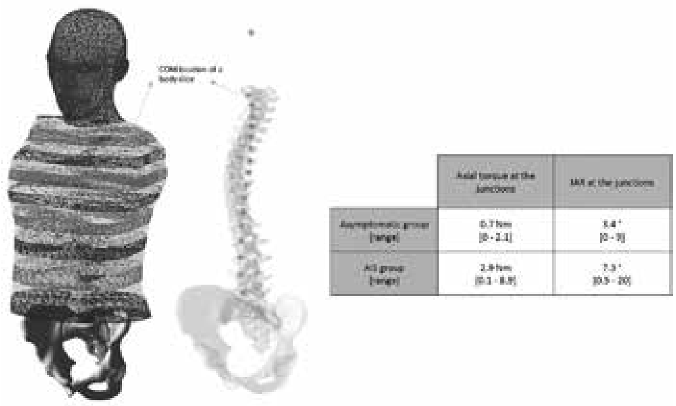
apex. Healthy group showed lower axial torques and IAR than AIS group (figure 1). Moreover, significant correlation was found between the maximal value of IAR and torque ($p<0.05$, $r=0.65$).

Conclusion
Gravitational torque and IAR were investigated using barycentremetry. Results show that junctions are areas of high IAR and high torsion moment. This suggests a potential role in the vicious cycle that leads to scoliosis progression.



210. Back to the Future; SSEP Monitoring Only for VEPTR and Growing Rod Lengthening

Frances Farley, MD; Kelly Roberts, BS, CNIM; Jordyn Sessel, BS; Ying Li, MD; Michelle Caird, MD; Daniela Minecan, MD

Summary
Multimodal IONM may be necessary for all VEPTR and Growing Rod insertions and lengthening where there was a change at insertion. SSEPs only may be necessary for VEPTR and Growing Rod lengthening.

Hypothesis
During EOS lengthening cases, SSEP monitoring alone is adequate.

Design
Level 3 Case comparison

Introduction
The necessity of and type of intraoperative neurophysiological monitoring (IONM) during early onset scoliosis (EOS) cases is controversial. All cases of early onset scoliosis involving vertical expandable prosthetic Titanium rib (VEPTR) and traditional Growing Rods (GR) were retrospectively reviewed to report all monitoring changes that occurred.

Methods
With IRB approval, all cases of EOS treated with GR and VEPTR, including insertions, exchanges and lengthening that had IONM were retrospectively reviewed. Any monitoring changes that occurred during the case were recorded. The data was divided into four groups: VEPTR placement and exchanges, VEPTR lengthening, GR placement and exchanges, GR lengthening.

Results
There were 486 cases involving monitoring, on 95 patients from 2009 to 2017. Of the 486 examined cases, 280 had monitoring with SSEPs only while 206 had both SSEPs and MEPs. Table 1 shows the monitoring changes that occurred in all groups. Upper extremity changes occurred in each group. MEP changes related to anesthetic level or technique also occurred in every group. A single patient experienced true changes in MEPs unrelated to anesthetic during Growing Rod insertion and again during subsequent lengthening.

Conclusion
IONM of cases of early onset scoliosis yielded upper extremity SSEP changes related to positioning. MEP changes were seen primarily related to anesthetics; however, lower extremity MEP changes occurred in one patient.

	Number of procedures	MEP/SSEP	SSEP	Anesthetic MEP Δ	UE Δ	LE Δ	True Change
VEPTR Insertions/Exchanges	76	21	55	2	5	0	0
VEPTR Lengthening	209	48	161	1	6	1	0
Growing Rod Insertions/Exchanges	37	20	17	9	1	2	2*
Growing Rod Lengthening	164	117	47	12	7	1	1*
Totals	**486**	**206**	**280**	**24**	**19**	**4**	**3**

*same patient

211. Biplanar Low Dose Radiography in Adolescent Idiopathic Scoliosis Does Not Result in Errors of 'Intent to Treat.'

Mariel Rickert, BS; Maged Hanna, MD, PhD; Jose A. Herrera-Soto, MD; Dennis Knapp, Jr, MD; Jonathan H. Phillips, MD

Summary
Transitioning into an ultra-low dose biplanar imaging does not induce any inaccuracies; therefore intent to treat by bracing or by surgery is not confounded by the new imaging technique.

Hypothesis
There is no significant difference in Cobb angle measurements between the ultra- low dose biplanar imaging system and conventional plane images.

Design
Retrospective case series.

Introduction
Recent advances in radiography have led to the development of ultra low dose biplanar techniques for scoliosis evaluation. This study addresses the concerns regarding accuracy of diagnosis and compares plane radiographs obtained conventionally with those acquired with the new biplanar ultra low dose technique in the treatment of Adolescent Idiopathic Scoliosis (AIS).

Methods
134 AIS patients who received ultra low dose biplanar imaging and conventional plane radiographs within a 12-month time period as part of routine imaging were retrospectively selected. 24 patients received spinal fusion and instrumentation, 19 females and 5 males, with a mean age of 13.5 years (range, 12-17). Surgically fused patients controlled for confounding curve progression across the two time points. Due to the lapse in time, unfused patients were excluded as a natural progression of the curve was unable to be differentiated from a technical discrepancy between imaging systems.Frontal plane curvature measurements were manually performed by two independent examiners. Cobb angles acquired from the standing conventional radiographs were compared to the standing EOS imaging to determine if clinical

discrepancy exists among the two methods.

Results
The relationship between primary plane and primary ultra low dose biplanar imaging Cobb angle measurements was positively correlated for observer 1 (r= .996, p < .01). Similarly, measurements by observer 2 were also positive and significant (r= .964, p < .01). Measurements of the secondary Cobb angle resulted in similar findings of positive correlation (observer 1 (r= .982, p < .01) observer 2(r= .962, p < .01).

Conclusion
Ultra low dose biplanar imaging provides clinically identical accurate measurements to conventional plane radiographs for patients with AIS. The results of this study provide spinal surgeons evidence that employment of the new imaging system will not result in errors of intent to treat.

212. Can Scoliosis with Syringomyelia (SM) be Corrected by Single-Stage Posterior Surgery Safely?

Jingming Xie, MD; Yingsong Wang, MD; Zhi Zhao, MD; Ying Zhang, MD; Ni Bi, MD; Tao Li, MD; Zhiyue Shi, MD

Summary
Scoliosis is often associated with SM. More spinal surgeons attempt single-stage spinal correction in these patients, which is different from traditional divided-stage procedure. From this retrospective study, we summarized our experiences in using single-stage posterior correction to treat scoliosis with SM (S+SM). Our conclusions supported that single-stage posterior correction can be a possible choice for S+SM; the individualized surgical design based on the spinal cord tension helped to promote the safety of correcting S+SM by single-stage posterior procedure.

Hypothesis
Single-stage posterior surgery could be a safe choice to correct S+SM.

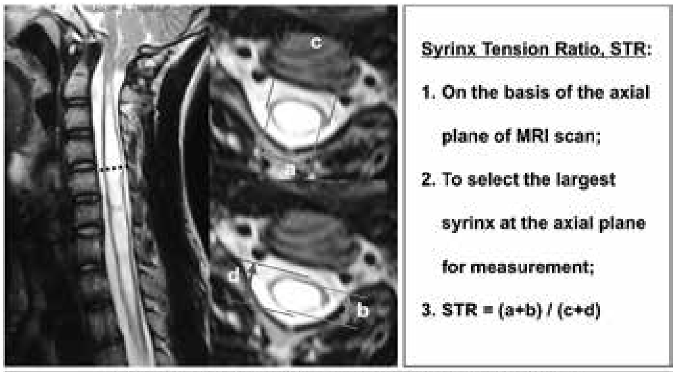
Design
A retrospective study.

Introduction
The existence of syrinx has been believed as a potential risk to threaten the spinal cord in surgical spinal correction. The traditional treatment of S+SM includes two divided stages: neurosurgical decompression before spinal correction. Recently, more surgeons attempt single-stage spinal correction to avoid multiple operations.

Methods
Twenty-eight continued cases of S+SM were treated by single-stage posterior correction were reviewed. The inclusion criteria of single-stage correction: Chiari 1 malformation with SM or idiopathic SM; without significant neurological deficit. Surgical design was developed from syrinx tension ratio (STR) (Fig.): Type 1: STR≤0.5 (no tension syrinx), if scoliosis <60°, a direct simple posterior correction was safe; Type 2: STR was 0.5-0.8 (lower tension syrinx), if scoliosis was 60°-80°, spinal osteotomy (≤grade 4) would be considered; Type 3: STR≥0.8 (higher tension syrinx), if scoliosis>80°, pre-op cranial-femoral traction could be used to evaluate the potential of the "sick" cord to tolerate tension changes, spinal shortening osteotomy (>grade 4) would be included to achieve correction under a tension-free condition of the cord.

Results
The averaging main scoliotic curve was 75.9°, of which 13 cases >80° and pre-op traction was used in 9; simple corrections in 7, with spinal osteotomy≤grade 4 in 9, with spinal osteotomy>grade 4 in 12. Averaging 67.4% postop coronal corrective rate was achieved without neurologic deterioration. The 5 years' follow-up shown no progressive neurologic deterioration: shrinking and stable syrinx were observed in 9 and 18 cases; only 1 with increasing syrinx received second stage neurosurgical shunting at postop 2 years.

Conclusion
On the basis of a fully consideration the potential tolerance of the "syrinx" spinal cord to the tension change following spinal corrective procedure, single-stage posterior correction can be a possible choice for S+SM without increasing neurological risks. STR can be a predictive index of spinal cord tension from different syrinx for individualized surgical design.



Summary of the 28 cases of scoliosis associated syringomyelia

		Total Patients	Types		
			Type 1	Type 2	Type 3
n/%		28	8/28.6	15/53.6	5/17.9
Age	< 18y (n/%)	22/78.6	4/14.3	15/53.6	3/10.7
	≥ 18y (n/%)	6/21.4	4/14.3	0	2/7.1
Cobb Angel of scoliosis	≤60° (n/%)	8/28.5	2/7.1	6/21.4	0
	60°-80° (n/%)	7/25.0	1/3.6	5/17.9	1/3.6
	≥80° (n/%)	13/46.4	5/17.9	4/14.3	4/14.3
Kyhposis	≤60° (n/%)	21/75.0	3/10.7	14/50.0	4/14.3
	60°-80° (n/%)	2/7.1	2/7.1	0	0
	≥80° (n/%)	5/17.9	3/10.7	1/3.6	1/3.6
Associated with Chiari malformation (n/%)		20/71.4	5/17.9	10/35.7	5/17.9
Pre-op traction (n/%)		9/32.1	3/10.7	4/14.3	2/7.1
Spinal osteotomy	None (n/%)	7/25.0	2/7.1	5/17.9	0
	≤Level 4 (n/%)	9/32.1	1/3.6	7/25.0	1/3.6
	> Level 4 (n/%)	12/42.9	5/17.9	3/10.7	4/14.3
Radiological outcome	Pre-op coronal Cobb (°)	75.9	86.1	66.8	86.6
	Post-op coronal correct (%	67.4	67.1	67.1	53.6
Syrinx outcome	Post-OP enlarge (n/%)	1/3.6	1/3.6	0	0
	Post-OP no change (n/%)	18/64.3	6/21.4	10/35.7	2/7.1
	Post-OP decrease (n/%)	9/32.1	1/3.6	5/17.9	3/10.7

213. Changes in Pelvic Incidence because of Subluxation of the Sacroiliac Joint in Severe Adult Spinal Deformity

Masatake Ino, MD; Naofumı Toda, MD; Takachika Shimizu, MD

Summary
We measured PI, PT, and SS using standing lateral X-ray in 16 adult spinal deformity patients whose PT were 30-40°, 18 patients whose PT was more than 40°, and 30 normal volunteers. In cases with excessive posterior pelvic inclination, it was considered that there was a possibility of PI increase with the sacroiliac joint subluxation.

Hypothesis
PI might change in severe adult spinal deformity cases with pelvic retroversion because of rotatory subluxation due to large off set between sacrum and femoral head.

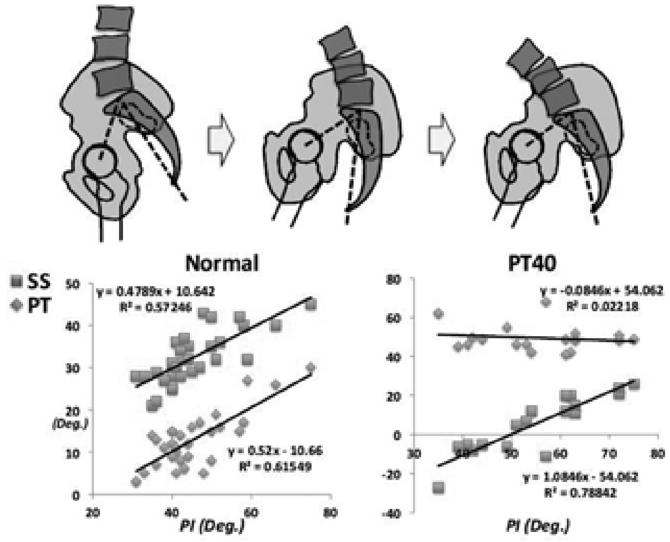
Design
retrospective study

Introduction
Pelvic incidence (PI) is supposed to remain unchanged despite age and posture. We considered that PI might change in cases severe adult spinal deformity with pelvic retroversion because of rotatory subluxation caused by a large offset between the sacrum and femoral head. The purpose of this study was to investigate whether there is a difference in PI value depending on the degree of pelvic retroversion.

Methods
We measured PI, pelvic tilt (PT), and sacral slope (SS) using standing lateral X-ray in 16 adult patients with spinal deformity whose PT were 30-40° (PT30 group), 18 patients whose PT was more than 40° (PT40 group), and 30 normal volunteers.

Results
The mean PI was 45.5° in the normal volunteers and 48.6° in the PT30 group with no significant difference. The mean PI was 55.7° in the PT40 group, and a significant difference was found between the patients in the PT40 group and normal volunteers ($p = 0.0035$). The change in PT and SS with increasing in PI showed an approximate straight line of $y = 0.52\times - 10.66$ (R2 = 0.62) in PT and $y = 0.48 \times +10.64$ (R2 = 0.57) in SS in normal volunteers, and they were almost parallel. On the contrary, the approximate straight line of $y = -0.07 \times +52.56$ (R2 = 0.01) in PT and $y = 1.07 \times -52.56$ (R2 = 0.71) in SS were found in the PT40 group.

Conclusion
The mean PI of the patients in the group PT40 group was larger than that of normal volunteers. It seems to support our hypothesis that "excessive PT causes sacroiliac joint movements to increase PI". In the PT40 group, SS linearly increased with increase in PI; however, increase in PT showed a plateau at almost 50°. This result suggests that when excessive extension of the hip joint reaches the limit, the compensation function fails and the sacrum is inclined forward with the forward inclination of the trunk. In cases of excessive posterior pelvic inclination, a possibility of increase in PI with subluxation of the sacroiliac joint was considered.



214. Characterize the Progression of AIS Curves Beyond 40°

W. Timothy Ward, MD; James Roach, MD; Tanya S. Kenkre, PhD; Jared Crasto, MD

Summary
Radiographic review of one surgeon's AIS patients indicates progression of AIS curves is considerably higher than published long term rates for the first 10 years after reaching 40° and may have remained almost 4 times higher for patients undergoing surgery after 5-10 years of follow up. Non-op patients showed long term progression rates consistent with published data after 10 years of follow up. We did not identify any factors accounting for the different rates of progression in these two groups.

Hypothesis
AIS curves progress more than 1°/yr. after reaching 40°.

Design
Retrospective radiographic review of AIS curves.

Introduction
We sought to use our large database of AIS cases to re-examine the current consensus on curve progression beyond 40° based on the Weinstein and Ponseti study (J Bone Joint Surg Am. 1983;65:447-455).

Methods
Radiographic review of one surgeon's patients whose curves reached 40° between the ages of 10 to 18 years included serial measures of 296 non-operated patients with average x-ray follow up of 4.9 yrs. ± 4.6 yrs. and 325 operated cases with average time to surgery of 1.7 yrs. ±1.6 yrs.

Results
Annualized Cobb progression in non-op patients ranged from 4.6 ±8.7°/yr. in the first 6 months after reaching 40°, decreased to 1.2 ±1.1°/yr. between 5 to10 years, and to 0.6 ±0.6 °/yr. after 10 years. Operated patients showed more rapid progression averaging 17.1 ±20.9 °/yr. in the first 6 months, 8.3 ±6.9 °/yr. between 1 to 5 years, 3.1 ±1.5°/yr. between 5 to 10 years, and 0.6 ±0.6° if surgery was done more than 10 years after reaching

40°. Cobb progression was associated with Risser sign. 12.2% of non-op patients first seen at Risser 0 or 1 progressed over 20° compared to only 2.7% first seen at Risser 4 or 5. 34.1% of operated patients presenting at Risser 0 or 1 progressed over 20° compared to 10.3% presenting at Risser 4 or 5. Both operated and non-operated thoracic or either component of double curves progressed more than thoracolumbar curves, and progression for all curves was also associated with Risser sign. Progression was not associated with curve magnitude at presentation, i.e. whether curve presented at 40° or more than 60°.

Conclusion
Our data suggest two different progression patterns: non-op patients had progression after 40°, 4 to 6 times greater than reported by Weinstein and Ponseti (0.75-1°/yr.) for the first 5 years, then tapering to 0.6°/yr. after 10 years; and an operative group with a 4 to 23-fold greater annualized progression during the 10 years preceding surgery than reported by Weinstein and Ponseti. We did not identify any factors accounting for the different rates of progression in these two groups.

215. Cobalt Chrome Versus Titanium Alloy Rods for Correction of Adolescent Idiopathic scoliosis: A Multi-Center, Randomized Clinical Trial

Daisuke Sakai, MD, PhD; Masato Tanaka, MD; Jun Takahashi, MD, PhD; Yuki Taniguchi, MD, PhD; Katsushi Takeshita, MD, PhD

Summary
A prospective, multi-center, randomized clinical trial was performed to assess if stiffer rods can obtain better correction in posterior spinal fusion for AIS. Results showed no significant difference in correction of coronal, sagittal and rotational profiles among groups using cobalt chrome or titanium alloy rods 12 months after surgery, suggesting that rod stiffness cannot outperform surgeon differences.

Hypothesis
Stiffer rods achieve better correction in posterior spinal for adolescent idiopathic scoliosis (AIS)

Design
Randomized clinical trial

Introduction
It has been reported that stiffer rods can provide greater correctional force with lesser rod deformation in pedicle screw-based posterior spinal fusion. However, it is unknown whether rod stiffness can outperform the difference of individual surgeons, which utilizes variety of surgical techniques to maximize their surgical outcomes. The aim of this study was to conduct a prospective, multi-center, randomized clinical trial investigating on the use of cobalt chrome versus titanium alloy rods on correction of AIS.

Methods
Sixty-nine patients (ages 10 to 19 years) with AIS types Lenke type 1, 2 and 3 and main thoracic curves to the right, ranging from 45 to 97 degrees, were recruited from 5 institutions and followed for 12 months. Patients were automatically allocated using age, main thoracic Cobb angle, active bending, Risser grade as stratified factors in a system equalizing groups using 6.0mm diameter cobalt chrome (CoCr, n=32) or titanium alloy (Ti, n=37) rods. Changes in coronal (main Cobb, CCI), sagittal (thoracic kyphosis angle (Th5-12; TK), lumbar lordosis angle (L1-S1; LL)) and rotational (rib hump (RH), apical vertebral rotation (AVR)) profiles were compared by radiograph and CT at final follow-up.

Results
Results showed that CoCr and Ti groups were adequately comparable after allocation (average age: 14.9, 14.2, main Cobb 58.5°, 56.9° and active bending 36.8°, 34.7°). Both CoCr and Ti groups achieved significant correction after surgery in coronal (main Cobb:19.1, 18.2, correction rate: 67.1, 68.4, CCI: 2.2, 2.2), sagittal (TK: 21.5, 22.8, LL: 54, 51.1) and rotational (RH: 6.9,7.0, AVR: 14.8, 14.9) profiles at final follow-up.

Conclusion
A multi-center, randomized clinical trial showed no difference in correction of coronal, sagittal and rotational profiles between groups using CoCr or Ti rods. Findings suggest that rod stiffness profiles cannot overcome the effect of differences between surgeons in obtaining significant correction in posterior spinal fusion for AIS.

216. Comparison of Cardiopulmonary Function in Patients with Congenital Scoliosis and Adolescent Idiopathic Scoliosis

Youxi Lin, MD; Chong Chen, MD; Haining Tan, MD; Xingye Li, MD; Wangshu Yuan; Hui Cong, MS; Jianxiong Shen, MD

Summary
Studies have pointed out that thoracic scoliosis had the potential to impair cardiopulmonary function. However, no researcher compared the exercise capacity of scoliotic patients with different etiology so far. Our study revealed that congenital scoliosis might exert more serious cardiopulmonary dysfunction on patients than adolescent idiopathic scoliosis did.

Hypothesis
Congenital scoliosis(CS) patients may have more serious cardiopulmonary dysfunction than adolescent idiopathic scoliosis(AIS) ones.

Design
A prospective study.

Introduction
Studies have revealed that thoracic scoliosis had the potential to induce cardiopulmonary dysfunction. Nevertheless, no research compared the exercise capacity of scoliotic patients with different etiology by now. We aimed to analyze the difference of exercise tolerance of patients with CS and AIS.

Methods
10 female patients with CS were included in this study, and they were matched by gender, age and coronal curvature with AIS subjects in the proportion of 1:2. Radiographic parameters of the spine were measured, and results of pulmonary function testing(PFT) and cardiopulmonary exercise testing(CPET) was collected. 2-tailed Student-t test was used to analyze differences.

Results
The average age was 14.5 years in CS group and 13.7 years in AIS group. No difference was found in anthropometric data(age, height and weight) and radiographic results(major coronal curvature, apical vertebral translation and number of thoracic vertebrae involved). In PFT, significant difference was found between groups in forced expired volume in one second(P<0.01), forced vital capacity(P<0.05), total lung capacity(P<0.01), but not in the ratio of forced expired volume in one second and forced vital capacity(P>0.05). In CPET, CS group had significantly lower oxygen intake(P<0.05) and maximal heart rate(P<0.01), which represented worse exercise capacity. Similarly, CS group had higher respiratory rate(P<0.01), lower tidal volume(P<0.01), breathing reserve(P<0.05), which indicated abnormal breathing pattern. Also, blood oxygen saturation at maximal exercise was lower(P<0.05). No difference was found in minute ventilation, oxygen pulse and maximal heart rate(P>0.05).

Conclusion
Worse restrictive pulmonary dysfunction was found in CS patients compared to matched AIS ones, and lower exercise capacity, abnormal breathing pattern and decompensation of gas exchange were revealed by CPET. In view of different pathogenesis, CS might exert more serious cardiopulmonary dysfunction on patients.

217. Comparison of Growth-Friendly Surgery with a Rib-Based Construct in Patients with Congenital Scoliosis and Those Without Congenital Scoliosis: A Five-Year Follow-up Study

Noriaki Kawakami, MD; Toshiki Saito, MD; Ryoji Tauchi, MD; Kazuki Kawakami, B.Kin; Tetsuya Ohara, MD

Summary
The clinical outcomes of growth-friendly surgery (GFS) with a rib-based construct (RBC) were investigated by dividing pts. with early onset scoliosis (EOS) into two groups: congenital scoliosis (CS) group and non-CS group; all patients were followed up for five years. While no differences in scoliosis magnitude, space available for the lung (SAL), and thoracic height (TH) were postoperatively recognized between the two groups, the non-CS group had a significantly higher rate of device-related complications (DRCs) and unplanned surgeries postoperatively.

Hypothesis
Pts. with CS have a better clinical course with fewer postop. DRCs than those without CS.

Design
Retrospective cohort study

Introduction
In GFS, the employment of RBCs that use distraction as the correcting force is one of the standard surgical procedures. Despite this, the ideal indication for an RBC is still uncertain due to its high rate of DRCs. The purpose of this study was to compare the clinical outcomes of RBC between pts. with CS and those without CS to develop a more precise indication for using RBDs in pts. with EOS.

Methods
68 pts. with EOS who were <10 years of age and who were surgically treated using an RBC were followed up for 5 years postoperatively. They were divided into two groups based on their etiology: CS and non-CS. The non-CS group included neuromuscular in 12 pts., syndromic in 11, and idiopathic in 3. DRCs were investigated in each group intraoperatively and within one year and 5 years postoperatively.

Results
The CS group included 42 pts. (male: 13, female: 29, age at the primary surgery: 5.8 years). The non-CS group included 26 pts. (male: 13, female: 13, age at the primary surgery: 6.8 years). The non-CS group exhibited greater scoliosis preoperatively (p = 0.0108), larger TH (p = 0.0109), and greater SAL (p = 0.0162) than the CS group. No significant differences were seen between the two groups in terms of the total number of operative procedures, magnitude of scoliosis, SAL, or the rate of increase in TH/y at 5 years postoperatively. The CS group has decreased amount of DRCs by 73% and unplanned return to OR by 16% compared to the non-CS group controlling for preop. major curve and TH (p=0.013, p=0.002).

Conclusion
Pts. with CS are more suitable than pts. without CS for receiving RBCs as the former group of pts. had lower rates of postop. DRCs and unplanned surgeries.

218. Congenital and Idiopathic Early Onset Scoliosis: A Comparison of Presenting Comorbidity Profiles

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Summary
Significant comorbidity in early onset scoliosis (EOS) patients often complicates management decision-making. EOS derived through congenital or idiopathic etiologies intuitively may present with different comorbidity profiles and peri-operative risk, although these profiles have not been adequately described or quantified. Our analysis describes relatively synonymous comorbidity clusters for both Idiopathic and Congenital EOS patients, suggesting a common clinical entity and developmental abnormalities. Despite similar clustering profiles, idiopathic patients were of equal or greater risk for increased comorbidity severity.

Hypothesis
Congenital and Idiopathic EOS patients have unique co-morbidity profiles.

Design
Retrospective Review of HCUP's Kids' Inpatient Database(KID).

Introduction
EOS derived through congenital or idiopathic etiologies may

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present different comorbidity profiles that have yet to be adequately described.

Methods
The KID was queried for ICD-9 codes of congenital(C-EOS) and idiopathic(I-EOS) scoliosis patients ≤10 y/o from 2003, 2006, 2009, and 2012. Demographics, incidence and comorbidities were assessed. Comorbidities were stratified by neurological, musculoskeletal, pulmonary, cardiovascular, and renal systems. K-means cluster, X2 and ANOVA analyses compared groups.

Results
7,310 C-EOS and 18,438 I-EOS patients were included. C-EOS was younger(3.72 vs 4.59 y/o, p<0.001), more male(52.6% vs 50.7%, p<0.001), and of similar race(p=0.084). C-EOS had higher comorbidity rates(95.1% vs 86.5%, p<0.001), despite lower Charlson index scores(0.38 vs 0.75, p<0.001). Cohort comorbidity prevalence can be seen in Table 1. Top Body-System Clusters: Concurrent pulmonary+neurologic for C-EOS(24.6%) and I-EOS(44.2%). C-EOS also exhibited concurrent Renal+-Cardiovascular(6.0%). I-EOS exhibited renal(10.8%) with concurrent cardiovascular+musculoskeletal(30.2%). Top Specific Clusters: Ostium secundum atrial septal defect in C-EOS(16%) and I-EOS(14%) with patent ductus arteriosus(35.7% vs 32.6%) or ventricular septal defect(24.3% vs 27.1%). Pulmonary disease(10.8% vs 18.9%) with concurrent pulmonary collapse(7.7% vs. 9.6%), restrictive lung disease(8.4% vs 11.1%), or pulmonary failure(11.7% vs 12.3%) in both C-EOS and I-EOS, with I-EOS exhibiting increased pulmonary disease(p=0.033) and restrict lung(p=0.015) rates.

Conclusion
Our analysis describes relatively synonymous comorbidity clusters for both Idiopathic and Congenital EOS patients, suggesting a common clinical entity and developmental abnormalities. Despite similar clustering profiles, Idiopathic patients were of equal or greater risk for increased comorbidity severity. Appropriate testing(renal ultrasound, echocardiogram, etc) should be utilized in preoperative optimization for EOS, regardless of deformity etiology.

Table 1. Overall Prevalence of Presenting Comorbidities Stratified by Body System

	Musculoskeletal	Pulmonary	Neurological	Cardiovascular	Renal
Congenital-EOS	91.3%	47.7%	28.7%	22.2%	15.1%
Idiopathic-EOS	57.9%	49.9%	32.5%	17.3%	10.8%

219. Consecutive Distraction Forces and Lengthening in EOS with Dual GR and its Relationship to Gender, Age, Deformity, Revision Surgery, Concavity, and Convexity

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Summary
Since the advent of dual growth rod technique, there has been sparse evidence on the actual magnitude of distraction forces (1-2 reports , but on single growth rods), and none on its association with patient's parameters such as gender, age, deformity, revision surgery, concavity, and convexity. The current study characterizes these parameters for 11 consecutive distraction episodes.

Hypothesis
1. The force required to distract a spine increases with every consecutive lengthening 2. The lengthening achieved decreases with every consecutive lengthening 3. The force required on concave side is higher than convex side 4. The force required after revision surgery is lower than non-revision cases

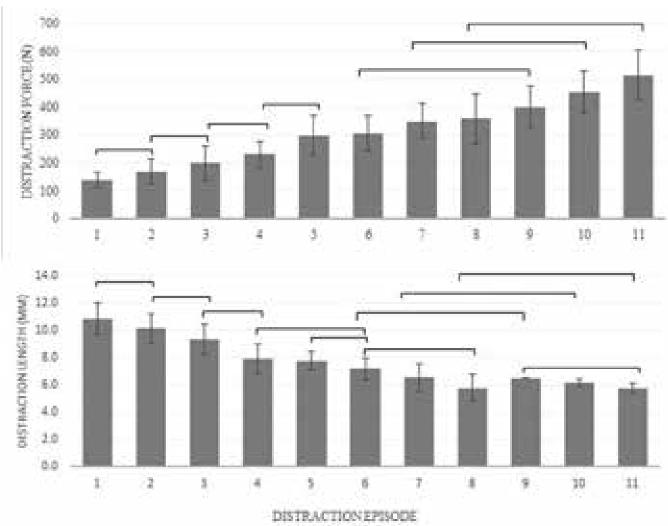
Design
A prospective single center study

Introduction
Dual GR have been extensively used as the preferred method for surgical treatment of EOS. However, the data on dual GR vis-à-vis actual magnitude of distraction forces and its association with patient parameters (gender, age, side: concave vs convex, extent of deformity and degree of correction scoliosis) and the effect of revision surgery is not available.

Methods
In a consecutive series of 47 patients with dual sub fascial GR, and a minimum follow up of 2 years, intraoperative distraction forces (N) and distraction achieved (mm) were measured and analyzed prospectively in 131 distractions constituting a total of 11 consecutive episodes.

Results
In cumulative, the distraction force increased by 268%, with 120% increase in the early stages (episodes 1-6) and 68% increase in the later stages (episodes 6-11). Whereas, the cumulative decrease in the length over 11 distractions episodes was 47%, with 34% and 20% in the early and later stages respectively. It was also observed that the distraction forces after implant revision was less compared to similar distractions in other patients for at least two consecutive episodes. In addition, the concave side required higher distraction force compared to convex side at each distraction. Nevertheless, the trend was independent of gender, age, extent of deformity and degree of correction.

Conclusion
The distraction forces and the lengthenings increased and decreased respectively with every consecutive distraction episode, with no correlation to gender, age, extent of deformity or the extent of correction. However, there existed a strong relationship between reduction in distraction forces following revision surgery, and the side of distraction.



220. Cost Analysis of a Growth Guidance System Compared with Magnetically Controlled and Traditional Growing Rods for Early-Onset Scoliosis in the US: An Integrated Health Care Delivery System Perspective

Scott John Luhmann, MD; Eoin McAughey, MS; Stacey Ackerman, PhD; <u>*David Bumpass, MD*</u>; Richard McCarthy, MD

Summary
Traditional growing rods (TGR), magnetically controlled growing rods (MCGR) and growth guidance systems (GGS) have demonstrated comparable radiographic outcomes in the treatment of early-onset scoliosis (EOS). The purpose of this study was to compare direct medical costs of GGS compared to TGR and MCGR using an economic model. Over a 6-year episode of care GGS had lower cumulative costs than MCGR and TGR, saving an estimated $25,226 vs TGR (16% decrease) and $29,916 vs MCGR (18% decrease).

Hypothesis
GGS, when compared to TGR and MCGR, will be cost saving over a 6-year episode of care.

Design
Cost analysis using a decision-analytic model.

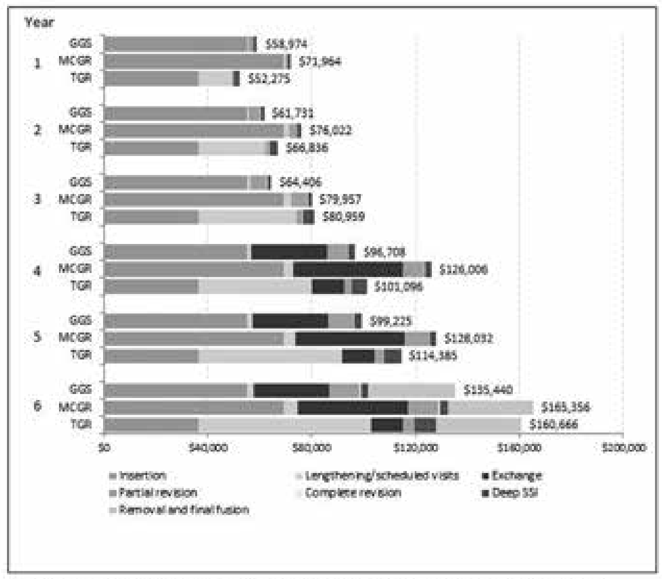
Introduction
TGR for EOS are effective but require repeated invasive surgical lengthenings that risk complications. Alternatives include MCGR that lengthen noninvasively and the GGS, which obviates the need for active, distractive lengthenings. Previous studies have reported promising clinical effectiveness for GGS similar to TGR.

Methods
An economic model was developed to estimate the cost of GGS compared with MCGR and TGR for EOS from a US integrated health care delivery system perspective. Using dual-rod constructs, the model estimated the cumulative costs associated with initial implantation, revisions due to device failure, surgical-site infections, device exchange (at 3.8 years), rod lengthenings (TGR, MCGR), and final spinal fusion over a 6-year episode of care. Model parameters were from peer-reviewed, published literature. Medicare payments were used as a proxy for provider costs. Costs (2016 US dollars) were discounted 3% annually.

Results
Over the 6-year episode of care, GGS was associated with fewer invasive surgeries per patient than TGR (GGS: 3.4; TGR: 14.4). GGS had lower cumulative costs than MCGR and TGR, saving an estimated $25,226 vs TGR (16% decrease) and $29,916 vs MCGR (18% decrease). Sensitivity analyses indicated that results were sensitive to changes in construct costs, rod breakage rates, months between lengthenings, and the care setting for TGR lengthenings.

Conclusion
GGS resulted in fewer invasive surgeries and deep SSIs than TGR and lower cumulative costs per patient than both MCGR and TGR over a 6-year episode of care. The analysis did not account for family disruption, pain, psychological distress, or compromised health-related quality of life associated with invasive TGR lengthenings.

Figure 1. Cumulative cost per patient (2016 USD) over six-year episode of care



Abbreviations: GGS, growth guidance system; HCP, healthcare professional; MCGR, magnetically controlled growing rod; SSI, surgical site infection; TGR, traditional growing rod

221. Cumulative Anesthesia Exposure in Patients Treated for Early Onset Scoliosis

<u>*Fady Baky*</u>; Todd Milbrandt, MD; A. Noelle Larson, MD

Summary
Early onset scoliosis patients are at risk for significant anesthesia exposure from multiple sources, with orthopedic procedures comprising the greatest number of hours. 43% of EOS patients had greater than 3 hours of anesthesia prior to the 3rd birthday, exceeding the FDA's recommendations. Neuromuscular and congenital patients received more cumulative hours of anesthesia than idiopathic patients.

Hypothesis
Patients with early onset scoliosis are at risk of receiving significant cumulative hours of anesthesia in childhood, particularly prior to age 3.

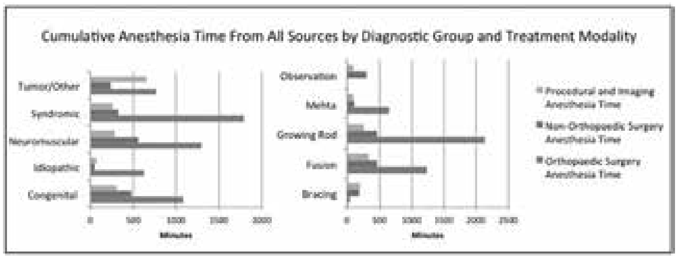
Design
Single center retrospective comparative study.

Introduction
In 2016, the U.S. FDA released a warning that repeated or lengthy use of anesthesia in children younger than age 3 may affect brain development. Observational studies show that children receiving multiple general anesthetics are at a higher risk for adverse neurocognitive outcomes. We sought to characterize anesthetic exposure in EOS patients and to determine risk factors for increased exposure.

Methods
69 EOS patients with mean 7.4 year follow-up (minimum 2-year follow-up) were treated between 2000-2014. Anesthesia type was recorded in three categories: 1) orthopaedic surgeries, 2) non-orthopaedic surgeries 3) imaging/associated procedures. Diagnoses included congenital, idiopathic, neuromuscular, and syndromic scoliosis (Figure). Treatments included observation, bracing, Mehta casting, growing spine, or fusion. Cumulative anesthesia time was recorded.

Results
Mean cumulative anesthesia time was 27.9 hours (1674 mins). Patients with neuromuscular (mean 2228 mins, $p = 0.006$) or congenital scoliosis (2132 mins, $p < 0.001$) received more anesthesia than those with idiopathic scoliosis (754 mins). Patients treated by fusion (2036 mins, $p< 0.001$) or growing spine procedures (2855 mins, $p< 0.001$) received more anesthesia than those treated by bracing. Patients who presented at a young age and those treated by Mehta casting were most likely to exceed 3 hours of anesthesia prior to age 3.

Conclusion
Disease severity, non-idiopathic diagnoses, and longer length of follow up were associated with increased anesthesia time. Overall, 43% of EOS patients exceeded the FDA warning dose of 3 hours of anesthesia exposure prior to age 3. These findings may help surgeons to counsel families and to develop strategies to reduce total anesthesia exposure in EOS patients.



222. Development and Validation of Prognostic Model Using the Sanders Maturity Stage in Untreated AIS

Lori Dolan, PhD; Stuart L. Weinstein, MD; Prakash Sitoula, MBBS, MS, MS (Orthopedics); Mark F. Abel, MD; Oheneba Boachie-Adjei, MD; Jacques L. D'Astous, MD, FRCS(C); Matthew Dobbs, MD; John Emans, MD; John M. Flynn, MD; Daniel W. Green, MD; Kenneth Guidera, MD; Matthew Halsey, MD; Kim W. Hammerberg, MD; Michael T. Hresko, MD; Henry J. Iwinski, MD; Antony Kallur, MD; Charles Mehlman, DO; Peter Newton, MD; Jean Ouellet, MD, FRCS(C); Nigel J. Price, MD; Christopher W. Reilly, MD; Kenneth J. Rogers, PhD, ATC; James Sanders, MD; Michael Schmitz, MD; Richard M. Schwend, MD; Suken Shah, MD; Kit M. Song, MD; Peter Sturm, MD; Kushagra Verma, MD, MS; W. Timothy Ward, MD; James Wright, MD, FRCS(C)

Summary
A model including the baseline Sanders maturity stage (SMS), the Cobb angle and presence of at least one thoracic curve is highly predictive of curve progression to surgical indications during skeletal growth. There is strong evidence for internal and external validity.

Hypothesis
SMS, Cobb angle, age and curve type predict curve progression to surgical indications (Cobb angle≥45° prior to Risser 4)

Design
Prognostic model development and validation

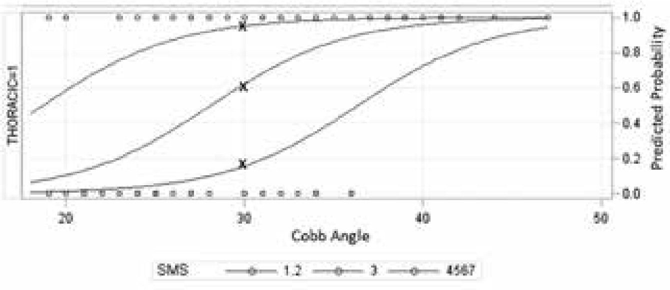
Introduction
The validity of the Sanders staging system as a maturity indicator has been satisfactorily established, however, its clinical value as a prognostic marker for the short- and long-term outcomes of AIS has not. Our purpose was to develop and validate a prognostic model estimating the risk of progression to surgical indications during skeletal growth using the SMS in untreated AIS.

Methods
115 patients were followed to either skeletal maturity (Risser grade 4), or to a Cobb angle of 45°+ or spinal fusion ("poor prognosis"). None were treated. Candidate variables included the baseline SMS, age, SRS curve classification, Cobb angle, and sex. Model calibration (Brier score) and discrimination (c-statistic) were evaluated. The model was then validated in jackknifed resamples of the dataset and in an independent dataset (n=117).

Results
The final model included the SMS (categorized as SMS 1-2, 3 or 4+), Cobb angle, and the presence of at least one thoracic curve (c-statistic =.92, Brier score=0.11). Relative to SMS 1-2, those at SMS 3 (OR=0.01, 95% CI=0.02-0.38), or 4+ (OR=0.01, 95% CI=0.001-0.05) had lower odds of a poor prognosis. The presence of a thoracic curve and increasing Cobb angle were associated with higher odds of the prognosis. The model was equally discriminative and calibrated in the jackknifed and external samples, providing strong evidence for internal and external validity. The graph shows the predicted probability of a poor prognosis for patients with at least one thoracic curve. For example, patients who present with a 30° Cobb angle, staged at SMS 1-2, have a 96% probability of a poor prognosis without treatment; the risk decreases to 68% at SMS 3, and 15% at SMS 4+.

Conclusion
This model validates the use of the Sanders maturity system to predict short-term natural history in patients with AIS. These

probabilities can be used to inform treatment decisions, as well as to assist in research evaluating the relative effectiveness of treatments for AIS.



223. Development of Preoperative Computer Models hich Accurately Predict Answers to all Individual Questions on SRS-22 at 2 year follow up: A Step Towards Individualized Medicine

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Summary
Informed decision making requires patient comprehension of expected outcomes of surgery. Predictive modeling was used to predict responses to the individual items of the SRS-22 instrument with 75-80% accuracy. Items related to pain, function, and self-image were most accurately predicted. These data can counsel patients regarding expectations and likelihood of achieving improvements in SRS-22 items at 2-year followup.

Hypothesis
Predictive modeling analyses will accurately predict responses to individual SRS-22 questions at 2-years postoperatively

Design
Retrospective modeling analysis

Introduction
Health related quality of life (HRQL) instruments are essential in a value-driven healthcare economy. HRQOL measures may be difficult for patients to interpret and appreciate. The purpose of this study was to create a predictive model for individual SRS-22 questions at 1 and 2 years after adult spinal deformity (ASD) surgery.

Methods
Two prospective observational cohorts were queried for ASD patients with SRS-22 data at baseline, 1 year and 2 years after surgery. 150 Covariates were used in the training models and included demographic data, surgical data, and perioperative complication data. Outcomes as answers of the SRS22r were dichotomized as “good” (4, 5) or “bad” (1-3). 6 different prediction algorithms were trained with 3-time horizons: baseline to 1 year, baseline to 2 years, and 1 year to 2 years. External validation was accomplished via an 80/20 data split for training and testing each model, respectively. Goodness of fit was measured using the area under receiver operating characteristic curves (AUROC) in the test set. Variable importance were calculated.

Results
561 Patients met inclusion criteria. The AUROC of most models were approximately 75-80% indicating successful fits. Items regarding back pain in the last 6 months(q1), level of activity(q5), domestic activity(q12) and feeling attractive with the current back condition(q19) of the SRS22 questionnaire were most accurately predicted. The models were less sensitive to questions regarding financial difficulties(q15), depression(q16) and days of sick leave or ceasing domestic activity in the last 3 months(q17).

Conclusion
Preop models to predict answers to each of the SRS-22 questions at 2-year followup were created with 75-80% accuracy. Items related to pain, function, and self-image were most accurately predicted. The ability to predict individual question responses may be useful in preoperative counseling of patients in the age of individualized medicine.

Table 1 Patient baseline probabilities and simulation at 2 year follow up

	Baseline Answer	Chance of "Good" at 2 Years	Chance of "Bad" at 2 Years	Chance of "Good" Wait 5 Years, Same Surgery	Chance of "Good" Wait 10 Years and 1 Revision Surgery
Q1	2	47.80%	52.20%	47.80%	47.80%
Q2	2	82.20%	17.80%	82.20%	77.20%
Q3	4	51.90%	48.10%	51.90%	51.90%
Q4	1	86.80%	13.20%	85.20%	81.00%
Q5	3	75.00%	25.00%	74.00%	72.00%
Q6	3	50.00%	50.00%	50.00%	50.00%
Q7	3	61.10%	38.90%	61.10%	61.10%
Q8	3	73.20%	26.80%	73.20%	72.00%
Q9	2	43.10%	56.90%	43.10%	43.10%
Q10	2	24.20%	75.80%	24.20%	27.20%
Q11	1	79.60%	20.40%	79.40%	74.20%
Q12	2	27.70%	72.30%	27.70%	27.70%
Q13	4	66.70%	33.30%	66.70%	66.70%
Q14	2	23.20%	76.80%	23.00%	24.20%
Q15	4	65.70%	34.30%	65.70%	65.70%
Q16	3	58.30%	41.70%	58.30%	58.30%
Q17	1	26.20%	73.80%	26.20%	28.00%
Q18	3	17.80%	82.20%	17.80%	20.40%
Q19	2	43.20%	56.80%	43.20%	43.20%
Q20	3	22.40%	77.60%	21.60%	23.60%
Q21	3	29.00%	71.00%	28.80%	32.20%
Q22	3	38.00%	62.00%	28.40%	28.40%

Patient: Female with no prior spine surgery, with anemia, employed, steady gait, 60 years old, 162cm height, 59 kgs weight, 137.22 sagittal balance, 58.4° of major curve cobb angle, 21.9° pelvic tilt, 42 ODI score baseline and more than 10 years with spine problems. **Surgery:** pelvic fixation, IBF, 8 fused vertebrae, posterior instrumentation, 0 SPOs, 9 levels between UIV and LIV.

224. Did Magnetically Controlled Growing Rods Change the Game Rules in Early Onset Scoliosis?

Senol Bekmez, MD; Ayaz Efendiyev, MD; Ozgur Dede, MD; Gokhan Demirkiran, MD; Mehmet Ayvaz, MD, Professor; *Muharrem Yazici, MD*

Summary
Magnetically controlled growing rod (MCGR) systems have been introduced to minimize the burden of repetitive lengthening surgery of traditional growing rod (TGR) to early onset scoliosis (EOS) patients. Good radiographic outcomes and minimizing

the number of surgical procedures with MCGR was not shown to make a difference in quality of life outcome studies when compared to TGR. However, since previous studies did not compare identical patient groups in terms of etiology, demographic and radiographic parameters, a true comparison is essential.

Hypothesis
MCGR provides significant improvement in quality of life outcomes by minimizing the number of the surgical procedures when compared with TGR.

Design
Retrospective case-matched series

Introduction
Patients with long sweeping congenital curves who underwent instrumented all-posterior convex growth arrest (CGA) and concave distraction with growing rod (TGR or MCGR) were retrospectively reviewed. Two cohorts were formed; one group that underwent CGA+MCGR and the other group that underwent CGA+TGR. Demographic parameters, follow-up time, number of lengthening procedures and unplanned procedures, radiographic parameters and complications were noted. The Early-Onset Scoliosis Questionnaire (EOSQ-24) was used to evaluate health-related quality of life (HRQoL) outcomes.

Methods
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Results
20 patients were included (10 MCGR, 10 TGR). No significant difference for average age, follow-up time, radiographic parameters or complications was noted (Table). Overall surgery per patient (index surgery, planned and unplanned procedures) were significantly lower in MCGR group (8.8 vs 1.3)(p=0.01). HRQoL analysis revealed no significant difference in any specific domain nor overall score of the EOSQ-24 questionnaire.

Conclusion
Although equally effective in controlling the deformity and superior in reducing the number of surgery with comparable complication rates, MCGR does not offer any significant improvement in HRQoL outcomes. It appears that TGR is still a reliable option in the treatment of EOS and it may be a bit early to announce MCGR as a game changer.

Parameter	TGR	MCGR	p
Gender (f/m)	8/3	10/2	0.586
Age at index surgery (years) [min/max]	5.9 [4-9]	6.6 [5-8]	0.218
Average f/u (months) [min/max]	44.9 [24-79]	39.3 [28-56]	0.971
Overall Surgery	8.8 [5-15]	1.3 [1-2]	0.01*
Unplanned Surgery	0.5	0.3	0.65
Instrumented segment Cobb (°) [min-max]			
Preop	60.5 [42-88]	61.8 [39-78]	0.842
Postop	39.7 [8-72]	42.3 [20-55]	0.780
Last f/u	36.4 [6-77]	31.9 [16-44]	0.661
Distracted segment Cobb (°) [min-max]			
Preop	34.4 [14-86]	36.8 [7-69]	0.549
Postop	15.7 [3-31]	24.2 [1-50]	0.211
Last f/u	13.1 [4-35]	15.9 [1-42]	0.604
T1-T12 height (mm/year) [min-max]	4.95 [2-7]	4.88 [3-8]	0.762
Convex height (mm/year) [min-max]	2.9 [0.4-4]	3.3 [0.3-5.3]	0.888
Concave height (mm/year) [min-max]	17.2 [4-26]	13.6 [8-19]	0.370

TGR: Traditional growing rod, MCGR: Magnetically controlled growing rod

225. Do Additional Bilateral Rib Ostoetomies to Multiple Ponte Ostetotomies Improve Thoracic Kyphosis Restoration Better in AIS Patients with Thoracic Hypokyphosis or Lordoscoliosis?

Sinan Kahraman, MD; Cem Sever, MD; Selhan Karadereler, MD; Yunus Emre Akman, MD; Yesim Erol, BS; Tunay Sanli, MA; Meric Enercan, MD; Azmi Hamzaoglu, MD

Summary
The addition of bilateral rib osteotomies (BRO) to multiple Ponte osteotomies (MPO) enables better kyphosis restoration in AIS pts with thoracic hypokyphosis (TH) or thoracic lordosis (TL). In both techniques, pulmonary function tests (PFT) showed improvement at the end of three years f/up.

Hypothesis
The additional BRO to MPO provides better kyphosis restoration.

Design
Retrospective

Introduction
The aim of this study was to evaluate the clinical, radiological outcomes & pulmonary functions at the end of min. 3 yrs follow up in AIS pts with TH or TL who underwent either only MPO or additional BRO to MPO for thoracic kyphosis restoration.

Methods
62 AIS pts (11M,51F) with TH(n=49) or TL(n=13) who underwent MPO with/ without BRO were included. Group

A: pts who underwent only MPO (n=40), Group B: pts who underwent BRO (between T4-T10) in addition to MPO (n=22). Corrections in the coronal plane, and the improvements in the sagittal plane (T2-T12),(T5-T12) were compared. Preop & f/up PFT were compared. The clinical assessment was done with SRS-22 and ODI.Statistical analyses were performed with T test and two way Anova.

Results
Mean age was 15.5 (13-18). Mean f/up was 69.5months (36-138).Correction rates for MT and TL/L curves were 88% and 78% for Group A, and 84% and 76%, for Group B respectively. Mean increases in T2-T12, T5-T12 angles in the sagittal plane were 19.3° and 17.8° for Group A, and 24.2° and 21.2° for Group B. Mean number of MPO were 3 (2-5) in Group A, and 4 (2-6) in Group B. When number of osteotomy levels were compared; mean correction was significantly higher in pts who underwent MPO more than 3 levels ($p<0.05$). In Group B, the mean number of BRO levels was 5 (3-8). Kyphosis restoration in the sagittal plane was better in Group B, however the difference was not statistically significant ($p>0.05$). Comparison of preop and f/up PFT showed significant improvement in both groups(p<0,05) .In f/up, SRS22r and ODI values were similar for both groups.

Conclusion
In AIS patients with TH and TL, the addition of BRO to MPO provides better kyphosis restoration. Better restoration of thoracic kyphosis was achieved when MPO performed more than 3 levels. BRO provide additional mobility to the vertebral segment, and thereby increase the pull back effect towards the rod posteriorly which contribute further kyhposis restoration. PFT showed similar improvement at the end of 3 yrs f/up.

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226. Do Posterior Growth Rods Preserve Pulmonary Function in Patients with SMA Type 2?

Michael Troy, BS; Patricia Miller, MS; Robert Graham, MD; Brian D. Snyder, MD, PhD

Summary
This study analyzes the impact of posterior growth rods to control neuromuscular (NM) scoliosis on pulmonary function and need for respiratory assistance in patients with spinal muscular atrophy type 2 (SMA2).

Hypothesis
SMA 2 patients with progressive NM scoliosis treated with posterior growth rods will experience improvements in Cobb angle, chest wall deformity and pulmonary function compared to age-matched SMA2 cohort treated by TLSO only.

Design
Retrospective Comparative study

Introduction
SMA is a genetically-inherited, NM disorder characterized by degeneration of α-motor neurons due to deletions or mutations in SMN1gene resulting in non-functional SMN proteins. Severity depends on the number of SMN2 rescue gene copies. Type 2, the intermediate form, is associated with progressive muscle atrophy, respiratory dysfunction, spine and thoracic (parasol rib) deformity.

Methods
Cobb angle, parasol deformity, forced vital capacity (FVC % normalized by height) were compared across SMA2 treatment groups at baseline and at most-recent followup using linear mixed modeling to determine if there were any differences in the change in outcomes over time across treatment groups. All tests were two-sided; $p<0.05$ were considered significant.

Results
23 subjects with SMA2 were identified (65% male) with an average baseline age of 8.3 years (1.8 to 23.8). 10 subjects underwent treatment of severe scoliosis with growth rods (GR), while 13 were treated by TLSO only (Table 1). The operative cohort had larger curves compared to nonoperative. The average correction with GR was the operative cohort had an average of 24° correction, while the TLSO group experienced an average progression of 15 ° (Table 1). Parasol deformity was similar between groups at baseline and did not change appreciatively with GR. All baseline patients demonstrated that Cobb angle was inversely related to and accounted for roughly a 40% variance in FVC%. Patients treated with GR exhibited a change in the relationship between Cobb angle and FVC%, with relative improvement (i.e. less decline) in FVC% relative to the change in Cobb angle (Graph 1).

Conclusion
SMA2 patients with greater scoliosis received treatment with GR. The severity of spinal deformity negatively impacted pulmonary function, accounting for roughly 40% of the variance in FVC%. GR improved spinal deformity and changed the predicted trajectory of scoliosis on pulmonary function.

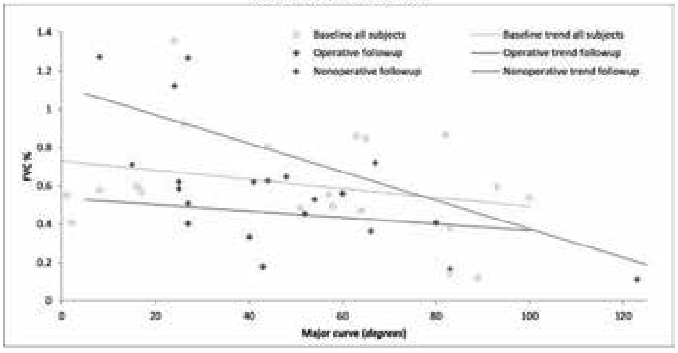
Table 1. Outcome characteristics by treatment group.

Outcome	Operative (n=10) Median	(IQR)	Nonoperative (n=13) Median	(IQR)	P
Major curve					
Baseline (degree)	64	(59 to 83)	20	(8 to 54)	0.01
Followup (degree)	42	(30 to 58)	46	(26 to 66)	0.92
Mean Change Overtime (95%CI)	-28.8	(-37.1 to -10.5)	15	(-4.2 to 34.2)	
Parasol deformity					
Baseline	0.65	(0.58 to 0.71)	0.74	(0.55 to 0.82)	0.54
Followup	0.52	(0.38 to 0.68)	0.56	(0.29 to 0.73)	1.00
FVC %					
Baseline (mean ± SD)	0.65	± 0.20	0.53	± 0.35	0.33
Followup (mean ± SD)	0.46	± 0.15	0.63	± 0.39	0.17
Nusinersin					
Baseline (freq (%))	4	(40%)	9	(69%)	0.22
Followup (freq (%))	5	(50%)	9	(69%)	0.42
Respiratory assistance					
Baseline (freq (%))	1	(10%)	3	(23%)	0.60
Followup (freq (%))	7	(70%)	6	(46%)	0.20

IQR, interquartile range

Graph 1.

Cobb Angle (Major Curve) vs. FVC%



227. Does Postoperative PI-LL Mismatching Affect Surgical Outcomes in Thoracolumbar Kyphosis Associated with Ankylosing Spondylitis Patients?

Bangping Qian, MD; Zhuojie Liu, MD; Yong Qiu, MD; Sai-hu Mao, MD; Jun Jiang, MD; Bin Wang, MD

Summary

A study aimed to investigate if pelvic incidence (PI) and lumbar lordosis (LL) mismatching affects surgical outcomes of 1-level lumbar pedicle subtraction osteotomy (PSO) for ankylosing spondylitis (AS)-related thoracolumbar kyphosis. The results showed that patients with postoperative PI-LL matching were more likely to have a better correction of sagittal plane.

Hypothesis

In AS patients treated with 1-level lumbar PSO, different post-operative PI-LL would lead to differing outcomes.

Design

Retrospective comparative study.

Introduction

To date, it's still unclear how spino-pelvic alignment impacts on the surgical outcomes in AS patients with thoracolumbar kyphosis. Therefore, the aim of this study is to investigate if PI-LL mismatching affects surgical outcomes in these patients after 1-level lumbar PSO.

Methods

Medical records of AS patients with thoracolumbar kyphosis, who underwent 1-level lumbar PSO in our institution, were retrospectively reviewed. Seventy AS patients who underwent 1-level lumbar PSO were enrolled with a mean age of 34.60±9.45 years (range, 17 yrs. to 59 yrs.) and a minimum of 2-year follow-up. Patients were divided into 2 groups according to postoperative PI-LL (44 in the Match Group and 26 in the Mismatch Group). Comparison of radiographical measurements and health-related quality of life (HRQoL) scores at baseline and at the last follow-up was performed between the 2 groups.

Results

At baseline, patients in the Match Group had smaller LL and pelvic tilt (PT) than their counterpart. At the last follow-up, along with smaller LL and PT, Match Group patients also had significantly smaller sagittal vertical axis (SVA, 3.31cm vs 6.27cm, p=0.001). Seventy-five percent (33/44) of the patients in the Match Group had a SVA < 5 cm at the last follow-up, while in the Mismatch Group, only 35% (9/26) of the patients did. No significant difference was found between the 2 groups regarding HRQoL scores.

Conclusion

Patients with postoperative PI-LL matching were more likely to have a better correction of SVA; they also tended to have a smaller preoperative PT. However, PI-LL mismatching didn't affect HRQoL scores at the last follow-up in these AS patients.

228. Does Rod Orientation and Use of Cross Connector Affect Spinal Height in Magnetically Controlled Growing Rod Patients?

Pooria Hosseini, MD; Behrooz Akbarnia, MD; Stacie Tran, MPH; Justin Zhang; Jeff Pawelek, BS; Charles Johnston, MD; Suken Shah, MD; John Emans, MD; Gregory Mundis, MD; Burt Yaszay, MD; Amer F. Samdani, MD; Peter Sturm, MD; Children's Spine Study Group; Growing Spine Study Group

Summary

In 57 EOS patients with dual MCGR spine-based constructs, orientation of the rods and presence of cross connector did not affect gains in rod length, thoracic height or spinal height after two years.

Hypothesis

MCGR rod orientation and presence of a cross connector does not affect spinal height gain.

Design

Multi-center retrospective review.

Introduction

Magnetically controlled growing rods (MCGR) are becoming popular in the management of early onset scoliosis (EOS). However, there are still unanswered questions regarding the details of this technique. The purpose of this study was to investigate the effect of rod orientation on the spinal height gain.

Methods

EOS patients with spine-based dual MCGR, minimum 2-year follow up, and available imaging were included from two multicenter EOS databases. The first analysis compared patients by rod orientation: standard (both rods lengthen in cephalad direction) or standard/offset (rods lengthen in two different directions). The second analysis compared the use of cross connectors: yes (CC+) or no (CC-).

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Results
Rod orientation analysis: 57 primary MCGR patients were divided into standard (n=18) and offset (n=39) groups. No significant differences in age, gender, BMI, follow up, ambulatory status, etiology, primary curve size, initial T1-S1 and T1-T12 heights, and number of distractions per year were observed (p>0.05). Left/right rod length gain per year and T1-T12 and T1-S1 height percentage change were similar between groups (p>0.05) (Table 1). 7 implant-related complications (IRC) (17.9%) including 6 anchor pullout and 1 rod fracture occurred in offset group, while standard rods had three IRCs (16.7%) including rod fracture, anchor pullout and screw loosening. However, IRC differences between groups were not significant (p=0.906). Cross connector analysis: The aforementioned parameters in CC+ (n=22) and CC- (n=35) were similar between groups except for number of distractions per year (CC+ 3.5 vs. CC- 2.9; p=0.029). To control for this difference, all height parameters were assessed using height gain per distraction. Left/right rod height, T1-T12 and T1-S1 per distraction were not statistically different between CC+ and CC- (P>0.05).

Conclusion
Rod orientation and presence of cross connector did not affect gains in rod length, thoracic height or spinal height in MCGR patients after 2 years.

Rod Orientation Analysis		Standard	Offset	p
Rod Height Gain/Year (mm)	Left	10 ± 4.1	9.9 ± 3.7	0.852
	Right	9.6 ± 4.2	10.1 ± 3.9	0.429
T1-S1 % Height Change		12.3 ± 13.6	12.8 ± 12.4	0.685
T1-T12 % Height Change		10.7 ± 10.8	10.6 ± 12.8	0.918

Cross Connector Analysis		CC-	CC+	p
Rod Height Gain/Year (mm)	Left	9.3 ± 3.5	10.8 ± 4.1	0.256
	Right	9.5 ± 3.8	10.6 ± 4.2	0.338
Rod Height Gain/Distraction (mm)	Left	3.7 ± 2.3	3.5 ± 1.8	0.922
	Right	3.8 ± 2.5	3.4 ± 1.7	0.743
T1-S1 % Height Change		10.6 ± 11.5	14.2 ± 14.4	0.87
T1-T12 % Height Change		10.2 ± 12.2	11.4 ± 12.2	0.979

229. Does the Insertion Angle of Monoaxial Thoracic Pedicle Screws Affect Post-Operative Thoracic Kyphosis in Adolescent Idiopathic Scoliosis?

Mohsen Karami, MD

Summary
Oblique insertion of monoaxial pedicle screws in thoracic vertebrae will negatively affect post-operative thoracic kyphosis in adolescent idiopathic scoliosis.

Hypothesis
Pedicle screw insertion angle will not affect post-operative sagittal angle of thoracic spine.

Design
To evaluate the effect of the insertion angle of monoaxial thoracic screws on the correction of thoracic hypokyphosis, a randomized clinical trial has been conducted.

Introduction
Post-operative thoracic hypokyphosis improves when rod derotation or differential rod technique is used during scoliosis correction. Other techniques like multiple Ponte osteotomies and stiffer rods might also affect thoracic hypokyphosis.

Methods
Twenty patients with Adolescent Idiopathic Scoliosis in whom thoracic fixation was needed, randomly allocated into two groups , in one group thoracic monoaxial pedicle screws inserted caudally within pedicles and in the other one, the screws were inserted parallel to the upper end plates. All cases were demonstrated Lenke type 1, 2 or 3 scoliosis. Group one patients aged 16.8±4.9 years and group two aged 13.7±2.8 years.

Results
The mean of insertion angle in group one and two were 6.5 and 2.3 degrees respectively. Pre-operatively, the mean of thoracic kyphosis in group one and two were 39.2 and 37 degrees respectively. Post-operatively, the mean of thoracic kyphosis in group one and two were 30.8 and 44.1 degrees respectively. Post-operative thoracic kyphosis improved meaningfully in group two (P value 0.001).

Conclusion
In conclusion, we do not advise to put thoracic screws obliquely to get strong purchase because this technique may jeopardise the correction of thoracic hypokyphosis.

230. Does the Severity of the Curve (Lenke 1 & 2) Affect the Distance of the Aorta to the Vertebra?

Chee Kidd Chiu, MBBS, MS; Keong Joo Lee, MBBS; Chris Yin Wei Chan, MD, MS; Mun Keong Kwan, MBBS, MS

Summary
We recruited 40 adolescent idiopathic scoliosis patients (Lenke 1 & 2) who had preoperative CT scan. The aorta-vertebra distance was measured and we found that the aorta was further away at the apical region. From T8 to T12 region, the aorta was further away in patients with a larger main thoracic Cobb angle.

Hypothesis
There is no difference between the severity of the curve (Cobb angle) and the distance of the aorta to the vertebra.

Design
A computerized tomography study

Introduction
There were no reports on the variation of the distance of the aorta to the vertebra in relation to the magnitude of the main thoracic Cobb angle for patient with adolescent idiopathic scoliosis.

Methods
A total of 40 adolescent idiopathic scoliosis patients with Lenke type 1 and 2 curve types who had preoperative CT scan were recruited. Preoperative CT scans in supine position were reconstructed using the MIMICS program. The aorta-vertebra distance (AVD), defined as the shortest distance between the aorta and the vertebra, were measured. Data collected were analysed with the SPSS statistical software.

Results
There were 34 female patients and 6 male patients with the mean age of 16.2 ± 3.6. There were 29 Lenke 1 and 11 Lenke 2

curves. The mean Cobb angle was 71.2° ± 16.8° and the range was 51° to 119°. The AVD ranged from 2.1mm to 5.1mm, with the shortest at L1 and the longest at T8. The aorta was found to be very near the vertebra (2-3mm) at T5, T12, L1, L2 and L3. The aorta was found to be further away (more than 4mm) at the apical region (T7 to T10). There were significant positive correlations between the magnitude of the main thoracic Cobb angle and the AVD from T8 to T12 ($p<0.05$). The correlations were weak ($r < 0.5$) at T8, T9 and T11, and were moderate ($r < 0.7$) at T10 and T12.

Conclusion

We found that the aorta was generally very near the vertebra with the distance ranging from 2.1-5.1mm. The aorta was very near the vertebra (2-3mm) at the proximal thoracic and the thoracolumbar region. The aorta was further away (more than 4mm) at the apical region. From T8 to T12 region, the aorta was further away from the vertebra in curves with larger main thoracic Cobb angles.

The mean aorta-vertebra distance (AVD) and its correlation with the curve Cobb angle for the thoracic and lumbar vertebral levels.

Level	AVD (mm)	r	p
T4	3.4 ± 2.8	-0.102	0.598
T5	2.6 ± 2.1	-0.110	0.507
T6	3.2 ± 2.2	-0.300	0.857
T7	4.6 ± 2.5	0.186	0.258
T8	5.1 ± 2.6	0.360	0.024*
T9	4.9 ± 2.6	0.453	0.004*
T10	4.2 ± 2.4	0.666	<0.001*
T11	3.2 ±1.9	0.498	0.001*
T12	2.5 ± 1.9	0.558	<0.001*
L1	2.1 ± 1.3	0.251	0.134
L2	2.5 ± 0.9	-0.109	0.513
L3	2.6 ± 0.9	-0.111	0.507

*significant
AVD = Aorta to vertebra distance

231. Durability of the Sagittal Plane in AIS Surgery. Durability of the Sagittal Plane in AIS Surgery: A 10-Year Followup Study

Michael P. Kelly, MD, MS; Munish C. Gupta, MD; Stefan Parent, MD, PhD; Baron Lonner, MD; Burt Yaszay, MD; Lawrence G. Lenke, MD; Amer F. Samdani, MD; Suken Shah, MD; Michelle Claire Marks, MS, PT; Peter Newton, MD

Summary

The sagittal plane in AIS is well-preserved at 10 year followup after surgery. There was a small, 4 degree, increase in LL over 10 years after surgery for AIS and a commensurate decrease in PI-LL. No differences were found when evaluating the effect of the lowest instrumented vertebrae on change in lordosis and no associations were found between postoperative TK and lumbopelvic parameters. At 10 years, SRS-Pain and SRS-Self Image scores were high.

Hypothesis

Low thoracic kyphosis (TK) after adolescent idiopathic scoliosis (AIS) surgery will lead to sagittal plane malalignment at 10 years postoperation.

Design

Longitudinal cohort study

Introduction

Restoration of TK after AIS surgery may allow for maximal lumbar lordosis (LL). Data suggest that inadequate restoration of TK may lead to loss of LL, though at 2 year followup overall sagittal plane alignment is good. There are no longer term followup studies examining the sagittal plane after surgery for AIS.

Methods

A prospective, multi-center cohort of surgically treated AIS patients was queried for patients with baseline, one-year, and minimum 10yr followup radiographic and outcomes data(Scoliosis Reseach Society-22). Standard radiographic parameters were measured including TK, LL, pelvic incidence (PI, when available), and C7 sagittal vertical axis(C7SVA). Changes in TK, LL, C7SVA, and change per distal motion segment were calculated between 1yr and 10yrs. Associations between 10yr TK and 10yr LL, PI-LL match, C7SVA, and SRS-Pain/Self Image were investigated with Spearman correlations.

Results

150 Patients were identified; 117 had 1yr and 10yr data (Female: 96 [82%], Lenke 1: 61 [52%], Lenke 5: 26 [22%], Lenke 2: 18 [15%], Posterior-only 65 [56%]). At 1yr median TK was 33 degrees (Interquartile range, 15), LL -58 (14), and C7SVA -1.8cm (4.8). Only 10 (8.5%) of patients had TK < 20 degrees(hypokyphosis). At 10yrs median TK 32 (14.5), LL -60 (17.5), and C7SVA -0.7cm (2.7). LL increased by a mean 4 degrees(95% CI 2 to 5.5), decreasing PI-LL to -8.4 (11) at 10yrs. Lumbopelvic parameters were not different when grouped by number of distal motion segments. Median 10yr SRS-Pain was 4.4 (0.8) and SRS-Self Image 4.6 (1.1). TK at 1yr did not correlate with change in lordosis at 10yrs nor change in LL-PI difference. TK did not correlate with any SRS-domain scores.

Conclusion

At 10yr followup, the sagittal plane is well preserved in AIS patients with a small increase in LL over 10 years. The change in LL was not different according to the number of preserved distal motion segments. SRS-Pain and Self-Image scores are high at 10 year followup and are not correlated to postoperative TK.

232. End-Growth Results of a Personalised Conservative Approach According to the SRS e BRAIST Inclusion Criteria and Outcomes

Stefano Negrini, MD; Sabrina Donzelli, MD; Jorge Villafañe, PhD; Francesca Di Felice, MD; Fabio Zaina, MD

Summary

Personalised conservative approach (PCA) is proposed by current Guidelines. We checked PCA according to two sets of criteria to define patients at higher risk and the relevant outcomes: SRS and BRAIST in a large prospective real-life study. Failures were 1.9% (BRAIST) and 3.1% (SRS). 38.1% of patients improved, increasing the rate of patients below 30° from 59.4% to 71.2% (BRAIST) and from 59% to 72.2% (SRS). PCA allows to obtain good results also using very strict inclusion and outcome criteria.

Hypothesis

A personalised conservative approach (PCA) to Adolescents with Idiopathic Scoliosis (AIS) can achieve good individualised results while reducing invasivity of treatments adapting to patients' needs

Design
Retrospective observational study nested in a prospective database including all outpatients of an Institute with 26 Centres

Introduction
Current Guidelines (Negrini 2012, 2018) propose PCA according to the step-by-step theory: treatment intensity increases with estimated risk factors, from observation to PSSE to soft, rigid and very rigid bracing. In the literature exists nowadays two sets of criteria to define patients at higher risk and the relevant outcomes: the SRS (Richards 2005) and BRAIST (Weinstein 2013). PCA has not yet been checked according with these criteria

Methods
We considered two partially overlapping populations according to the SRS and BRAIST criteria. SRS inclusion criteria (in brackets BRAIST if different): age 10 or more (10-15), Risser 0-2, 25-40° (20-40°), no prior treatment, female premenarchal or less than 1 year postmenarchal. End of observation: Risser 3, medical prescription. Outcomes: SRS (BRAIST): % of patients >44° (>49°), or progressed (>4°). We added SRS-SOSORT Consensus (Negrini 2014) outcomes: % of patients <30°, improvement (>4°) Treatment: PCA including observation, PSSE (SEAS school), soft (SpineCor), hard (Sibilla) and very rigid (Sforzesco) braces. Statistics: descriptive; ROC curves to check the starting Cobb degrees able to predict with best sensitivity and specificity the final outcomes

Results
42 and 81 patients dropped out, leaving 735 and 687 in SRS and BRAIST respectively. Failures were 1.9% (BRAIST) and 3.1% (SRS). 38.1% of patients improved, increasing the rate of patients below 30° from 59.4% to 71.2% (BRAIST) and from 59% to 72.2% (SRS). The ROC curves for failures had an area of 76.5 (SRS) and 81.0 (BRAIST) with a point of cohort of 25.5 giving a sensibility of 95.5% and 92.3% and specificity of 63% and 63.5% respectively for SRS and BRAIST

Conclusion
PCA allows to obtain good results using the SRS and BRAIST inclusion criteria, also considering the SRS-SOSORT Consensus outcomes

		BRAIST	SRS
Number		687	735
Treatment	Observation	0,1%	0,3%
	PSSE (SEAS School)	6,2%	6,9%
	Soft brace (SpineCor)	9,4%	6,8%
	Rigid brace (Sibilla)	49,4%	44,1%
	Very rigid brace (Sforesco)	41,2%	49,1%
Above 50° (BRAIST)	Start	0,0%	0,0%
	End	1,9%	1,8%
Above 45° (SRS)	Start	0,0%	0,0%
	End	3,3%	3,1%
5° Cobb change (SRS-SOSORT)	Progressed	18,5%	16,6%
	Improved	38,1%	38,2%
Below 30° (SRS-SOSORT)	Start	59,4%	59,0%
	End	71,2%	72,2%

233. Evaluation of Lateral Atlantodental Interval (LADI) Asymmetry in Pediatric Patients
Andrew Huh, BS; Janit Pandya, BS; Andrew Jea, MD

Summary
Asymmetry of the LADI has been reported in healthy adult and pediatric patient populations with or without a history of trauma, both on plain radiographs and CT. Asymmetry of LADI may also rarely indicate ligamentous injury or atlantoaxial rotatory subluxation, which if present could lead to catastrophic sequelae, a diagnostic dilemma (normal variant vs. ligamentous injury). Although low yield, this leads pediatric providers to investigate further with more intensive and costly imaging studies, such as dynamic CT or MRI.

Hypothesis
We hypothesize that there is no appreciable difference in LADI across gender and pediatric age ranges. In addition, we believe that asymmetry of the LADI is not unusual in asymptomatic children evaluated by cervical computed tomography.

Design
Retrospective cross-sectional study.

Introduction
The study of normative radiographic measurements for the developing pediatric spine is incomplete. The purpose of this analysis is to determine the normal range of asymmetry of the lateral atlantodental interval, and define age- and gender-related differences.

Methods
A total of 3072 children age 0 to 18 years who underwent CT of the cervical spine were identified at Riley Hospital for Children between 2005 and 2017. Patients were stratified by gender and age (in years) into 36 cohorts. Following this stratification, patients within each group were randomly selected for inclusion until 15 patients in each group had been measured (quota sampling). Only those patients with "normal" CT scans were included for analysis. A CT scan was considered "normal" if there was no evidence of congenital spine abnormality, prior

spine surgery, or traumatic spine injury. In addition, we reviewed the electronic medical record of these patients to confirm there was no evidence of delayed or missed cervical spine injury on subsequent follow-up in clinic or readmission to the hospital. A total of 540 patients were included for study. Right and left linear measurements were performed on the CT axial plane at the C1 mid-lateral mass level.

Results
The overall mean difference between the right and left LADI was 0.09 +/- 1.23 mm (range, -6.05 – 4.87 mm). The magnitude of this asymmetry remained statistically insignificant across age groups (p = 0.278) and gender (p = 0.889).

Conclusion
Asymmetry of the LADI is not unusual in asymptomatic children. There is no appreciable difference in magnitude of this asymmetry across age ranges and gender. Pediatric neurosurgeons, emergency room physicians, and radiologists should be aware of normative values of asymmetry when interpreting CT scans of the cervical spine. This may prevent unnecessary further workup with dynamic CT or MRI.

234. Evaluation of the Performance of an Adult Spinal Deformity Surgical Decision-Making (ASD-SDM) Score

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Summary
This study investigated the performance of an ASD-SDM score in comparison with the decision-making factors. The ASD-SDM score had significant correlations with multiple decision-making factors and was most useful to guide the surgical decision.

Hypothesis
The ASD-SDM score can quantify the decision to pursue surgical management with respect to multiple decision-making factors.

Design
Multicenter, prospective study of consecutive ASD patients

Introduction
The decision-making process for ASD patients is highly complex. The ASD-SDM score, which we developed, has been the sole scheme to guide the surgical decision for ASD patients. This study aimed to assess the correlation between the ASD-SDM score and the decision-making factors, which have been previously described, and compare their discriminative capacities to select surgical patients.

Methods
Included in this study were 1088 ASD patients. The ASD-SDM score was a cumulative scoring system, which consists of 4 factors and ranges from 0 to 10 in younger patients (≤40 years); and 5 factors, from 0 to 12 in older patients (>40 years). Analysed decision-making factors were back and leg pain evaluated by VAS; HRQoL measures (SF-36, SRS-22 and ODI); coronal Cobb angle; and sagittal deformity according to the SRS-Schwab simplified modifier. The correlations between the ASD-SDM score and the decision-making factors and their performance to discriminate the surgical patients, using the area under the curve (AUC) of receiver operating characteristic curve, were assessed.

Results
The average of ASD-SDM score was 3.9±2.4 and 6.6±2.7, in the younger and older patients, respectively. Spearman's correlation analysis showed significant correlations between the ASD-SDM score and decision-making factors in both age groups. The AUC of ASD-SDM score was 0.77 (95% CI: 0.71-0.81, P<0.001) and 0.78 (95% CI: 0.75-0.81, P<0.001) in the younger and older age groups, respectively, and significantly higher than the ones of the decision-making factors.

Conclusion
This study indicates that the ASD-SDM score is a useful tool to guide the surgical decision for ASD patients, reflecting multiple decision-making factors.

235. Fragility Fracture Risk in Elderly Patients with Cervical Myelopathy

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Summary
Fragility fractures are a significant source of morbidity and mortality in elderly patients. CSM is associated with increased rates of fragility fractures in elderly patients when compared to baseline population rates. The present study demonstrated that CSM patients are at increased odds of experiencing a fragility fracture when compared to the general population. Interestingly, we found that surgery was protective, and significantly reduced the risk of fragility fractures in this high-risk population.

Hypothesis
Surgery for cervical spondylotic myelopathy (CSM) may reduce the risk of fragility fractures, due to a decreased risk of falls.

Design
Retrospective analysis of Medicare insurance database.

Introduction
Cervical spondylotic myelopathy (CSM) is a common disease in the elderly. Progression of myelopathic symptoms, including gait imbalance, can be a source of morbidity as it can lead to increased falls. The purpose of this study was to assess the rate of fragility fractures in patients with CSM and to determine if surgical management reduces fragility fracture incidence in this patient population.

Methods
Records of elderly patients with Medicare insurance from 2005 to 2014 were retrospectively reviewed. Three mutually exclusive populations of patients were identified for analysis, including a cohort of patients with a diagnosis of CSM, but who were not

treated with surgery; a cohort of patients with CSM who were treated with surgery; and a group of control patients who had never been treated with cervical spine surgery nor were diagnosed with CSM. Incidence of fractures of the distal radius, proximal humerus, proximal femur, and lumbar spine were assessed and compared between cohorts, adjusted by age, sex, and Charleson Comorbidity Index.

Results

A total of 1,182,022 patients were identified. Of the identified patients, 86,943 had a diagnosis of CSM, 34,792 underwent cervical spine surgery, and 1,095,079 were treated as control patients. Compared to general population controls, the 12-month adjusted odds of experiencing at least one fragility fracture were 1.62 times higher in patients with CSM who were not treated with surgery (P < 0.001). Compared to non-surgically treated CSM patients, the odds of experiencing at least one fragility fracture were reduced by 0.73 times in surgically treated patients (P < 0.001). Analogous odds ratios were 1.37 (P < 0.001) and 0.82 (P < 0.001) at 3 years.

Conclusion

Fragility fractures are a significant source of morbidity and mortality in elderly patients. CSM is associated with increased rates of fragility fractures, though surgical management of CSM may be protective against risk of fragility fracture.

236. Frailty Phenotype Predicts Length of Stay Following Spine Surgery

__Shane Burch, MD, MS, FRCS(C)__; Sigurd H. Berven, MD

Summary

Frailty is a clinical syndrome that characterizes the risk of an adverse health outcome. Two wide-spread approaches to measure frailty exist: the phenotypic model (PF) and the frailty index (FI). The FP model is characterized by unintentional weight loss, exhaustion, weakness, slow walking and low physical activity measured on a 5 point scale. The current study demonstrates the predictive ability of FP to determine length of stay and disposition following spinal surgery.

Hypothesis

FP predicts patients who are at increased risk for length of stay and disposition following spine surgery.

Design

A retrospective analysis of a prospectively collected cohort.

Introduction

Frailty is a clinical syndrome that characterizes the risk or vulnerability of a patient to an adverse health outcome. Two wide-spread approaches to measure frailty include: the phenotypic model (PF) and the frailty index (FI). The frailty phenotype (FP) characterized by unintentional weight loss, exhaustion, weakness, slow walking and low physical activity as measured on a 5 point scale, offers a method to stratify patients into low (robust), moderate (pre-frail) or high risk (frail). The purpose of the study is to determine if FP predicts patients who are at increased risk for length of stay and discharge to facilities other than home following surgery.

Methods

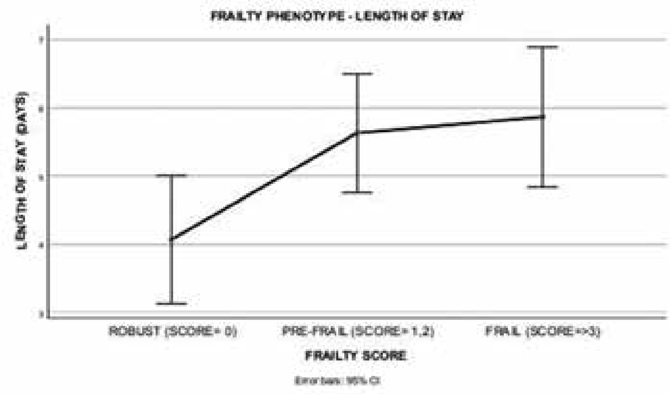
A retrospective analysis of a prospectively collected cohort of patients (n= 740), a subset of whom age >60 underwent spinal surgery (n= 132). Using the scoring method of Woods et al., the frailty phenotype was measured using five domains: unintentional weight loss, exhaustion, weakness, slow walking and low physical activity with scores ranging from 0 (robust), 1-2 (pre-frail) and 3-5 (frail) . VAS, SF-36, EQ5D and ODI scores were also recorded. Disposition and length of stay data were determined for each patient. The comparison of the robust, pre-frail and frail groups were assessed using ANOVA for continuous variables and Chi-square tests for categorical variables.

Results

77 females and 55 males (mean age of 70.8) were included. 46 patients with adult spinal deformity vs 86 with cervical or lumbar degenerative conditions were included. 44 robust, 51 pre-frail and 37 frail patients were identified. Mean LOS for the entire cohort was 5.17 days (range 1-17 days). Shorter length of stay (4.07 days) occurred in robust patients vs pre-frail or frail patients (5.86 days, p=.031). Robust patients were more likely to go home following surgery (84%) vs skilled nursing facilities than pre-frail or frail patients (51%, p=0.001).

Conclusion

The frailty phenotype (FP) may predict LOS and disposition for patients with spinal disorders.



237. Golden Mean Skeletal Age Hand Analysis in Adolescent Idiopathic Scoliosis(AIS)

William McKinnon, MD; __Michael J. Faloon, MD, MS__; Woojin Cho, MD, PhD; Arash Emami, MD; Conor Dunn, MD; Suken Shah, MD

Summary

Skeletal age radiographs of hand of AIS pts treated both operatively (AIS-op) & conservatively (AIS-nonop) were compared to controls(C). AIS pts have longer Distal Phalanx (DP) of ring finger than C. AIS-op showed significant bigger MP than AIS-nonop.

Hypothesis

Differences may exist between the carpal length ratios of AIS pts when compared against controls.

Design

Retrospective case control study

Introduction
Since Classical times, the inter-relationship of bone length ratios to development, function, and aesthetics has been studied. AIS pts have been shown to display particular morphologic bone formation. This study compares the intrinsic hand ratios of AIS pts to healthy controls (C).

Methods
200 consecutive pts evaluated for AIS at a single institution from 2007-2014 were reviewed. 68 were diagnosed with AIS. Pts with complete medical records & radiographs were included in the analysis. Pts w/ concomitant genetic, metabolic, neuromuscular, skeletal, connective tissue or physeal disorders were excluded. Pts were separated into two groups AIS & C. All images were stored in the same PACS system & measured by a single author. Two length measurements 1)anatomical length & 2)center of rotation were made on PA skeletal age hand X-rays for each metacarpal(MC), proximal(PP), middle(MP) & distal phalanx-(DP) of each finger. Statistical analysis was performed comparing the actual lengths of each bone and ratios of MC/PP, PP/MP, & MP/DP for each group. Subgroup analysis of surgically treated AIS (AIS-op) and non-operative AIS (AIS-nonop) was also performed.

Results
60 pts were included; 30 in AIS and 30 in C. Mean age of AIS group was 14.0 yrs(11-18). 9 underwent surgical intervention, 21 non-operative. Group C consisted of 30 pts. Mean age 13.25 yrs(11-18). AIS pts have significant longer DP of ring finger (RF) in center of rotation (p=0.028) & bigger center of rotation MP/DP ratio (p=0.047). AIS-op-group showed significant bigger MP of RF in center of rotation than AIS-nonop (p=0.022) and bigger MP/DP ratio (p=0.036). No other differences between anatomic lengths of AIS & C were found.

Conclusion
Bone length ratios were fairly consistent throughout all groups. AIS pts have significant longer DP of ring finger (RF) than C. AIS-op pts had longer MP length & MP/PP ratio in RF than AIS-nonop pts. We hope this data can be used as a predictive value for treatment of AIS.

238. Growing-Rod Treatment Improves Nutritional Condition of Pediatric Scoliosis Patients

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Summary
Growing-rod treatment is widely accepted for early-onset scoliotic patients. It is unclear that whether it improves nutritional status of patients. We reviewed 52 patients who had growing rod implantation with minimal 2-year follow up. Their weight-for-age were compared to general population of China and the standard deviation (SD) was calculated. We found that the number of patients whose body weights lower than 2 SD decreased with growing-rod treatment.

Hypothesis
Growing-rod treatment may improve nutritional condition of pediatric scoliotic patients.

Design
A case series study

Introduction
Children with early onset scoliosis may suffer malnutrition resulting from compromised respiratory function, food intake and lack of exercises. Growing-rod treatment may relief chest deformities and improve their condition of breathing. However, literature regarding on if growing-rod treatment improves nutritional condition of affected children has not been reported.

Methods
Total of 52 patients with early onset scoliosis who had growing-rod implantation and a minimum of 2-year follow-up were enrolled. Their body weights (BW) were extracted from medical records during each hospitalization and were compared to the reference curve of weight-for-age in Chinese population. The reference curve was published by Li et al. in 2013 based on 94302 school children derived from two cross-sectional national population census in China. At each age, the body weight was divided into 6 levels partitioned by the median weight-for-age (M) and two standard deviations (SD) of two sides. The nutritional condition was evaluated by the level of weight. According to the reference of World Health Organization (WHO) published in 2007, BW below M minus 2SD (-2SD), i.e. lowest 4.6%, was considered malnutrition.

Results
The average age of initial growing-rod implantation was 6.9 years, with 34 (71%) females. The median follow-up period was 35 months with minimum 24 months. Preoperatively, BW of 15 children (28.85%) were below -2SD. At 2-year's follow-up, the number was reduced to 6 (11.54%), achieving 93.33% of decrease. Among 26 patients had been followed up for more than 3-years, 10 (38.46%) had BW below -2SD. At 3-year's follow-up, the number reduced to 1 (3.85%).

Conclusion
Pediatric patients with early onset scoliosis have high rate of malnutrition. Growing-rod treatment significantly improves nutritional condition of scoliotic patients with malnutrition.

239. Growth Guidance Constructs with Sliding Pedicle Screws Results in 1/5th of Normal T1-S1 Growth

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Summary
The change in T1-S1 observed through the follow up period in early onset scoliosis (EOS) patients treated with guided growth constructs with apical fusion (GGC) was approximately 1/5th of predicted growth.

Hypothesis
The change in T1-S1 observed with GGC will be close to normal growth.

Design
Retrospective multicenter review.

Introduction
Guided growth with apical fusion is an alternative to distraction based growing rods (GR) for the treatment of EOS. A recent report of GGC with pedicle screws of patients treated primarily at the center where the procedure was invented reported surprisingly good growth compared to GRs.

Methods
Retrospective review of EOS patients treated with GGC with pedicle screws between 2007 and 2013 was performed from a multicenter database prior to final fusion. Inclusion criteria were <10 years at index surgery and minimum 2 year follow-up. Patients with GGC performed at the inventor's institution or prior spinal instrumentation were excluded. Predicted normal T1-S1 change during the growth period was calculated for each patient based on Dimeglio's growth rates.

Results
21 patients with the following diagnoses met the inclusion criteria: syndromic (N=9), neuromuscular (N=6), idiopathic (N=3) and congenital (N=3). Mean age at time of index surgery was 5.7 years (range: 2.7 to 8.5years) and mean follow-up was 5.1 years (range: 2.4 to 8.9 years). Preoperative mean Cobb angle was 75^{0} (range: 33^{0} to 111^{0}). Mean Cobb angle decreased from preoperatively to postoperatively by 47^{0}(range, -73^{0} to -8^{0}). From postoperatively to final follow-up the Cobb angle increased by a mean of 16^{0} (range: -11^{0} to 44^{0}). Mean increase in T1-S1 length from preoperative to postoperative was 54.2 mm, and change from postoperative to final follow-up was 13.4mm (2.5mm/year, 20% predicted growth). 15/21 (71%) patients underwent a total of 30 revision surgeries most commonly for implant complications (n=21) and7/21 (33%) underwent definitive fusion at a mean of 5.1 ±1.2 years after guided growth surgery.

Conclusion
The change in T1-S1(2.5 mm/year) was far below predicted growth, and that seen in distraction based growing rods (12.1 mm/year).

	Our Guided Growth Study N=22	McCarthy et al. 2015 Shilla Series N=40	Akbarnia et al. 2012 Growing Rod Series N=23
T1-S1 height change during growth period (mm/year)	2.5	8	12.1
Overall Cobb angle correction from pre-op to final follow-up (^{0})	-31	-30	-46
Total number of additional surgeries/patient	1.5	1.9	7.2

240. Health-Related Quality of Life and Low Back Pain of Patients Surgically Treated for Adolescent Idiopathic Scoliosis After 20 Years or More of Follow-Up

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Summary
Early-stage corrective fusion provided acceptable QOL status, but AIS patients had severe low back pain and poor self-image status than the healthy controls at middle age. Sagittal spinopelvic malalignment resulted in worse long-term outcomes after surgery.

Hypothesis
Adolescent idiopathic scoliosis (AIS) who underwent corrective fusion have lower quality of life (QOL) status compared to the normal subjects.

Design
Long-term follow-up study.

Introduction
Clinical outcomes in surgically treated patients with AIS who have reached middle age remain unknown.

Methods
Thirty-one AIS patients [mean age at op. 14.4 years (11–20 years); mean follow-up 29.3 years (20–46 years)] who had undergone corrective fusion (anterior fusion: 9 patients, posterior fusion: 21, anterior/posterior combined fusion: 1) between 1973 and 1994 were included. QOL status was assessed using visual analog scale (VAS) of low back pain, Oswestry Disability Index (ODI) and Scoliosis Research Society Instrument 22 (SRS-22). Ninety-three healthy age- and sex-matched volunteers without a history of scoliosis were selected as a control group.

Results
There were significant differences in low back pain VAS and the self-image domain of SRS-22 between the 2 groups (both comparisons, p<0.05), but the 2 groups were similar with the pain, function and mental health domains. (see, Table) With regard to correlations between QOL assessments and radiographic parameters at the final follow-up, coronal parameters had no correlations with the QOL assessments. On the other hand, SVA had a significant correlation with the function domain (p<0.05). PT had significant correlations with the ODI, the pain, self-image, function and satisfaction domains (all comparisons, p<0.05). PI-LL mismatch had significant correlations with the pain and function domains (both comparisons, p<0.05).

Conclusion
AIS patients maintain acceptable QOL status 20 years and over after surgery, but complain remarkable low back pain and lower self-image than the controls. Moreover, sagittal spinopelvic malalignment impact on QOL status including satisfaction than scoliotic deformity.

Table: Summary of the investigating parameters

	AIS (n=31)	Control (n=93)	p value
Radiographic parameter at the final follow-up			
C7 plumb line translation, mean (SD), [mm]	-9.8 (20.8)	—	—
UT curve Cobb angle, mean (SD), [°]	31.5 (14.5)	—	—
correction rate, mean (SD), [%]	-7.7 (39.6)		
MT curve Cobb angle, mean (SD), [°]	50.5 (15.9)	—	—
correction rate, mean (SD), [%]	29.2 (20.4)		
TL/L curve Cobb angle, mean (SD), [°]	30.5 (13.9)	—	—
correction rate, mean (SD), [%]	35.4 (28.9)		
Sagittal vertical axis (SVA), mean (SD), [mm]	16.9 (55.2)	—	—
Thoracic kyphosis (TK), mean (SD), [°]	30.9 (13.8)	—	—
Thoracolumbar kyphosis (TLK), mean (SD), [°]	11.7 (12.2)	—	—
Lumbar lordosis (LL), mean (SD), [°]	-39.8 (17.4)	—	—
Pelvic incidence (PI), mean (SD), [°]	51.6 (14.5)	—	—
Pelvic tilt (PT), mean (SD), [°]	20.9 (12.1)	—	—
Sacral slope (SS), mean (SD), [°]	30.9 (10.4)	—	—
QOL assessment			
Low back pain VAS (from 0 to 100), mean (SD)	35.6 (32.8)	18.2 (23.6)	0.0076
ODI, mean (SD), [%]	13.6 (14.8)	8.1 (8.3)	0.0763
SRS-22 Pain domain, mean (SD), [point]	4.0 (0.8)	4.1 (0.7)	0.5581
Self-image domain, mean (SD), [point]	2.9 (0.9)	3.5 (0.6)	0.0002
Function domain, mean (SD), [point]	4.2 (0.8)	4.5 (0.5)	0.0728
Mental health domain, mean (SD), [point]	3.7 (1.0)	3.6 (0.8)	0.2285
Satisfaction domain, mean (SD), [point]	3.4 (0.9)	—	—

Abbreviations: SD, standard deviation; UT, upper thoracic; MT, main thoracic; TL/L, thoracolumbar/lumbar

241. Impact of Expansion Thoracostomy on Patients with Scoliosis and Fused Ribs Treated with Rib-Based Growing Constructs

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Summary
151 patients with early onset scoliosis and rib fusions were treated with rib-based constructs. Patients treated with thoracostomy (103 patients) achieved greater increase in T1-S1 height than the patients who did not undergo thoracostomy (48 patients).

Hypothesis
Patients with congenitally fused ribs who underwent thoracostomy upon implantation of rib expansion devices would achieve improved spinal height over the treatment course compared to those who did not undergo thoracostomy.

Design
Retrospective review of prospectively collected registry data.

Introduction
Patients with fused ribs may develop thoracic insufficiency syndrome. Treatment for severe early-onset spinal deformity with rib fusions often includes the placement of rib expansion devices with surgical division of the fused ribs (thoracostomy). The effect of thoracostomy on spinal growth has not been fully examined.

Methods
Two multicenter registries of primarily prospectively collected data were searched for patients with fused ribs and implantation of a rib-based device. 151 patients with rib fusions treated with rib-based constructs (primarily prosthetic rib/rib based constructs) and minimum 2-year follow-up were included. 103 patients were treated with expansion thoracostomy at the time of implantation, while 48 patients received device implantation alone. There was no difference in severity of the preoperative deformity between patients who received expansion thoracostomy and those who did not (Table).

Results
At latest follow-up, the expansion thoracostomy group had a greater total improvement in T1-S1 height (7.2 cm vs. 4.8 cm, p = 0.004). There was no difference between the two groups in change in spinal height at each lengthening procedure. Thoracostomy patients underwent more total surgeries (11.5 vs. 9.6, p = 0.031) and more lengthenings (8.3 vs. 6.6, p = 0.017) of their constructs than the comparison group despite similar length of follow-up.

Conclusion
Patients who underwent expansion thoracostomy achieved greater improvement T1-S1 height than those who underwent implantation of rib expansion device alone. The expansion thoracostomy group was also treated with more lengthenings than the control group perhaps indicating fewer 'diminishing returns' with long-term successful lengthening in the thoracostomy group. Further work is needed to evaluate whether thoracostomy impacts pulmonary function.

Table

	Thoracostomy	No Thoracostomy	p-Value
Number of Patients	103	48	
Gender (F/M)	50/53	30/18	
Age at Implantation (Years)	4.54	5.08	0.33
Preop Mean Major Cobb Angle (Degrees)	66	64	0.54
Mean Preop Kyphosis (Degrees)	40	38	0.5
Mean Preop T1-T12 Ht. (cm)	13.5	14.4	0.19
Mean Preop T1-S1 Ht. (cm)	23.3	24.6	0.18
Mean Time to Follow Up (Years)	6.8	5.8	0.08
# of Lengthenings	**8.3**	**6.6**	**0.017**
Total # of Surgeries	**11.5**	**9.6**	**0.031**
# of Revision Surgeries	2.3	2	0.48
Total Change in T1-T12 Ht. (cm)	4	2.8	0.07
Total Change in T1-S1 Ht. (cm)	**7.2**	**4.8**	**0.0043**
Initial Implantation Change T1-T12 Ht. (cm)	1.13	0.89	0.55
Initial Implantation Change T1-S1 Ht. (cm)	2.01	1.24	0.2
All Lengthenings Change T1-T12 Ht. (cm)	3.7	3	0.32
All Lengthenings Change T1-S1 Ht. (cm)	**6.7**	**4.7**	**0.05**
Post-Treatment Cobb (degrees)	56	56	0.91
Post-Treatment Kyphosis (degrees)	51	48	0.44
Change in Cobb (degrees)	-10	-8	0.73
Change in Kyphosis (degrees)	10	9	0.84
Final Fusion Change T1-T12 Ht. (cm)	1.3	1.4	0.89
Final Fusion Change T1-S1 Ht. (cm)	2.2	1.6	0.57

242. Improvement of Function Outcome Using 6-minute walk in Patients with Congenital Scoliosis Treated by Growth Friendly Surgery; Five Years Follow-up Study

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Summary

6-minute walk increased at 5-year follow-up in children who underwent growth friendly surgery using rib-based constructs at a rate seen in normal children while lung function did not change as FVC % of predicted

Hypothesis

Growth friendly surgery improves functional outcome measured by 6-minute walk.

Design

A retrospective cohort study

Introduction

The 6-minute walk is a functional outcome metric used to assess patients with underlying cardiopulmonary and neuromuscular disease. It has not been widely used for children with early onset scoliosis (EOS) nor have changes in the 6-minute walk over time and during surgical treatment been described in this group. We report changes in 6-minute walk, body mass index (BMI), and lung function forced vital capacity (FVC) before and after serial surgical treatment for congenital scoliosis and compare the results to changes reported in normal children.

Methods

A retrospective cohort study examining associations between coronal major curve, FVC as % predicted based on arm span, Body Mass Index based on norms, 6-minute walk in absolute distance in children with EOS with congenital etiology who underwent growth friendly surgery using rib-based constructs.

Results

This study included 44 consecutive patients who were 5.8±1.8 years old, with major curve of 72±28°, a BMI of 53±30%tile of Japanese age-specific norms, an FVC=58±17%, and a 6-minute walk of 344±86m prior to surgery (Table). Each child underwent an average of 9.8±1.4 procedures during the study period. 14 of 44 (32%) underwent spine fusion or implant removal by the end of the study. After 5-year period, FVC was 54±16% predicted. Over the 5-year period of study, 6-minute walk increased by 86±97m (17.2m/year) compared to the normal increase per year of a distance of 16-25m. The change in FVC as a % predicted did not correlate with the change in 6-minute walk as a % of incremental change over 5 years (p=0.30).

Conclusion

Over 5 years of surgical treatment for congenital scoliosis, major coronal curve is reduced, BMI decreased, lung function did not change as FVC % of predicted, and 6-minute walk increased in absolute terms at a rate seen in normal children over time. This improvement in 6-minute walk distances despite persistent limitation in lung function suggests improved function in other domains, such as balance, may be more important.

	Pre-Op	Immediate Post-op	1-year Post-op	2-year Post-op	5-year Post-op
Major Curve (°)	72±28	53±23°	--	56±22	52±23
BMI (%tile)	53±30	--	51±29	43±31	34±27
FVC % Predicted (%)	58±17	--	57±15	57±15	54±16
6-minute Walk (m)	344±86	--	374±74	390±78	434±80

243. Incidence of Adolescent Idiopathic Scoliosis: A Modern U.S. Population-Based Study*

Joshua Jay Thomas, BS; A. Noelle Larson, MD; William J. Shaughnessy, MD; Todd Milbrandt, MD; Anthony A. Stans, MD

Summary

In this 20-year study, the population-based incidence of scoliosis declined once a county-wide school screening program was discontinued. Overall incidence of curves > 20 degrees was 85.5 per 100,000 during school screening and dropped to 57.3 per 100,000 after school screening was ended. Incidence of bracing and surgery at the time of initial diagnosis were stable. These are lower rates of scoliosis than historically reported.

Hypothesis

Discontinuation of a county-wide school screening program would result in decreased incidence of scoliosis in population-based cohort.

Design

Population-based cohort.

Introduction

Recent data shows that bracing prevents curve progression in adolescent idiopathic scoliosis. However, there is limited recent data describing the incidence of scoliosis in adolescents in a current U.S. population and the effect of school screening on scoliosis incidence. We sought to evaluate the population-based incidence of scoliosis in a modern cohort of U.S. patients over a 20-year period.

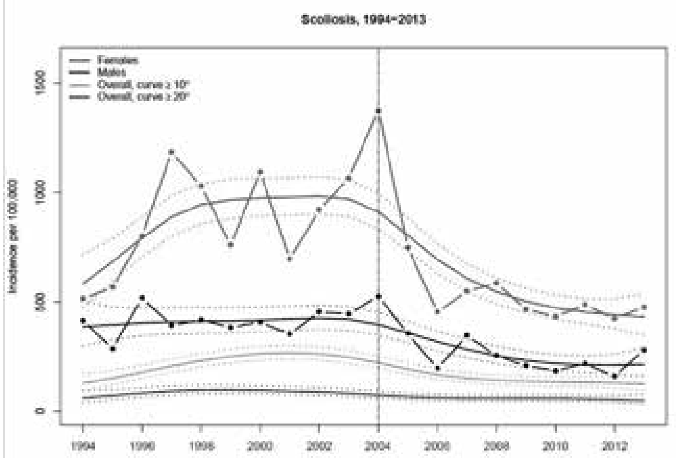
Methods

Population-based county cohort of 1782 children aged 10-18 years with AIS first diagnosed between January 1, 1994 and December 31, 2013. A formal school screening program run by the county health department was discontinued in 2004. Complete medical records were reviewed to confirm AIS diagnosis and to extract radiographic and treatment details. We also considered overall incidence as well as radiographic-proven scoliosis with a coronal Cobb angle measuring greater than 10° and 20°. Previous published work has confirmed that 99% of all county patients receive all medical care at centers in the database. Age- and sex -specific incidence rates were calculated and adjusted to the 2010 US population. Poisson regression analyses were performed to examine incidence trends by age, sex, and calendar per

Results

The overall age and sex-adjusted annual incidence of AIS diagnosis was 522.5 (95% CI, 498.2, 546.8) per 100,000 person-years (Figure). Incidence for curves > 20 degrees was 85.5 per 100,000 (71.5, 99.5.) between 1994- 2003, and dropped to 57.3 per 100,000 (46.1, 68.6) from 2004-2013 (p<0.001). The overall incidence of AIS defined by a radiograph with Cobb angle greater than 10° was 181.7 (95% CI, 167.5, 196.0) per 100,000 person years. The incidence of bracing and surgery at initial diagnosis was relatively stable at 16.6 and 2.0 per 100,000 person years, respectively.

Conclusion
The incidence of scoliosis over 20 degrees was between 1-2 per 1000 individuals. Incidence of a new scoliosis diagnosis decreased over the study period, which may have been affected by the discontinuation of school screening.



244. Incidence of VACTERL Associations in the United States Pediatric Population and Associated Frequency Among Congenital Spinal Diagnoses

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Summary
In the United States pediatric population, the most common VACTERL associations are ACR, CRL, and VCR. VACTERL associations are present in 2.43% of tethered cord patients, 0.93% of diastematomyelia, 0.53% spina bifida, 0.47% of Klippel Feil, 0.33% of scoliosis, and 0.06% of Chiari malformation patients.

Hypothesis
The incidence of VACTERL associations in the pediatric population in the United States is underestimated in the current literature.

Design
Retrospective analysis of the Kid Inpatient Database(KID) 2003-2012.

Introduction
VACTERL associations, though rare, can have debilitating consequences. Little work has been done to assess these associations on a national level to determine incidence of these occurrences and look at what other conditions these patients present with.

Methods
KID supplied hospital- and year-adjusted weights allowed for accurate assessment of incidence of VACTERL associations, as well as many body system congenital anomalies. VACTERL association was defined as the presence of at least three component defects. VACTERL associations include: vertebral anomalies(V), anorectal malformations(A), cardiovascular anomalies(C), tracheoesophageal fistula(T), esophageal atresia(E), renal anomalies(R), and limb defects(L).

Results
5552 discharges in KID have a VACTERL association with an incidence of 3 per 100,000 in the United States. 84.5% of patients have three component defects, 13.5% have 4 components, 1.9% have 5 components and 1.9% have 6 components making up their VACTERL diagnoses. The most common clusters of defects for a VACTERL association are ACR(36.1%), CRL(25.7%) and VCR(9.3%). The most common concurrent defects presenting with each VACTERL component are presented in Table 1. In looking at conditions of the spine and spinal cord, VACTERL associations are present in 2.43% of tethered cord patients, 0.93% of diastematomyelia, 0.53% spina bifida, 0.47% of Klippel Feil, 0.33% of scoliosis, and 0.06% of Chiari malformation patients. The most common VACTERL components for scoliosis patients are ACR(40%) and CRL(23.3%), the most common for Chiari patients are CRL(64.8%), and ACR for tethered cord syndrome(51.4%) and Klippel Feil(49.2%).

Conclusion
The most common VACTERL associations are ACR, CRL, and VCR in the United States pediatric population. VACTERL associations are present in 2.43% of tethered cord patients, 0.93% diastematomyelia, 0.53% spina bifida, 0.47% Klippel Feil, 0.33% scoliosis, and 0.06% Chiari.

Table 1. Most common concurrent defects associated with each VACTERL component defect.

VACTERL Component	Most Common Concurrent Defects
V	C (79.4%)
	R (63.8%)
A	C (84.1%)
	R (77.9%)
C	R (78.7%)
	A (53.9%)
T	C (85%)
	E (61.7%)
E	C (83.8%)
	R (61.7%)
R	C (87.4%)
	A (55.4%)
L	C (85.3%)
	R (74.2%)

245. Influence of the Postoperative Apex Location of Thoracolumbar Kyphosis on Clinical Outcomes of Osteotomy for Ankylosing Spondylitis Patients

Bangping Qian, MD; Zhuojie Liu, MD; Yong Qiu, MD; Sai-hu Mao, MD; Jun Jiang, MD; Bin Wang, MD

Summary
A study aimed to evaluate the influence of the postoperative apex location of thoracolumbar kyphosis on clinical outcomes of 1-level lumbar pedicle subtraction osteotomy (PSO) for anky-

losing spondylitis (AS) patients. Patients with postoperative apex located at T8 or above tended to have a better sagittal vertical axis (SVA) correction (within 47 mm). For ideal postoperative apex re-localization, a higher level of osteotomy is recommended.

Hypothesis
AS patients with different postoperative apex locations would have diverse clinical outcomes after 1-level lumbar PSO.

Design
Retrospective comparative study.

Introduction
Re-localization of apex after corrective surgery is often found in AS-associated thoracolumbar kyphosis. However, the influence of this postoperative re-alignment on sagittal balance and clinical outcomes has not been investigated.

Methods
Sixty-two patients with a minimum follow-up of 2 years were divided into 2 groups according to the postoperative apex location (Group 1, T8 or above; Group 2, T9 or below). Radiographical measurements and clinical outcomes were compared between the 2 groups preoperatively, postoperatively and at the last follow-up, including spino-pelvic parameterssuch as SVA, 3 postoperative apex-related parameters such as the horizontal distance between the C7-vertical line and the apex (DCA) and the scores of health-related quality of life (HRQOL) questionnaires.

Results
The SVA differed significantly both postoperatively (25.7 mm vs. 59.1 mm, P<0.001) and at the last follow-up (32.9 mm vs. 61.3 mm, P=0.003) between the 2 groups, and a smaller DCA was found in Group 1 (69.1 mm vs. 103.1 mm, P<0.001). Subgroup analysis demonstrated that patients in Group 1 had an average SVA<47mm. Notably, a significant correlation was found between postoperative SVA and DCA (r=0.642, P<0.001).Patients underwent osteotomy at L3 had limited apex re-localization but better SVA correction than those at L1 or L2. However, no significant difference was found in HRQOL between the 2 groups.

Conclusion
AS patients with apex located at T8 or above after surgery tended to have better SVA correction (within 47 mm) than those who had a more caudally located apical vertebra. For ideal postoperative apex re-localization, a higher (closer to or at the preoperative apex) level of osteotomy is recommended.

246. Influence of Treatment on the Relationship Between Body Image Disturbances and Depression Among Non-Operative Adolescent Idiopathic Scoliosis Patients

Duygu Kuzu, MA; Tunay Sanli, MA; Meric Enercan, MD; Haluk R. Berk, MD; Azmi Hamzaoglu, MD

Summary
The aim of the study is comparing treatment groups either having brace or exercise treatment or not in relation to depression and body Image dissatisfaction. According to the results, patients who have treatment have less depressive symptoms and have more satisfaction with their body image. Findings shows treatment effect may contribute both psychological and physiologic well being.

Hypothesis
Patients who has treatment either brace or exercise have less depression and body dissatisfaction

Design
Prospective study and convenience sampling method

Introduction
Appearance related concerns in individuals with adolescent idiopathic scoliosis can result in impairment in daily functioning, psychological problems, or body image disturbances. The impact of treatment effect over body image dissatisfaction and depression was not investigated. The aim of the study was to investigate whether there is a relationship between these two factors and others that might affect this relationship.

Methods
76 (60F/16M) non- operative adolescent idiopathic scoliosis patients with mean age 15 years (12-20) were included into the study. Mean major Cobb angle was 26 (15-70). Beck depression inventory, body mass index scores, body image disturbances scale and SRS-22(Self-image subscale) were used. Pearson correlation statistics and t- test were assessed with SPSS.

Results
Results showed that scoliosis patients were dissatisfied only by disease specific parts of the body, yet this was not significant (r=.21, p>0.05). Patients who were dissatisfied with their bodies tended to have more depressive symptoms (r=.54, p<.001). Patients who had either brace treatment or exercise according to scoliosis showed less depression and body dissatisfaction scores (p<.001). Moreover, SRS-Self-image subscale and body image disturbances are highly correlated(r=.51,p<.001). In this study scoliosis patients weighed significantly less and had significantly lower BMI scores (M=19), however did not have any related physiologic disturbances. There were no differences between either F/M for all measures.

Conclusion
In this study it was possible to identify the number of factors which influenced body image satisfaction and psychological well-being. A novel finding of this study was that patients who received either brace or exercise treatment had better outcomes with respect to depressive symptoms and body image dissatisfaction, compared to those without any treatment.

247. Is Adolescent Idiopathic Scoliosis a Comorbid Factor for the Development of Chronic Pain Syndrome?

Catherine Ferland, PhD; Don Daniel Ocay, BS; Andrew Tice, MD; Abdulaziz Bin Shebreen, MBBS; Jean Ouellet, MD, FRCS(C)

Summary
Seventy-nine patients with AIS complaining of chronic pain underwent a pain assessment highlighting individual differenc-

es. Sagittal abnormalities (LL/PI mismatch, sagittal imbalance, cervical kyphosis) were present in more than 50% of the cohort. Functional disability was reported by 49% of the patients, poor sleep quality by 73%, and 16.5% had presence of neuropathic pain. A suboptimal endogenous inhibitory pain control was observed in 46%, and 11% of patients demonstrated temporal pain summation, suggesting that pain management should be individualized.

Hypothesis
Not all patients with Adolescent Idiopathic Scoliosis perceive pain similarly.

Design
Cohort-based cross-sectional study.

Introduction
Characterization of chronic back pain of patients with Adolescent Idiopathic Scoliosis (AIS) is scarce. Quantitative sensory testing (QST) provides hints of the facilitatory and inhibitory pain responses of patients, both at the peripheral and central levels. The purpose of this study was to better characterize patient with AIS and chronic pain by evaluating various domains of pain, relating it back to quality of life of these patients.

Methods
Patients aged between 10 and 21 years diagnosed with AIS with a history of back pain for more than three months were recruited. Patients completed self-report questionnaires (pain intensity, type and location, anxiety and depressive symptoms, functional disability, and sleep quality) and underwent QST (mechanical and thermal pain thresholds, temporal summation and conditioned pain modulation). Patients also had standard imaging and quantification of their spinal deformity. Inferential analysis was conducted.

Results
Seventy-nine patients were recruited. Overall, the pain was experienced as constant and daily, of moderate intensity and located mainly at the thoracic level. X-ray measurements revealed that 54.4% had cervical kyphosis, 53.2% had a mismatch between their lumbar lordosis and their pelvic incidence, and 43.0% had sagittal imbalance greater than +/- 2 cm. Self-report questionnaires revealed that 49.4% of the cohort had mild-to-severe functional disability, 73.4% had poor sleep quality, and 16.5% of the patients had a neuropathic pain component. QST identified 5.1% were hypersensitive to touch, 45.6% were hypersensitive to pressure pain, 45.6% had a suboptimal or inefficient endogenous inhibitory pain control, and that 11.4% demonstrated presence of temporal summation of pain, all factors predisposing to chronic pain syndrome.

Conclusion
Patients with AIS are not experiencing pain similarly, suggesting that patients' pain should not be treated all in the same way. Heightened pain assessment and proper individualized pain management need to be developed.

248. Is Posterior Fixation Alone Without Anterior Fusion an Effective Treatment of Andersson Lesion in Ankylosing Spondylitis?

Samir Dalvie, MD, MS; Siddharth Shah, MS, DNB, FCPS; Ravi Ranjan Rai, MS; Nigil Sadanandan, MS, DNB

Summary
Surgical management of Andersson Lesion (AL) in Ankylosing Spondylitis (AS) is controversial as to the selection of approach. We retrospectively reviewed eleven patients operated with posterior-fixation alone using pedicular screw fixation without osteotomy, bone grafting or anterior fusion procedure, and evaluated the outcomes of treatment. All patients exhibited osseous fusion and improvement in VAS and neurology at final follow-up.

Hypothesis
Posterior fixation alone without anterior fusion is effective treatment of Andersson Lesion

Design
Retrospective study of prospectively collected data

Introduction
Andersson lesion (AL) is characterized by anterior as well as posterior defect and instability. Circumferential fusion is considered the definitive treatment for the tricolumnar spinal pseudoarthrosis secondary to AL. This study was aimed at evaluating whether posterior fixation alone is effective as the definitive treatment of AL, hence avoiding the additional morbidity of additional procedures such as anterior fusion or osteotomy.

Methods
Eleven patients (11/11 males, mean age 52.1 years) diagnosed with AL, underwent posterior pedicle screw fixation alone without bone grafting or anterior procedure. Outcome variables included radiographic assessment, visual analogue scale(VAS) for backpain and neurological assessment over mean follow-up 30.2 months.

Results
All patients presented with backpain associated with radiculopathy (18.2%), neurological deficit (27.3%). Nine (81.8%) AL were noted in the thoracolumbar region (D8-L2), one each in lumbar (L3-4) and cervical (C6) regions. Anatomically, lesions were transdiscal (81.8%), transvertebral (36.4%) and mixed (18.2%) with posterior elements involved in all patients. Posterior pedicle screw fixation with mean 6.1 instrumented vertebral levels and mean 10.5 screws, were instrumented in each patient. Average operative time was 169.1mins; blood loss 359.1ml. Postoperatively, VAS improved significantly (p=0.0001) in all patients and neurological recovery noted in all three patients. Osseous union was seen in all patients; as bony fusion mass transvertebral AL and bridging bone formation in transdiscal AL, with no significant change in kyphosis (11.7o vs. 9.5o; p>0.05). No surgical complications were reported.

Conclusion
Spinal stabilization using posterior pedicle screw fixation alone is effective in the treatment of AL; thereby avoiding the additional complexity and morbidity associated with anterior procedures. Mechanical stability provided by posterior implantation is sufficient to facilitate circumferential healing and fusion of the AL

249. Is Postoperative Admission Necessary Following Lengthening of Spinal Growing Implants?

Kenneth Shaw, DO; Nicholas Fletcher, MD; Dennis Devito, MD; Joshua Murphy, MD

Summary
A retrospective review of the NSQIP-P database was performed, comparing complication rates within 30 days of surgery for patients undergoing surgical lengthening of spinal implants with growing instrumentation according to postoperative admission status. 796 cases were identified, with 73% of cases being performed on an inpatient basis. Overall rate of any complication was 3.5% and did not differ based on admission status.

Hypothesis
Postoperative admission status will not influence 30 day complication rate for patients undergoing surgical lengthening of spinal implants with growing instrumentation.

Design
Retrospective Case Control Analysis of Prospective National Database

Introduction
Early onset scoliosis is commonly treated with growing spinal implants to facilitate continued growth of the spine and thorax. Recent changes in insurance coverage have mandated that some patients be admitted following a lengthening procedure, while others allow for outpatient surgery. The aim of this study is to evaluate the effect of postoperative admission status on 30 day perioperative complications.

Methods
Surgical lengthenings of spinal implants in patients with growing instrumentation were identified from the 2014-15 NSQIP Pediatrics database by CPT code. 30-day postoperative complications were classified according to the Clavien-Dindo system, subdivided according to post-surgical admission status. Admission status, ASA classification, tracheostomy, neuromuscular diagnosis, ventilator dependence, and nutritional support were considered as possible risk factors in univariate and multivariate logistic regression analyses.

Results
Of 796 cases identified, 73% were performed on an inpatient basis. Patients with tracheostomy or ventilator dependence were more likely to undergo post-operative admission. Overall rate of any complication was 3.5% and did not differ by admission status (2.8% inpatient vs 3.8% outpatient). On univariate analysis, ventilatory dependence, need for nutritional support, and ASA classification >2 placed patients at significantly higher risks for any postoperative complications. Multivariate analysis identified ventilator dependence as an independent risk factor for any postoperative complications.

Conclusion
Postoperative admission status did not affect the rate of 30 day perioperative complications following lengthening of a spinal growth implant. Outpatient lengthening appears to be safe for most patients however consideration for postoperative admission should be given for those who are ventilator dependent.

250. Lumbar Lordosis Does Not Correlate with Pelvic Incidence in the Cases with Lordosis Apex above L3

Osamu Tono, MD; Kazuhiro Hasegawa, MD; Masashi Okamoto, MS; Shun Hatsushikano, BS; Haruka Shimoda, MD; Kei Watanabe, MD, PhD; Katsumi Harimaya, MD, PhD

Summary
Sagittal spinopelvic alignments were different according to the location of apex of lumbar lordosis (LL). Lumbar lordosis does not correlate with pelvic incidence (PI) in the cases with lordosis apex above L3.

Hypothesis
LL always correlates with PI even in cases with different lumbar sagittal profiles.

Design
Cross-sectional cohort study.

Introduction
Lumbar lordosis positively correlates with pelvic incidence. The shape of the lordosis, however, varies, even with the same LL values, and the relation between the variation and the sagittal alignment is not clear. The purpose of this study is to test the hypothesis.

Methods
Standing whole spine alignment was measured with a biplanar imaging system with 3D capabilities in consecutively enrolled 100 healthy adults (46 men, 54 women, mean age 40.9 years), and the gravity line of each subject was defined using a simultaneous force plate measurement. The apex of lumbar lordosis was defined as the most anterior lumbar vertebra or intervertebral disc from the gravity line. Subjects were stratified into three groups according to the location of the apex (UppA: an apex of lumbar lordosis located between L1-L3, MedA: an apex of lumbar lordosis located from L3/4 to L4/5, LowA: an apex of lumbar lordosis located at L5 or below.). PI, PT, SS, TK, LL, SVA, TPA, and knee flexion angle (KF) were compared between groups. The correlation between LL and PI was also compared among the groups.

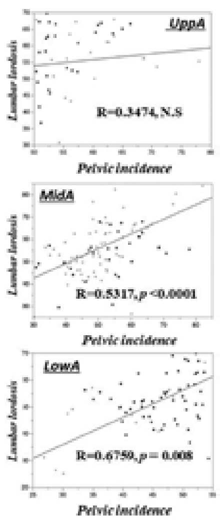
Results
LL significantly correlates with PI in the pooled data ($LL=24.6+0.587*PI$, $R=0.535$, $p<0.0001$). Then the alignments were compared among three groups (UppA: n=19, MidA: n=67, and LowA: n=14). PI and SS differed significantly among the three groups, and LL was significantly different between LowA and MidA / UppA. SVA and TPA were partly different among the groups, but TK and KF did not differ among groups. LL and PI were significantly positively correlated in the MidA and LowA groups, but not in the UppA group (Table 1).

Conclusion
Sagittal spinopelvic alignments were different according to the location of apex of LL. Contrary to the hypothesis, the correlation coefficient between PI and LL was not significant in the cases with apex above L3, suggesting that the relationship between PI and LL is not always constant, and whole sagittal alignment should be taken into account in surgical planning.

Sagittal alignment parameters (mean ± SD) and p-value of each comparison

	UppA (n=19)	MidA (n=67)	LowA (n=14)
	UppA-MidA	MidA-LowA	UppA-LowA
PI	60.5±7.16	50.3±9.12	38.6±8.4
	<0.0001	0.0003	<0.0001
PT	15.5±6.94	9.7±6.50	8.24±6.6
	0.0019	NS	0.0192
SS	45.0±8.62	40.6±7.35	30.3±8.6
	0.0181	0.0004	<0.0001
TK	40.7±11.13	42.7±10.94	43.1±7.2
	NS	NS	NS
LL	55.8±9.35	55.9±11.25	44.5±12.6
	NS	0.0162	0.0225
SVA	1.4±2.9	-0.2±2.2	3.6±4.3
	NS	NS	0.0182
TPA	12.3±7.81	5.6±6.42	-1.3±2.0
	0.0020	NS	0.0014
KFA	-0.04±3.3	-1.04±4.92	-0.89±3.6
	NS	NS	NS

UppA: an apex of LL located between L1-L3, MedA: the apex located from L3/4 to L4/5, LowA: the apex located at L5 or below
KFA: knee flexion angle



251. Magnetic Growing Rods in the Treatment of Nonambulatory Neuromuscular Scoliosis: How Do They Compare to Traditional Growing Systems?

Amer F. Samdani, MD; Joshua M. Pahys, MD; John Smith, MD; Solomon Samuel, PhD; Michael Vitale, MD; Ron El-Hawary, MD, MS; John M. Flynn, MD; Jeffrey Sawyer, MD; Randal R. Betz, MD; Steven Hwang, MD

Summary
Sparse literature exists on the efficacy of magnetic growing rods (McGR) for the treatment of patients with neuromuscular scoliosis (NMS). Our results suggest that in comparison to traditional growing systems (TrGS), McGR provide similar immediate radiographic results with improved maintenance of correction. Although the follow-up for TrGS is significantly longer than for McGR, to date the latter has shown lower infection rates and resulted in fewer unplanned returns to the operating room.

Hypothesis
McGR will provide equivalent radiographic outcomes but fewer unplanned returns to the operating room than TrGS in patients with NMS.

Design
Retrospective review of a prospective data set.

Introduction
McGR have become the primary surgical treatment modality for patients with early onset scoliosis. Sparse literature exists on their efficacy in patients with NMS. In this report, we compare the outcomes of patients with NMS treated with either McGR or TrGS.

Methods
A prospectively collected multicenter database was retrospectively reviewed to identify consecutive patients with nonambulatory NMS who had placement of either bilateral McGR or bilateral TrGS (VEPTR and growing rods). 37 patients were treated with McGR and 155 with TrGS. We compared these groups with respect to clinical and radiographic outcomes using the Mann-Whitney test.

Results
The two groups were similar with respect to age at implantation (McGR: 7.1 ± 2.2 years, TrGS: 7.0 ± 2.6, p=0.8) and preoperative major Cobb angle (McGR=73.2º ± 24.1, TrGS=69.4º ± 24.4, p=0.3) with maximal preoperative kyphosis higher in the McGR group (McGR=66.8º ± 31, TrGS=53.3º ± 31, p=0.03). Length of follow-up was longer for the TrGS group (58.2 ± 30.1 vs. 15.9 ± 8.3 months). Immediate post-op, major Cobb (McGR=37.7º ± 16.6, TrGS=42.2º ± 19.4, p=0.24), and kyphosis (McGR=42.56º ± 23.5, TrGS=35.5º ± 20.7, p=0.3) were similar between the groups. However, McGR had better maintenance of correction at most recent follow-up (McGR=31.4º ± 10.2, TrGS=59.1º ± 20.9, p=0.003). To date, the infection rate is lower for McGR (10.8%) compared to TrGS (25.2%), and unplanned surgical intervention has occurred in 29.4% (10/34) in the McGR group and 51.6% (80/155) of TrGS patients.

Conclusion
McGR provides similar immediate radiographic results to those patients treated with TrGS. Preliminary results suggest improved maintenance of correction with McGR, lower infection rates, and fewer unplanned surgical procedures in this demanding population. However, longer follow-up is required to confirm the sustainability of these early observations.

252. Minimum Clinically Important Difference in Oswestry Disability Index Domains and Their Impact on Adult Spinal Deformity Surgery

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Summary
Minimum clinically important difference (MCID) for total and individual domains of Oswestry Disability Index (ODI), the score distribution and change over time after adult spinal deformity surgery were calculated. MCID of the total ODI was 11%. In the pain and standing domain, >60% of patients obtained MCID, although the acquisition rates of personal care, lifting, sleep, and sex domains were relatively low.

Hypothesis
Despite the common use of Oswestry Disability Index (ODI) in assessing adult spinal deformity (ASD), there is no robust study defining minimum clinically important difference (MCID) values for ODI, which domain of ODI has better or worse outcome in ASD surgery, and whether good correction encourages good clinical results.

Design
A retrospective study

Introduction
The aim of present study is to calculate MCID for total and individual domains of the ODI and assess score distribution and changeover time, with a minimum of 2 years follow-up, in surgically treated ASD patients.

E-Poster Abstracts

Methods

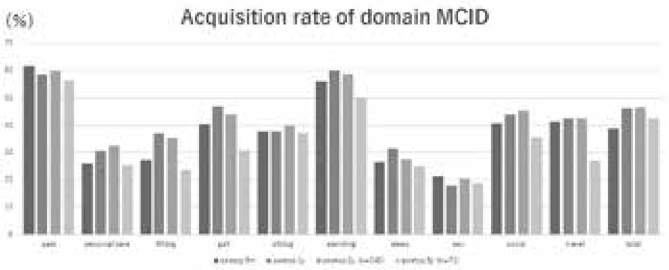
This study included 240 consecutive ASD patients with >2-year follow-up. We calculated MCID values of total and individual ODI domains using total or part of the Scoliosis Research Society-22R (SRS-22R) as anchors. Using current MCID values, we measured the acquisition rates in patients who obtained MCID at follow-up both in total and individual domain ODI. Different pathology, age, lower instrumented vertebrae, and upper instrumented vertebrae location were analyzed.

Results

MCID of the total ODI score was 11% with area under the curve of 0.737, and each domain ranged 0–2 and was mostly 1 in ASD surgery. In the pain and standing domain, >60% of patients obtained MCID, although the acquisition rates of personal care, lifting, sleep, and sex activity domains were relatively low (20%–35%). Patients with MCID had more radiographic improvement in lumbar lordosis, sagittal vertical axis, and T1 pelvic angle than those without ($p < 0.05$).

Conclusion

To our knowledge, this is the first study to describe MCID of ODI (11%) after ASD surgery. In the pain and standing domain, most patients obtained MCID, although the acquisition rates of MCID in personal care, lifting, sleep, and sex activity domains were low. Therefore, spinal surgeons must counsel patients regarding improvements and setbacks of ASD surgery.



253. Natural Course of Sagittal Modifiers: PI Minus LL, SVA and Pelvic Tilt -Data from 626 Asymptomatic Volunteers

Yasutsugu Yukawa, MD; Hiroshi Yamada, MD; Hiroshi Hashizume, MD; Akihito Minamide, MD, PhD; Hiroshi Iwasaki, MD, PhD; Shunji Tsutsui, MD; Masanari Takami, MD, PhD; Fumihiko Kato, MD

Summary

Full length, free-standing spine radiographs were obtained in 626 asymptomatic volunteers, including 50 subjects in each gender and each decade from 20 to 70. Sagittal modifiers of pelvic incidence minus lumbar lordosis (PI-LL), sagittal vertical axis (SVA) and pelvic tilt (PT) were measured. PT>20 or PI-LL>10 was often seen in healthy subjects and increased with aging. However SVA > 40mm is very rare even in elderly.

Hypothesis

NA

Design

Prospective imaging study in large number of cohort.

Introduction

Spinopelvic sagittal alignment has had more importance in the reconstructive surgery of the spine. However normal alignment values and those aging changes (natural course) are still not clear. We performed prospective radiographic analysis to elucidate standard values of sagittal modifier; PI-LL (pelvic incidence minus lumbar lordosis), PT (pelvic tilt) and SVA (sagittal vertical axis).

Methods

A total 626 asymptomatic volunteers were enrolled in this study, including 50 subjects in each gender and each decade from 20 to 70. Full length, free-standing spine radiographs were obtained in all subjects. Lumbar lordosis (T12-S1, LL), pelvic tilt (PT), pelvic incidence (PI) and sagittal vertical axis (SVA) were measured using measurement software. The threshold of spinopelvic parameters with disability were considered to be PT 20° or more, SVA 40 mm or more and PI-LL 10° or more.

Results

The average values (degrees) were 49.7 ± 11.2 of LL, 14.5 ± 8.4 of PT, 53.7 ± 10.9 of PI and 4.0 ± 11.4 of PI-LL. The mean value of SVA was 3.1 ± 12.6 mm. In this study group, advancing age led to an increase of the rate of subjects with PI-LL>10 or PT>20. However there were only two individuals (1 male and 1 female) with SVA > 40mm. About half subjects of 8th decade (age 70-79) showed > 10 degrees in PI-LL.

Conclusion

PT>20 or PI-LL>10 was often seen in healthy subjects and increased with aging. However SVA > 40mm is very rare even in elderly.

254. Natural History of the Aging Spine. Natural History of the Aging Spine: Development of an Atlas of Sagittal Parameters in the Asymptomatic Population over the Adult Lifetime

Mark Attiah, MD, MS; Bilwaj Gaonkar, PhD; Diane Villaroman, BS; Christine Ahn, BS; Rogelio Medina, BA; Tianyi Niu, MD; Joel Beckett, MD; *Luke Macyszyn, MD, MS*

Summary

There have been several studies of sagittal balance in the standing position of volunteer subjects. However, there are no established normative values for sagittal alignment parameters that encompass the entire spine or that span all decades of life. This study aimed to quantify cervical, thoracic and lumbar sagittal parameters in asymptomatic individuals to provide insight into how normal spine alignment changes with age. Parameters that might serve as important targets when performing deformity correction surgery were identified.

Hypothesis

Cervical lordosis and thoracic kyphosis will increase linearly with age, while lumbar lordosis is reduced.

Design

Retrospective Cross-Sectional Population Study

Introduction

There have been numerous studies demonstrating increased pain and disability when patients fall outside of certain accepted parameters. However, these parameters were established based on patients suffering from spinal deformities. It remains unknown how these parameters change over a lifetime in asymptomatic individuals.

Methods

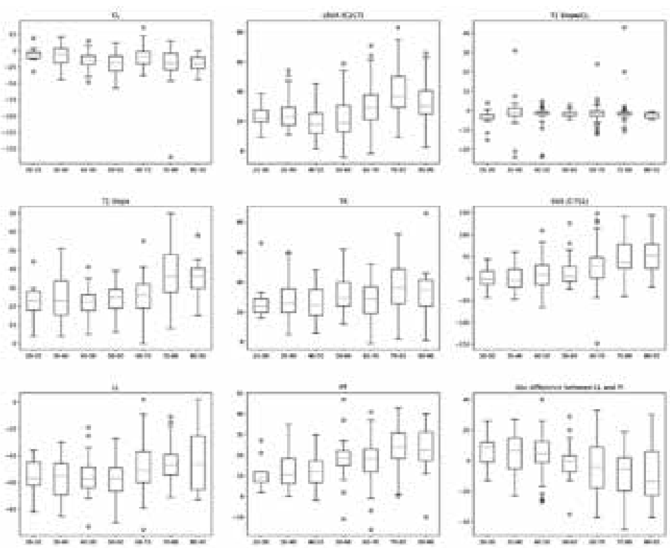
Sagittal scoliosis radiographs of 211 asymptomatic patients were evaluated. The following parameters and relationships were measured or calculated: Cervical lordosis (CL), thoracic kyphosis (TK), lumbar lordosis (LL), pelvic index (PI), sagittal vertical axis (SVA), cervical sagittal vertical axis (cSVA), and T1 slope, TK/LL, truncal inclination (TI), pelvic tilt (PT), LL-PI, LL/PI, and T1 slope/PI. Patients were subdivided by decade of life and regression analysis was performed to delineate the relationship between each consecutive age group and the aforementioned parameters.

Results

Cervical lordosis (r = 0.60), thoracic kyphosis (r = 0.83), and, SVA (r = 0.88), cSVA (r = 0.51), and T1 slope (r = 0.77) all increase with age. Truncal inclination (r = 0.36) and T1 slope/CL remain stable over all decades (r = 0.01). LL starts greater than PI, but in the 6th decade of life, LL becomes equal to PI and in the 7th decade becomes smaller than PI (r = 0.96). The ratio of TK/LL is stable until the 7th decade of life (r = 0.80), while PT is stable until the 6th decade (r = 0.91).

Conclusion

This study further refines the generally accepted LL = PI ±10 by showing that patients under the age of 50 should have more LL compared to PI, while after the 5th decade the relationship is reversed. SVA was not as sensitive across age groups, exhibiting a marked increase only in the 7th decade of life. Given the reliable increase of CL with age, and the stability of T1 slope/CL, this represents another important relationship that should be maintained when performing cervical deformity/fusion surgery.



255. One Bracing Prescription Does Not Fit all AIS Patients: One Bracing Prescription Does Not Fit all AIS Patients: Less Mature Patients with Larger Cobb Angles Require More Hours in Brace.

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Summary

A model including the hours a brace is worn, baseline modified RisserPlus grade, the Cobb angle, and age is highly predictive of curve progression to surgical indications during skeletal growth. Importantly, this is the first validated model predicting the benefit of different doses of bracing relative to no treatment. This study provides clinicians with prognostic evidence to share with families to jointly develop and evaluate individualized, risk-based treatment options.

Hypothesis

Less mature patients with larger Cobb angles require more hours of bracing to prevent progression to surgical indications.

Design

Prognostic model development and validation

Introduction

Few externally-validated prognostic models exist to guide non-operative AIS treatment. Most are too complicated for clinical use or do not include variables related to the "dose" of brace wear. Our purpose was to develop and validate a prognostic model estimating the risk of progression to surgical indications in untreated and brace-treated AIS.

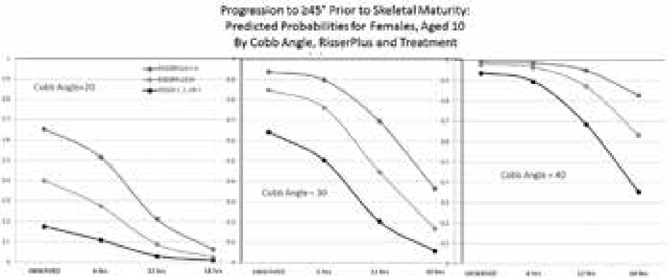
Methods

248 girls (braced n= 153, observed n= 95) were followed to either skeletal maturity (Risser grade 4), or to a Cobb angle of 45°+ or spinal fusion ("failure"). Candidate variables included the modified RisserPlus (Risser 0- (open triradiate), Risser 0+ (closed triradiate), or Risser 1-3), age, SRS curve classification, Cobb angle, in-brace curve correction and average hours of brace wear (none to 24 hours/day). Model calibration (Brier score) and discrimination (c-statistic) were evaluated. The model was then validated in an independent dataset (n=176).

Results

The final model included modified RisserPlus, age, Cobb angle, and hours of wear (c-statistic = 0.87, Brier score = 0.14). There was minimal loss of discrimination or calibration in the independent dataset (c-statistic = 0.80, Brier score = 0.18). To illustrate, the graph demonstrates the probability of failure related to RisserPlus and hours of wear in 10-year old girls with Cobb angles of 20°, 30° and 40°. For example, an untreated 10 year old at Risser 0- with a 30° curve has a 94% probability of reaching 45° prior to maturity; the probability decreases to 90, 70 and 37% with 6, 12, and 18 hours of brace wear, respectively.

Conclusion
This model validates expectations and previous research that less mature patients with larger Cobb angles require more hours of bracing to decrease the risk of progression to surgical indications.



256. Optimising Navigation Guided Spine Surgery through a Lean Principles Approach

Derek Cawley, FRCS; Joseph S. Butler, PhD FRCS ; Vijay Mahalingam Rajamani, MS; Susanne Selvadurai, BSc(Hons); Dimpu Bhagawati, MBBS, FRCS; Alexander Gibson, FRCS; Sean Molloy, MBBS, FRCS, MSc (eng)

Summary
While ensuring optimal instrumentation accuracy and patient safety, the ION was evaluated during its implementation for AIS surgery to enhance the workflow of this technique.

Hypothesis
Through the application of lean principles, the introduction of routine intra-operative 3D image-guided navigation (ION) to adolescent idiopathic scoliosis surgery could improve workflow and identify waste in productivity

Design
Case Series

Introduction
ION spine surgery has become useful for selected procedures including minimal access spine surgery, spinal deformity, difficult spinal anatomy, obesity, ankylosing conditions and revision surgery. Its use in the paediatric population and trauma have been met with caution given the flexibility or instability of the spine which may lead to inaccuracies when inserting instrumentation.

Methods
The first 20 AIS patients undergoing ION spinal deformity surgery were repeatedly audited to identify areas for improvement. The primary outcome was that ION was deployed in a safe and accurate manner for the purposes of inserting instrumentation in AIS surgery. The secondary outcome was the safe assimilation of ION into the theatre environment for this type of surgery. Potential waste was also highlighted. The resultant optimal technique, involving surgical, anesthetic, radiographic and ancillary teams was then identified.

Results
A total of 321 screws were inserted IN 20 AIS patients. Mean blood loss was 240mls (SD 142) and mean operative time was 208mins (SD 61), with consistent decreases across successive tertiles. The mean Cobb improved from 63° pre-operatively (SD 14.8°) to 27° post-operatively (SD 10.0°). 7 productivity waste areas were also identified. Surgical details with most impact were fastidious attention to the reference frame, instrumenting initially farthest from the reference frame and avoiding relative spinal motion. Work flow is best optimised by performing all scans in one acquisition, having placed the reference frame only at the cephalad aspect and without requiring a post-instrumentation scan.

Conclusion
The introduction of a technique such as ION for spinal surgery in AIS is augmented and optimised through the use of lean principles, making this valuable technical adjunct a welcome facility in the theatre environment.

257. Ossification of the Posterior Longitudinal Ligament in Cervical Spine Cases: High Complication Rates May Have Led to Decreased Use of Anterior Approach in the US from 2005-2013

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Summary
Cervical ossification of the posterior longitudinal ligament(C-OPLL) has yet to be studied on a national level. In a nationwide analysis of hospital discharges across the U.S., 4601 C-OPLL discharges were identified, with increasing prevalence over the last decade. Morbidity rates have increased for C-OPLL discharges. Anterior approach surgeries were associated with higher complication rates. From 2005-2013, surgical rates have remained constant however rates of anterior-only surgery and decompression-only procedures decreased, and posterior-only and combined approach surgeries have become more common.

Hypothesis
This study examined nationwide data to estimate the prevalence of C-OPLL and investigate trends in surgical treatment and outcomes.

Design
Retrospective review of the Nationwide Inpatient Sample (NIS) 2005-2013

Introduction
C-OPLL is characterized by ectopic bone formation within the ligament, and can elicit cervical spinal canal stenosis. Surgical treatment strategies for C-OPLL are debated in the literature.

Methods
NIS queried for patients with a diagnosis code for C-OPLL

(ICD9 723.7). NIS supplied hospital- and year-adjusted weights allowed for accurate assessment of prevalence. Descriptive statistics assessed patient demographics, comorbidities, surgical factors, and complications. Trends analyzed using ANOVA.

Results

4601 C-OPLL discharges were identified (56.7 years, 43% female). The prevalence of C-OPLL has increased from 2005 to 2013 (0.7 to 2.1 per 100,000,P<0.01). Surgical rates and trends of C-OPLL discharges are presented in Table 1. Overall, complications were most highly associated with A surgeries (A: 15.5%, P: 10.4%, A/P: 16.6% P<0.001). Anterior-only surgeries had the highest rates of dysphagia (0.7%, P<0.001) and dural tears (A: 5.6%, P<0.001). The overall mortality rate was 0.8%, with P surgery associated with the highest rate (A: 0.7%, P: 1.6%, P=0.002). The overall surgical rate for C-OPLL fluctuated over time, but did not significantly change (P=0.291). Complications have increased (2005: 6.8%, 2013: 9.3%, P<0.001). Rates of anterior-only surgery have decreased, with a corresponding increase in P and A/P surgeries (P<0.001).

Conclusion

In a nationwide analysis of hospital discharges across the U.S., 4601 C-OPLL discharges were identified, with increasing prevalence over the last decade. Morbidity rates have increased for C-OPLL discharges. Anterior approach surgeries were associated with higher overall complication rates. From 2005-2013, overall surgical rates have remained constant however rates of anterior-only surgery and decompression-only procedures decreased, and posterior-only and combined approach surgeries have become more common.

Cervical OPLL Concurrent Diagnoses, Surgical Rates and Overall Trends

Concurrent Diagnoses		**Frequencies**	
Cervical Spondylotic Myelopathy		37.7%	
Cervical Spinal Cord Injury		6.9%	
Overall Surgical Rate		89.4%	
Anterior-Only Approach		62.1%	
Posterior-Only Approach		21.5%	
Combined Approach		16.4%	
Fusion to Atlantoaxial Region		1.5%	
Decompression-Only		15.8%	
Trends from 2005-2013	**2005**	**2013**	**P-Value**
Age	54.7 years	57.0 years	0.001
Gender (% Female)	41.1%	43.7%	0.007
Asian	3.6%	8.6%	0.001
White	60.4%	55.6%	0.001
Hypertension Rates	43.6%	53.0%	<0.001
Diabetes Rates	1.8%	4.0%	0.017
Overall Surgical Rate	92.5%	84.8%	0.296
Anterior-Only Approach	67.5%	44.4%	<0.001
Posterior-Only Approach	13.6%	25.2%	<0.001
Combined Approach	11.4%	15.2%	<0.001
Decompression-Only Surgery	21.6%	14.8%	0.012
Corpectomy	3.6%	27.2%	<0.001
Complication Rate	6.8%	9.3%	<0.001

258. Outcome of Single Stage Posterior Spinal Fusion (PSF) Using Skip-Level Pedicle Screw Instrumentation in Adolescent Idiopathic Scoliosis (AIS) Patients with Cobb Angle > 90°

Chris Yin Wei Chan, MD, MS; Shun Herng Tan, MBBS; Ling Hui Loh, MBBS; Chee Kidd Chiu, MBBS, MS; Mun Keong Kwan, MBBS, MS

Summary

Single stage PSF using skip-level pedicle screw instrumentation was performed in 70 AIS patients with Cobb angle > 90°. The average correction rate was 61.0 ± 10.7% with good spinal balance. The fusion rate was 98.5%. At 2 years, overall SRS 22r scores, self-image domain and satisfaction domain demonstrated significant improvement.

Hypothesis

Single stage PSF using skip-level pedicle screw instrumentation in severe scoliosis > 90° results in optimal spinal balance, high fusion rate and low complication rates.

Design

Retrospective study

Introduction

Combined anterior-posterior approach, pre-operative halo-traction or posterior vertebral column resection in severe scoliosis leads to good correction but has higher operative risks.

Methods

Single stage PSF using skip-level pedicle screw instrumentation was performed in 70 AIS patients with Cobb angle > 90° and followed up for a minimum of 2 years. Outcome measures included side bending correction index (SBCI), C7-CSVL distance, apical vertebral translation (AVT), clavicle angle, T1 tilt, cervical axis and radiographic shoulder height (RSH). Spinal fusion was assessed using computed tomography and plain radiographs. Clinical complications and SRS 22r scores were documented.

Results

The average age was 15.8 ± 5.2 years. Mean screw density was 1.3 ± 0.1. Operative time averaged 200.4 ± 50.6 minutes with blood loss of 1749.5 ± 1005.2 ml. C7-CSVL distance improved from 15.8 ± 9.3 to 8.4 ± 6.0mm (p < 0.001) at final follow up. T1 tilt, cervical axis, clavicle angle and RSH also significantly improved. The Cobb angle improved from 104.3 ± 12.5° to 40.8 ± 13.1° at final follow-up (p < 0.001) leading to a mean correction rate of 61.0 ± 10.7%. At 2 years, the SRS 22r overall scores (3.6 ± 0.4 to 3.9 ± 0.5, p < 0.001), self-image domain (2.5 ± 0.6 to 3.7 ± 0.7, p < 0.001) and satisfaction domain (3.8 ± 0.9 to 4.2 ± 0.7, p = 0.009) showed significant improvement. Fusion rate was 98.5%. There was one patient who had intra-operative seizures and two patients who had superficial wound infections.

Conclusion

Single stage PSF using skip-level instrumentation led to an average correction rate of 61.0 ± 10.7% with good spinal balance after 2 years. The fusion rate was 98.5%. Overall SRS 22r scores, self-image domain and satisfaction domain demonstrated significant improvement at 2 years.

Figure 1: Case illustration of severe AIS with good post-operative spinal balance and bony fusion

259. Outcomes of Growing Rod Graduates for Severe versus Moderate Early-Onset Scoliosis

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Summary

Comparative study of children with severe (major curve = MC) vs. moderate (MC <90°) early onset scoliosis (EOS) who completed growing rod treatment (completion of lengthenings with or without final fusion). Graduates in the severe group were significantly less likely to have≤45º compared to the moderate group at latest follow-up. T1-T12 length was ≥18 cm in 73% MC≥90° and ≥22 cm in (49%) Final fusion increased T1-S1 height more compared to observation only in the severe group.

Hypothesis

Growing rod graduates with severe EOS present will have larger residual curves and shorter spinal height at FFU and may benefit more from final fusion procedure compared to patients with moderate EOS.

Design

Retrospective review of a prospective multicenter EOS database.

Introduction

Severe EOS represents a challenge regarding adequate deformity correction and spinal length.

Methods

Severe EOS (MC ≥90°) was present in 41 children who were treated with growing rods ≤10 years (mean age 5.5 yrs, follow-up 9.8 yrs) and who had minimum 2-year follow-up after the final lengthening with or without definitive spinal fusion. From the same database, 41 matched controls (for age, gender, and type) with moderate EOS (MC<90°) (mean age 5.4 yrs, follow-up 8.0 yrs). Twenty-eight patients (68%) in the severe group and 12 patients (29%) in the control group underwent final fusion at completion of treatment (FFU)(p=0.0010).

Results

Pre-operative MC was 102° in the severe vs. 64° in the control group (p<0.001) and was corrected to 56º and 36º, respectively (p<0.001) at FFU (Table). Fourteen patients (34%) in severe and 33 patients (80%) in control group had a residual MC ≤45º at FFU (RR 0.43, 95%CI 0.20–0.56, p<0.001). At FFU 30 patients (73%) in the severe and 36 patients (87%) in the control group had T1-T12 length ≥18 cm (RR 0.83, 95%CI 0.67–1.04, p=0.095). T1-S1 height improved more in children who had final fusion (mean 122 mm) vs. observation only (mean 87 mm) in the severe group (p=0.034). Thirty-six patients (88%) in the severe group and 27 patients (66%) in the control group sustained ≥1 complication during all treatment (RR 1.33, 95%CI 1.04–1.71, p=0.035) (2.7 [0-14] and 2.1 [0-10] total respectively).

Conclusion

Delaying surgery beyond 90° MC results in larger residual deformity and more complications than beginning at a lesser MC.

Table I. Clinical and Radiographic Features and Results

Characteristics	Severe Graduates (N = 41)		Control Graduates (N = 41)		P Value
	N (%)	Mean (Range)	N (%)	Mean (Range)	
Age at surgery (yr)		5.5 (1.4–9.7)		5.4 (1.4–9.9)	0.85
Age at final follow-up (yr)		15.0 (10.2-24)		13.5 (9.8-20)	0.011
Follow-up (yr)		9.8 (3.4–21)		8.0 (3.3–13.4)	0.0091
Type of EOS					
Congenital	8 (20)		8 (20)		1.0
Idiopathic	13 (32)		13 (32)		
Neuromuscular	13 (32)		13 (32)		
Syndromic	7 (17)		7 (17)		
No. of lengthening procedures		7.0 (3–15)		8.2 (3–18)	0.11
Total no. of surgical procedures*		8.8 (3–20)		9.5 (3–23)	0.38
Final fusion	28 (68)		12 (29)		0.0010
Major Curve (°)					
Preoperative		102 (90, 139)		64 (33, 88)	<0.001
Final follow-up		56 (10, 91)		36 (12, 89)	<0.001
>45° residual MC at FFU	14 (34%)		33 (80%)		<0.001
Spinal height, T1-S1 (mm)					
Preoperative		226 (138, 380)		266 (145, 416)	0.0010
Final follow-up		337 (159, 447)		361 (260, 510)	0.093
Thoracic height, T1-T12 (mm)					
Preoperative		143 (73, 244)		157 (72, 257)	0.15
Final follow-up		213 (80, 291)		224 (139, 321)	0.27
≥18 cm at FFU	30 (73)		36 (87)		0.095
≥22 cm at FFU	20 (49)		23 (56)		0.51

*Includes index procedure, lengthening procedures, revisions, and final fusion, if applicable.

260. Paravertebral Muscles Show Cross Activation in Double but also in Single AIS curves, with a Correspondent Oxygen Consumption: An Electromyography and Near Infrared Spectroscopic Study†

Barbara Piovanelli, PT; Massimiliano Gobbo, MD; Jorge Villafañe, PhD; Sabrina Donzelli, MD; Fabio Zaina, MD; <u>*Stefano Negrini, MD*</u>

Summary

Using electromyography (EMG) to check muscle activity and Near Infrared Spectroscopy (NIRS) to check metabolic consumption during the Biering-Sorensen endurance test we found a correlation between the two. The most activated muscles were those on the convex side of scoliosis, associated with those on the opposite side above or below the curve (depending on whether it was thoracic or lumbar). This pattern was present not only in patients with double major curves, but also in individuals with a single curve.

Hypothesis

To check the relationship between muscle activation and metabolic adaptation through a fatiguing protocol in Adolescents with Idiopathic Scoliosis (AIS)

Design

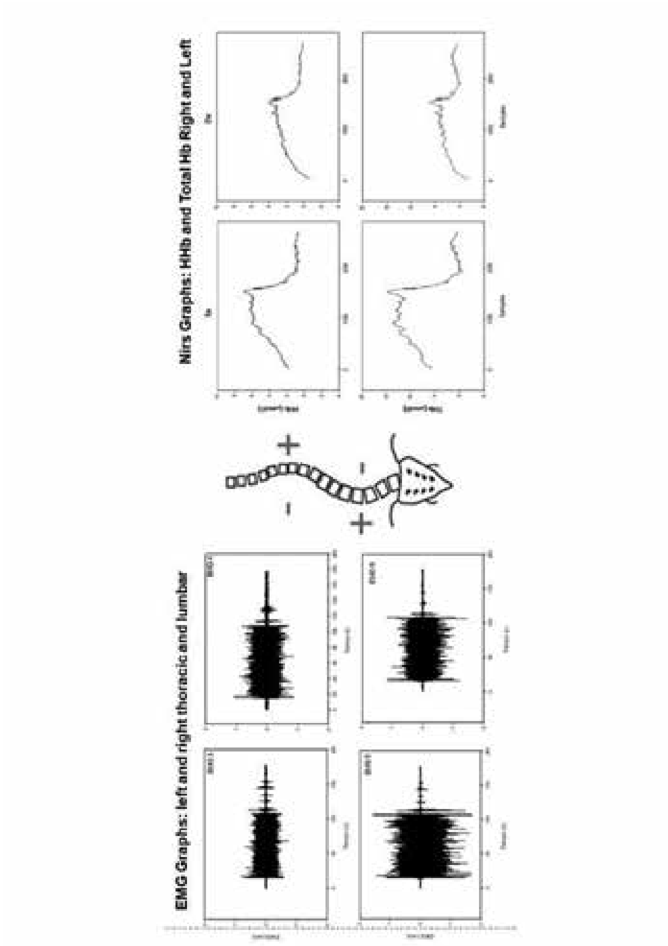
Cross-sectional study

Introduction
Previous studies have shown a different muscle activation between the concave and convex side of the scoliotic curve. Few studies have investigated the metabolic component of paravertebral muscles. Near Infrared Spectroscopy (NIRS) provide a non-invasive, in-vivo, real-time monitoring of tissue oxygenation. The modification of the latter may express the peculiar balance between oxygen delivery and consumption.

Methods
19 patients (17 females and 2 males) diagnosed with AIS aged between 10 and 15 years were recruited. The protocol involved the placement of 8 electromyographic (EMG) and 2 NIRS probes. The EMG probes were bilaterally placed on the paravertebral muscles (D3, D11, L4 level, respectively) and on biceps femoris muscles. The NIRS probes were bilaterally placed at L4 level. Subjects were asked to perform the Biering-Sorensen endurance test until muscle exhaustion. NIRS allow to check deoxy-hemoglobin (HHb) production, that was used to evaluate local muscle oxygen consumption. Numeric Rating Scale and SRS-22 questionnaire have also been administered.

Results
The study confirmed greater EMG muscle activity in the convex side. It also demonstrated a correlation between increased electrical activity and increased regional oxygen consumption. The most important discovery concerned muscle cross-activation: the most activated muscles were those on the convex side of scoliosis, associated with those on the opposite side above or below the curve (depending on whether it was thoracic or lumbar). This pattern was present not only in patients with double major curves, but also in individuals with a single curve.

Conclusion
Increased muscular activation at the convex side of the scoliotic curve has been confirmed and corresponded to metabolic oxygen consumption. In subjects with a single scoliotic curve, the activation and metabolic pattern found is equal to subjects with double curves.



261. Pedicle Screw Impinging the Aorta: A Diagnostic Dilemma Resolved on Prone CT Scan

Vishal Sarwahi, MBBS; Jesse M Galina, BS; Stephen Wendolowski, BS; Beverly Thornhill, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
Pedicle screw (PS) aortic misplacements are asymptomatic but are a treatment dilemma. A CT scan in both supine and prone position better delineates aorta- screw relationship.

Hypothesis
Prone CT helps delineate aorta-screw relationships

Design
Retrospective chart review

Introduction
PS misplacement rate is reported between 6-15%. Studies looking at misplacements on a per patient basis show up to 14% of patients have screws at risk (impinging vital structures). A screw abutting the aorta is a management challenge and often requires vascular surgery intervention. However, CT scans routinely done in supine position may overestimate screw-aorta relationship. Change in patient position may allow the aorta to roll away and, in most cases, reveal an uncompromised aorta. This will allow safe removal of pedicle screws without any vascular intervention.

Methods

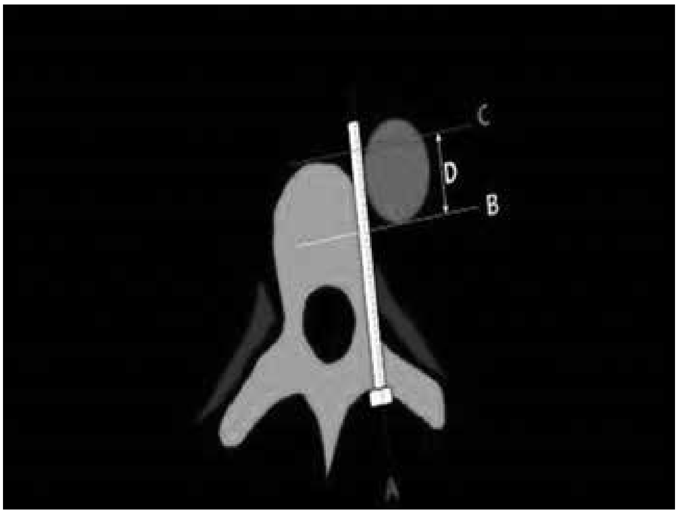
111 patients with post-op CT, who underwent PSF for spinal deformity, from 2004-2009, were evaluated. Patients with concerning screw-aorta relationship underwent a prone CT scan. Mobility of the aorta was determined as described in Figure 1. This was to document general mobility of the aorta. Distance (D) was compared using prone and supine CT scans. Pair t-test and signed rank tests were utilized.

Results

2295 screws were reviewed, 45 screws in 27 patients were in proximity to the aorta. 36 of these were in close proximity, but not impinging (>1cm aorta-screw distance). 14 screws (7 patients) were impinging (<1cm). On prone CT, 13 out of the 14 instances the aorta moved away from the screw (median 2.6mm). The mean distance above the level of the misplaced screw was 2.97mm (p=0.17), and 3.8mm (p=0.001) below. In one instance the relationship was unchanged on prone CT. No screw was noted to violate the lumen or distort the aorta.

Conclusion

Supine CT-scan alone is not entirely accurate in determining screw-aorta relationship. Prone-CT scan provides additional information for better delineation. This additional diagnostic step can change the treatment option by limiting the need for vascular intervention. When in doubt, the additional use of an arteriogram can allow for improved visualization.



262. Posterior Surgical Treatment for Thoracolumbar Focal Kyphosis: Minimum 3 Years Follow-Up

Yan Zeng, MD; Zhongqiang Chen, MD; Xiaochen Qu, MD

Summary

The surgical treatment for focal kyphosis in thoracolumbar spine is high challenging, however, it can achieve expectable results. Fifty-seven patients of focal kyphosis underwent posterior corrective surgery. The surgical technique was apical segmental resection osteotomy with dual axial rotation correction. All patients had a kyphosis angle ≥ 60° and the average kyphosis angle was 94.6°. The mean follow-up time was 46.1 months, and the average kyphosis corrective rate was 68.2%. No permanent spinal cord injury happened in this series.

Hypothesis

The posterior surgical treatment for moderate to severe focal kyphosis can get satisfactory clinical results, although great causion should be taken to avoid various of complications.

Design

Retrospective cohort study

Introduction

The present study retrospectively reviewed 57 patients with moderate to severe focal kyphosis who underwent apical segmental resection osteotomy with dual axial rotation correction surgery, and evaluate the radiological and clinical outcomes of the patients at minimum 3 years of follow-up.

Methods

Fifty-seven patients with moderate to severe focal kyphosis of the thoracolumbar spine underwent apical segmental resection osteotomy with dual axial rotation correction surgery. Local kyphosis angles were measured, and the spine sagittal balance were evaluated. The height of patients, the Frankel grading for neurological functions, the ODI for life quality, the VAS for back pain and the patient satisfactory index for satisfaction (PSI) to surgery were applied before surgery and at follow-up. The radiological and clinical outcomes were further analyzed in different sub-groups of patients according to etiology, severity of kyphosis, age, level of kyphosis apex, Frankel grade before surgery, and complications.

Results

The average follow-up time of patients was 46.1 months. The average kyphosis angle reduced from 94.6° before surgery to 31.0° after surgery,. The sagittal balance of the spine, height of patients, Frankel grading, ODI and VAS were improved. The PSI showed a satisfied rate of 91.2%. The clinical improvement rate was significantly higher in patient with kyphosis apex at lower thoracic spine or thoracolumbar segment, Frankel grade E before surgery and no complication group. The incidence of intra-operative and early-stage complications was 38.6%, and the incidence of instrumentation failure was 10.5%. All complications got good relief after appropriate intervention.

Conclusion

Apical segmental resection osteotomy with dual axial rotation correction is an effective procedure to treat moderate to severe focal kyphosis. The prevention of serious neurological complications is fundamental to achieve the ideal clinical results.

263. Posterior-Anterior Vertebral Vector Based Projected Images in the Analysis of the Scoliotic Spine

Tamás Illés, MD, PhD; Jean Dubousset, MD

Summary

Comparison of 824 patients with scoliosis the 3D angles generated by EOS with projected angles calculated from the vector parameters of postero-anterior vertebra vectors, which also coincide the postero-anterior axis of vertebrae. A strong correlation was observed in all angles in all three planes. Furthermore, by using vertebra vector-based top-view images alone, all factors

playing a role in the appearance of scoliosis (vertebral rotation, lateral displacement, fontal and sagittal curves) can be visualized and analyzed in parallel.

Hypothesis
Vertebra vector based projected scoliosis visualization is an accurate 3D measurement which provides the ability to characterize the curves in the horizontal plane as well.

Design
Comparing values of the "3D angle" obtained by sterEOS™ 3D software and the projected angles calculated by vector vertebral coordinates.

Introduction
The global appearance of scoliosis in the horizontal plane is not known. The diagnosis of scoliosis is almost exclusively based on frontal and lateral radiographs, as rotational changes in the horizontal plane are ignored. The posterior-anterior vertebra vector display significantly simplifie the simultaneous representation of spine deformities in all three planes.

Methods
824 patients with scoliosis (105 cases before and after surgery, 719 cases without surgery) were analyzed based on preoperative full-body standing anteroposterior and lateral radiographs obtained by the EOS™ 2D/3D system. The 3D surface reconstructions of the spinal curves were performed, and the 3D clinical parameters were exported by using sterEOS™ 3D software. In all cases, the vertebral vectors and its three planes coordinates were also determined also for mathematical analysis of the curves. Statistical analysis: descriptive, means comparison, Pearson correlation (SPSS 16.0) was performed.

Results
In the frontal plane, the correlation coefficients (r) between the two methods were 0,950 preop and 0,935 in postop. In the sagittal planes for kyphosis r was 0,893 and 0,896 pre and postop. In the horizontal plane, the rotation measured on apical vertebra with two methods showed very strong correlation (preop r=0,963, postop r=0,968).

Conclusion
The vertebra vector projections show the scoliotic curvatures in all three planes with the same precision as the other methods. This surgeon-friendly, graphical method of visualization significantly facilitates the understanding of the 3D nature of scoliosis. The approach is simple. These results are sufficient for visual analysis and provide significant clinical information on the three anatomical planes. Furthermore, this visualization represents a reasonable compromise between mathematical purity and practical use.

264. Posterior-Only 360 Degree Osteotomy with Dual-diameter Rod Reconstruction in the Treatment of Congenital Cervicothoracic Scoliosis: a More Than 2-year Follow-up

Qianyu Zhuang, MD; Ye Tian, MD

Summary
A retrospective study of prospective database from a consecutive series of congenital cervicothoracic scoliosis treated by posterioronly 360 degree osteotomy and dual-diameter rod cervicothoracic reconstruction. Our strategy was proved to offer excellent correction in both the coronal and sagittal planes with acceptable neurologic risk.

Hypothesis
Posterioronly 360 degree osteotomy and dual-diameter rod cervicothoracic reconstruction can offer excellent correction in both the coronal and sagittal planes with acceptable neurologic risk.

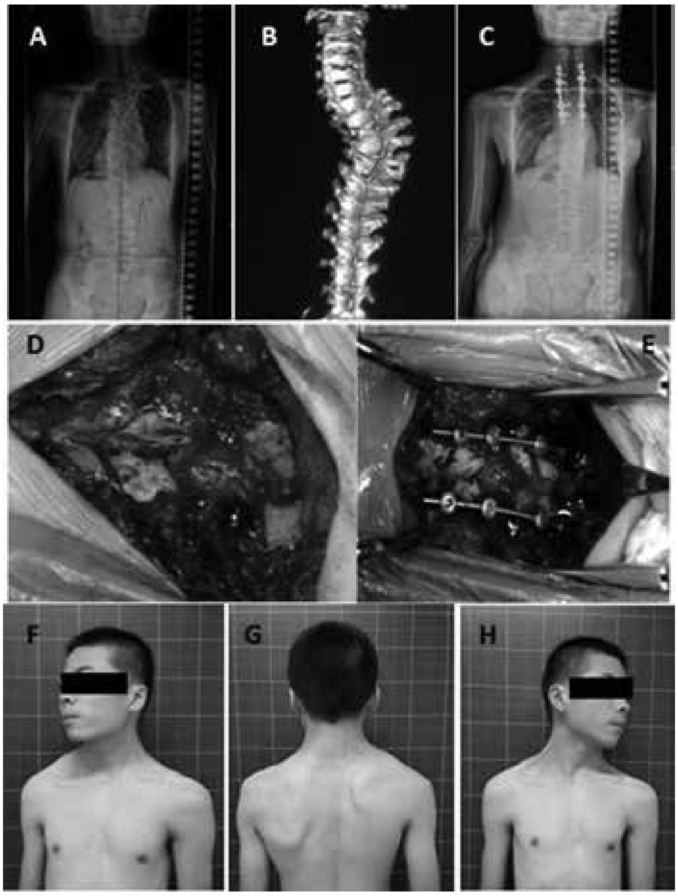
Design
Retrospective study of prospective database.

Introduction
Congenital cervicothoracic scoliosis poses a challenging and perplexing problem. The lack of a mobile spine above the deformity results in increasing tilt of the head and developing asymmetric facial changes.

Methods
This retrospective study of a prospective collected database comprises a consecutive series of 18 congenital cervicothoracic scoliosis (due to hemivertebra, segmentation failure, etc.), with at least a 2-year follow-up (24-132 months). Surgical reports and patient charts were reviewed. Radiographic parameters included segmental scoliosis and kyphosis, compensatory scoliosis, T1-slope, neck coronal/sagittal tilt, cervical trunk shift, cervicothoracic kyphosis, cervical lordosis, and C2-7 sagittal vertical axis, cervical tilting, etc.

Results
The mean follow-up period was 49.6 months (24-132 months). The mean segmental scoliosis was 43.1 degree preoperatively, 13.4 degree postoperatively (67.9% correction rate), and 13.1 degree (69.6%) at the latest follow-up. T1 slope was corrected from 23.9 degree prior to surgery to 8.1 degree at the last follow-up), and neck coronal tilt was changed from 12.50 degree to 4.7 degree accordingly. Complications include 6 transient upper extremities numbness, 2 pleural effusion, 1 distal adding-on, 1 neurologic deficit. Among them, 3 cases underwent revision surgery.

Conclusion
Posterior-only 360 degree osteotomy and dual-diameter rod cervicothoracic reconstruction can offer excellent correction in both the coronal and sagittal planes with acceptable neurologic risk. This strategy is not only corrective of the deformity but also preventive of compensatory curve progression, thus avoiding long fusion and related function loss.



265. Prediction of the 3D Selective Thoracic Fusion Outcomes in Lenke 1 Adolescent Idiopathic Scoliosis

Saba Pasha, PhD; Patrick Cahill, MD

Summary
We previously developed and validated a 3D postural balance score. Using this balance scoring system, we aimed to determine whether patients with an improved balance score (similar to non-scoliotic) at the immediate post-op will have better radiographic outcomes at 2 year after selective thoracic fusion (STF). We showed patients with a postural balance score similar to the non-scoliotic group have a significantly higher magnitude of spontaneous lumbar curve correction (SLCC) at 2-year compared to those with a poor balance score.

Hypothesis
3D configuration of spinopelvic alignment at immediate post-STF is associated with improved radiographic outcomes and higher rate of spontaneous lumbar curve correction at 2-year follow-up.

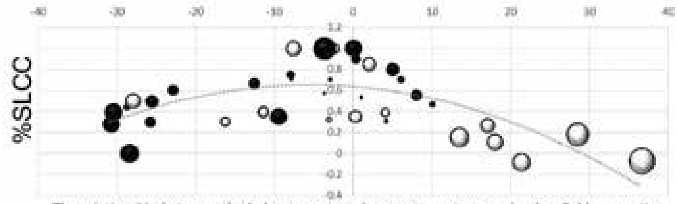
Design
Prospective

Introduction
Global balance plays an important role in patients' surgical outcomes. While frontal and sagittal balances have been used conventionally to evaluate balance in AIS, they fail to capture the 3D nature of the curve. Using a previously validated balance score in AIS, we seek to determine the link between the immediate post STF postural balance and radiographic outcome of STF at 2 years. We suspect the SLCC is tied to the patients' immediate post-op postural balance however it has not been validated through a quantitative balance score.

Methods
Bi-planar stereoradiography of 62 AIS patients with a main right thoracic curve undergoing STF were registered prospectively and follow-up for 2 years. 20 non-scoliotic controls with spinal X-rays were included. Thoracic and lumbar Cobb angles kyphosis, lordosis, thoracic and lumbar apical rotation and translations, frontal and sagittal balance, and pelvic sagittal parameters were used to calculate the balance score at first erect post-op as was previously developed and validated. The balance score at first erect was correlated to the rate of lumbar curve correction at 2 year follow-up in the cohort.

Results
The balance score at immediate post-op ranged between [-30, 42]. The balance score for the non-scoliotic controls was between [-8, 10]. A significant correlation was found between the % SLCC and the postural balance score, $R2=0.43$, $p<0.05$. Patients with a balance score between -10 and 10 at immediate post-op showed at an average of 82% of SLCC at 2-year post STF which was significantly higher than the rate of SLCC (38%) in patients with a balance score -10< or 10>.

Conclusion
The new postural balance score can predict the long-term outcomes of the STF by considering the 3D configuration of the spine and pelvic alignment. A balance score calculated at first erect can accurately predict the rate of SLCC at 2 year. A harmonic change in the 3D spinopelvic parameters is required for an improved STF outcome.



The relationship between the balance score and percent spontaneous lumbar Cobb correction (SLCC) at two year follow-up after STF. Each point represent a patient and the size of each point is representing the measured SVA at the first erect visits (black negative SVA, white positive SVA)

266. Predictive Modeling of 30- and 90-day Return to ED after Elective Spine Surgery: Analysis of 5,444 Patients from a Single Center

Jeffrey Gum, MD; Yehia Khalil, PhD; Mladen Djurasovic, MD; Portia Steele, MS; Steven Glassman, MD; Leah Yacat Carreon, MD, MS

Summary
Return to ED is common 30- and 90-days after elective lumbar spine surgery. The strongest predictors of 30- and 90-day ED visit were zip code, previous ED admission and number of chronic medical conditions. The majority of visits were for pain issues. ED visits may be avoidable with pre-op medical optimization and counseling.

Hypothesis
Modifiable risk factors that drive 30- and 90-day return to the emergency department (ED) after elective spine surgery can be identified.

Design
Retrospective longitudinal cohort

Introduction
Unplanned ED visits after spine surgery have been studied utilizing administrative databases which lack granularity. Single center longitudinal analysis allows for more accurate determination of cause and cost. Identification and control of modifiable risk factors prior to surgery may decrease unnecessary ED visits

Methods
A prospective, multi-surgeon, single-center surgical database combined with hospital administrative data was queried for patients admitted from 2013 to 2017 for elective spine surgeries with DRG codes 456-460. Predictive models were created for 30- and 90-day ED visits. 18 variables were used the training models. Validation was done using an 80/20 data split for training and testing each model. Goodness of fit was measured using the area under receiver operating characteristic curves (AUROC) in the test set.

Results
Of 5,444 patients identified, 450 (8%) and 729 (13%) returned to the ED within 30- and 90-days after surgery. The AUROC for both models was between 0.64-0.66 consistent with a successful fit. The majority of patients (144, 32%) returned for pain related issues. The strongest predictors of 30-day ED visit were zip code (OR:1.9, CI:1.4-2.8, p=0.000), previous ED admission (pED) (OR:1.4, CI:1.1-1.8, p=0.002), and number of chronic medical conditions (OR:1.3, CI:1.0-1.6,p=0.024). The strongest predictors of 90-day ED visit were pED (OR:2.4, CI:1.8-3.4, p<0.001), zip code (OR:1.4, CI:1.2-1.7, p=0.000), and number of chronic medical conditions (OR: 1.4, CI:1.1-1.7,p=0.002).

Conclusion
After elective spine surgery, return to ED is common 30- and 90-days post-op. The majority of the visits are avoidable with potentially modifiable risk factors. In the era of value-based care and in the setting of bundled payment models, it is important to recognize risk factors for unnecessary resource utilization. These models can help counsel patients regarding appropriate ED utilization after spine surgery.

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267. Predictors of Cost for Posterior Spine Fusion Surgery in Adolescent Idiopathic Scoliosis

Fady Baky; Todd Milbrandt, MD; William J. Shaughnessy, MD; Anthony A. Stans, MD; Scott Echternacht; <u>A. Noelle Larson, MD</u>

Summary
With our robust methodology, surgeons' fees represented 15% of AIS surgery costs. Intraoperative costs represented 70% of AIS surgery costs, with implants representing nearly 1/3 of the total cost. Bundled payments for AIS should include adjustments for fusion levels and curve type.

Hypothesis
Implant and operative expenses would account for the majority of hospital costs for AIS surgery.

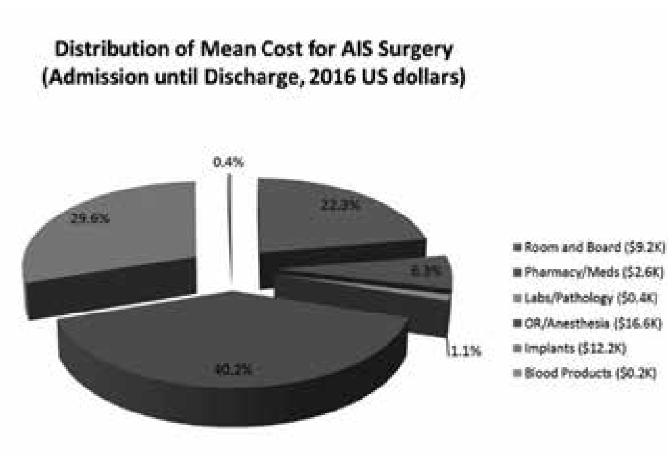
Design
Cost analysis using microcosting valuation techniques.

Introduction
With rising healthcare costs and the advent of bundled payments, it is essential to understand predictors of cost for surgical procedures. We sought to determine the effect of curve type, length of stay, and implants on the cost of AIS surgery using standardized, inflation-adjusted costs for services and procedures.

Methods
Cost data from admission until discharge was available on a total of 152 patients undergoing spinal fusion surgery for AIS from 2009-2016. Cost data was obtained from our institutional research database, which contains line item details for every procedure or service billed. Widely accepted bottom-up microcosting valuation techniques were used to generate standardized inflation-adjusted estimates of each service cost. Costs were assigned to resource utilization using methods similar to Medicare payment models applied to all patients' services, regardless of payer to normalize costs. The resulting assigned costs for all services are then adjusted to 2016 USDs using GDP implicit price deflators. Length of stay, # of screws, # of levels, curve magnitude, and curve type was assessed by review of x-rays and medical records to determine which factors most impacted cost of care.

Results
Mean cost of AIS surgery was $48,058+/-9379. Implant costs and surgical/anesthesia costs accounted for nearly 70% of the total cost (Figure). Mean number of screws was 16+/-.5, mean number of levels fused was 11.2+/-2.2, and mean implant density 1.45+/-0.35. There was no detected difference in cost vs. ASA score or BMI. On logistic regression, number of screws, number of levels fused, increased curve magnitude, and Lenke curve type (3, 4, 6 > 1, 2, 5) were all associated with increased cost (p<0.01). Mean normalized surgeon fees (Medicare Part B) were $7,045+/-1732.

Conclusion
Room and board only made up 22% of hospital costs. Primary areas for cost savings include reduction in implant and surgical costs.



268. Predictors of Wound Infections After Correction Surgery in Neuromuscular Scoliosis

M. Burhan Janjua, MD; Brandon Toll, BA; Amer F. Samdani, MD; Joshua M. Pahys, MD; Steven Hwang, MD

Summary

Gram negatives were the common offending pathogens and presented early. The use of titanium instrumentation was associated with more than 50% of infections. All infections were deep and were treated with wound washout followed by IV antibiotics.

Hypothesis

Wound inoculation with gram negatives and/or mixed pathogens could be the primary pathogens involved. Moreover, pulmonary comorbidity, previous operations, and radiographic parameters could be major risk factors.

Design

Retrospective study

Introduction

Complications are more prevalent in neuromuscular scoliosis (NMS) versus idiopathic scoliosis surgery. We wished to elucidate risk factors in NMS with a focus on surgical site infection after correction surgery.

Methods

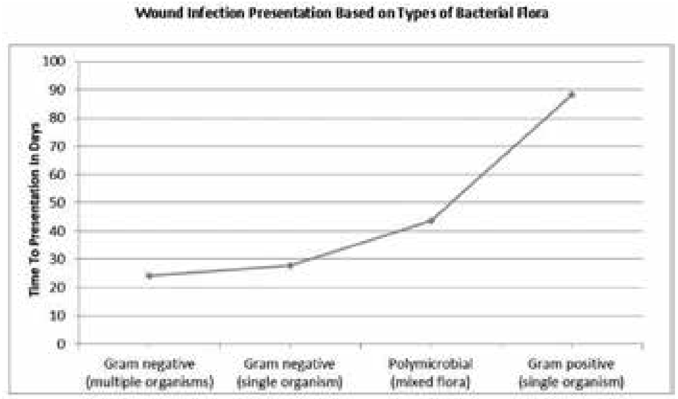
All patients treated surgically for NMS from Jan. 2008 to Dec. 2016 with a minimum of 2-year follow-up were retrospectively reviewed. Demographics, radiographic parameters, offending pathogens, and other data regarding wound infection were recorded.

Results

60 patients (29 M and 31 F) with a mean age of 14.0 ± 2.7 years were reviewed. There were 22 complications in 16 patients (27% prevalence). Wound infection was a major complication (32%); 100% were deep infections. Primary pathogens were E. coli (40%), Proteus (33%), Pseudomonas (26%), Enterococcus (26%), and Klebsiella (20%). Less common pathogens (13%) included Serratia, MRSA, and S. aureus (Fig. 1). 60% were gram negatives, 20% were gram positives, and 20% were inflicted to both types. 60% of infections were associated with use of Titanium, 20% had Cobalt Chrome, and in 20% both CC+Titanium was used. 13% underwent instrumentation removal/replacement. All patients underwent wound washout and were treated with IV antibiotics followed by oral antibiotics. Mean duration of IV antibiotics for gram positives in weeks was 12.5 (SD±5.88) and for gram negatives 7.67 (SD±3.70), with Titanium rods was 9.88 weeks (SD±6.45); CC was 8.33 weeks (SD±1.70); and CC+Titanium was 6.67 weeks (SD±4.11). Oral antibiotics were used for gram positive pathogens for 12.3 weeks (SD±9.41) and for gram negative pathogens 7.83 weeks (SD±6.61)

Conclusion

Wound infection is a major complication. Gram negatives were the primary pathogens; 100% of infections were deep, and all required washout followed by IV antibiotics. Titanium rods were associated with >50% of infections. Our data highlight major risk factors for wound infection in patients with NMS.



269. Preoperative 3D Analysis Can Predict Optimal Outcomes After Selective Thoracic Fusion in Adolescent Idiopathic Scoliosis

Vidyadhar Upasani, MD; Madeline Cross, MPH; Carrie E. Bartley, MA; Megan Jeffords, MS; Tracey P. Bastrom, MA; Stephen George, MD; Stefan Parent, MD, PhD; Burt Yaszay, MD; Peter Newton, MD

Summary

AIS patients with less preoperative axial plane deformity were more likely to achieve an optimal STF 2 years postoperatively. Preoperative 3D analysis allows for a better understanding of the axial plane deformity and can aid in choosing a STF.

Hypothesis

Preoperative 3D radiographic parameters can differentiate between optimal and suboptimal postoperative outcomes after selective thoracic fusion (STF) in AIS.

Design

Retrospective comparative study

Introduction

Traditionally, STF is recommended when the Cobb angle, apical translation, and axial rotation of the thoracic (TH) curve are 20% larger than that of the lumbar (L) curve. Recently, biplanar radiography has allowed a better understanding of the 3D deformity in AIS.

Methods

AIS patients with Lenke 1-4 curves with a B or C lumbar modifier who underwent posterior STF were reviewed. Only patients with preop and 2yr postop 3D spine reconstructions were included. Previously published predictors of optimal outcomes after STF were used to group patients as "optimal" or "suboptimal". Patients who met ≥3 of the following criteria at 2yr were considered "optimal" (≤2 criteria were "suboptimal"): Deformity Flexibility Quotient <4, 2yr lumbar Cobb <26°, coronal balance <2cm, trunk shift <1.5cm, and lumbar ATR <5°. Preop 3D radiographic parameters and surgical data were compared between groups using ANOVA. Classification and Regression Tree analysis was used to determine which factors were most predictive of achieving an optimal outcome.

Results

56 patients were included. 43 (77%) had an optimal outcome.

Preop, the optimal group had less rotation in the TH and L apices, within the fused segment, in the stable vertebra, and less absolute difference in rotation between the TH and L apices (all p<0.05; Table). No differences between groups were observed in LIV selection, LIV relative to stable or neutral, surgeon, Lenke type, or lumbar modifier (p>0.05). CART analysis showed that the single most predictive 3D variable of a successful outcome was having an absolute difference in rotation of the TH to L apical vertebrae of ≤32°.

Conclusion

Preoperative 3D analysis can provide important understanding of the axial plane deformity in AIS. Assessment of the absolute difference of the apical rotation of the thoracic and lumbar curves can quantify the magnitude of axial plane deformity present and was found to be an important predictor of optimal outcome after STF

Table: Comparison of 3D radiographic parameters between the optimal and suboptimal groups.

Preoperative 3D Predictor	Optimal (≥3 criteria)	Suboptimal (≤2 criteria)	p-value
Thoracic Cobb Angle	53 ± 8	56 ± 10	0.259
Absolute difference of the apical rotation TH to L	24 ± 6	31 ± 7	**<0.001**
Apical vertebral rotation ratio (TH:L)	1.6 ± 3	1.5 ± 1	0.84
T1-T5 Kyphosis	18 ± 8	19 ± 5	0.703
T5-T12 Kyphosis	6 ± 14	12 ± 8	0.142
T10-L2 Kyphosis	-8 ± 11	-3 ± 8	0.182
T12-S1 Lordosis	-61 ± 12	-61 ± 13	0.32
Axial Rotation: Upper Thoracic Curve Apex	7 ± 5	7 ± 6	0.855
Axial Rotation: Thoracic Curve Apex	-13 ± 7	-18 ± 8	**0.034**
Axial Rotation: Lumbar Curve Apex	10 ± 6	13 ± 4	**0.045**
Axial Rotation: Stable Vertebra	-1.8 ± 5	-5.6 ± 8	**0.036**

270. Preoperative Prediction of Cost and Catastrophic Cost (CC) in Adult Spine Deformity (ASD) Surgery: Feasibility Analysis of Predictive Analytics to Establish 90 Day Bundled Payments

Miquel Serra-Burriel, PhD; Justin Smith, MD, PhD; Jeffrey Gum, MD; Michael P. Kelly, MD, MS; Ferran Pellisé, MD; Ahmet Alanay, MD; Emre Acaroglu, MD; Francisco Javier Perez-Grueso, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD, MS; Samrat Yeramaneni, PhD, MBBS, MS; Richard Hostin, MD; Corinna Zygourakis, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher Shaffrey, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher Ames, MD; European Spine Study Group; International Spine Study Group

Summary

Bundled payment models and risk sharing initiatives have been proposed as means of controlling ASD surgery cost, but these approaches require accurate cost prediction. This study demonstrates that direct cost in ASD surgery can be reliably predicted in a preoperative setting and that CC outliers can be predicted preoperatively with 90% accuracy. The high degree of cost variance explained by factors such as site and surgeon suggest potential efficiency gains offered by standardization in patient selection and treatment strategies.

Hypothesis

A predictive analytic model to preoperatively determine direct cost and CC outliers can be developed using a cohort of ASD surgeries with actual direct hospital costs.

Design

Direct cost modeling based on prospective multicenter ASD data

Introduction

ASD surgery accounts for 6% of US healthcare costs. There has been increasing interest in cost prediction for bundled payment models and risk sharing initiatives. CC outliers are typically excluded in bundled payment settings making their preoperative identification critical.

Methods

We performed regression models (generalized linear regression and random forest) for direct costs and classification models (random forest) for CC for ASD surgery. The goal of the regression models was to explain the determinants of direct costs (patient, surgical and contextual factors). The goal of the CC models was to predict which patients would have a direct CC (>$100,000).

Results

210 ASD patients (83% women, 45% revisions) from 4 sites in 4 geographic US areas were included. Cost data were actual direct costs incurred to the hospital. Average index cost per patient was $75,772. 14.8% of patients had a cost above the $100,000 threshold. Direct cost could be predicted preoperatively using random forest models with an accuracy of 72.1% (Example case in Figure). Of total variance explained, 22.6% was site and surgeon fixed-effects. Top predictors of cost in order were: surgeon, number of levels fused, interbody fusion and site. Catastrophic cost was predicted with 90.4% accuracy and 87.7% AUC. In our sample alone, reducing the CC occurrence by one-third the associated savings would be $452,181. Across the US this savings would extrapolate to at least $80 million/yr.

Conclusion

Direct cost in ASD surgery can be reliably predicted preoperatively. The high degree of variance explained by factors such as site and surgeon suggest potential efficiency gains offered by standardization in patient selection and treatment strategies. CC outliers can be predicted with >90% accuracy preoperatively.

Figure

	Model 1 (reg.) Cost Prediction	Model 2 (class.) Probability of cost > $100,000
Baseline	$107,761.90	75.2%
If reduce by 5 levels fused	$ 87,434.78	64.2%
"Most expensive surgeon"	$115,354.00	77.8%
"Least expensive surgeon"	$104,729.10	73.0%

Example Patient: Female with no prior spine surgery, more than 10 years with spine problems, no comorbidities, employed, 57.29 years old, 160cm height, 63.5 kgs weight, 2.85 Frailty index, ASA grade 3, 21.43 pelvic tilt, 50.71 SVA and 36.98 major curve cobb angle. **Proposed Surgery:** posterior approach, pelvic fixation, 15 fused vertebrae, decompression yes, interbody fusion, posterior column osteotomies

271. Prophylactic Application of Local (Intra-Wound) Antibiotic Does Not Decrease Acute Surgical Site Infections in AIS Patients.

Amy McIntosh, MD; Kiley Poppino, BS

Summary

The 90 day acute surgical site infection (SSI) rate was not lowered by the prophylactic application of local antibiotic into the

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bone graft/wound prior to closure in AIS patients undergoing PSF surgery. For purposes of antibiotic stewardship, this practice should be reserved for pediatric scoliosis patients with a higher risk for acute SSI (neuromuscular and syndromic diagnoses), and discouraged in the AIS patient population.

Hypothesis
We hypothesized that intra-wound/local antibiotic application would not lower the rate of acute SSI in AIS patients undergoing PSF surgery.

Design
Retrospective review prospectively collected data

Introduction
In 2013, a consensus best practice guideline recommended that prophylactic vancomycin powder be added to the bone graft/local wound in pediatric scoliosis patients that are at high risk for developing an acute SSI. AIS patients are the lowest risk population for the development of acute SSI, with a published rate of 1%. Many surgeons are using prophylactic intra-wound antibiotic in their AIS patients undergoing PSF, despite the lack of evidence to support its use.

Methods
From 2015-2017, prospective data from a single institution was collected on patients who underwent PSF for AIS. This data was retrospectively reviewed within 90 days of surgery. Two cohorts were compared. A power analysis determined a total of 348 patients was necessary to detect a 1% difference between the cohorts. Group 1: had application of prophylactic local antibiotic (vancomycin +/- gentamycin) into the bone graft/wound prior to closure, and Group 2: was the control group (no local antibiotic). All patients in participated in a pre-operative Chlorhexidine Gluconate (CHG) skin cleansing protocol for 2 days prior to surgery, underwent intra-operative sterile site prep with CHG, and had appropriate IV prophylactic antibiotics dosing within 1 hour of incision.

Results
405 AIS patients (77M: 328F) average age (13.9±2.1 years) underwent PSF surgery from 2015-2017. Group 1 included 168 (41.5%) patients (34 M : 134F) with an average age (14.18±2.2) years. Group 2 contained 237(59.5%) patients (38M: 199F) with an average age (13.8±1.98 years). The BMI and pre-op major Cobb angle was similar in both groups 21.5 vs. 21.98; and 63.8 vs. 62.1. There were 0 acute SSI in both groups (p = 0.99).

Conclusion
The prophylactic use of intra-wound antibiotic demonstrated no statistical effect on the rate of acute SSI (0%) in AIS patients. This practice should be reserved for high risk patients, those with neuromuscular and syndromic diagnoses.

272. Quality of Life in 1519 Treated or Untreated Males and Females with Idiopathic Scoliosis

Elias Diarbakerli, PT; Anna Grauers, MD, PhD; Aina Danielsson, MD, PhD; Allan Abbott, PhD; Paul Gerdhem, MD, PhD

Summary
Progressive idiopathic scoliosis is a disease usually affecting females. Therefore, females have most often been targeted in studies concerning idiopathic scoliosis. This study compares quality of Life in males and females, showing no significant difference between the groups.

Hypothesis
Quality of Life in males and females with idiopathic scoliosis does not differ significantly

Design
Cross-sectional

Introduction
Idiopathic scoliosis is a three-dimensional deformity affecting the growing spine. The prevalence of larger curves, requiring treatment, is higher in females. The aim of this study is to describe quality of life in males and females with idiopathic scoliosis

Methods
This cross-sectional study comprised 1519 individuals with idiopathic scoliosis (1308 females) with a mean (SD) age of 35.3 (14.9) years. They all answered the Scoliosis Research Society 22 revised (SRS-22r) questionnaire and EQ-5D. 528 (450 females) were surgically treated, 535 were brace treated (485 females) and 456 were untreated (373 females). The SRS-22r subscore (excluding the satisfaction domain), the SRS-22r domains and the EQ-5D index score were calculated. Subgroup analyses based on treatment and age were performed. Statistical comparisons were performed using analysis of covariance with adjustments for age and treatment. A p-value less than 0.05 was considered as statistical significant.

Results
The mean (SD) SRS-22r subscore (SD) for males was 4.19 (0.61) compared to females who had 4.05 (0.61) (p=0.010). The males also had higher scores on the SRS-22r domains function (4.56 vs 4.42), pain (4.20 vs 4.00) and mental health (4.14 vs 3.92) (all p<0.05, adjusted for age and treatment). The mean (SD) EQ-5D index score was 0.85 (0.22) for males and 0.81 (0.21) for females (p=0.10). There were minor differences when comparing on gender in treatment and age groups.

Conclusion
When compared to females, males with idiopathic scoliosis tend to have slightly higher scores in the scoliosis specific SRS-22r but not in the generic quality of life measurement EQ-5D. Quality of life is overall similar between males and females in treatment and age groups.

273. Radiation-free 3D Ultrasound Can Provide Sagittal Profile of Adolescent Idiopathic Scoliosis*

Tin Yan Lee, MS; Jason Pui Yin Cheung, MBBS, FRCS, MS; Weiwei Jiang, PhD; Connie Lok Kan Cheng, BS; Kelly Ka-Lee LAI, BS; Haris Begovic, PhD; Dino Samartzis, DSc; Michael To, MBBS, FRCS; *Yong-Ping Zheng, PhD*

Summary
Three-dimensional (3D) ultrasound could provide non-ionizing and accessible evaluation of vertebrae features and spinal curvature. In this study, 3D ultrasound was demonstrated to be reliable and valid for spinal sagittal curvature of patients with

scoliosis, in terms of excellent intra- and inter-rater reliability and good correlation and agreement with traditional X-ray Cobb. 3D ultrasound is demonstrated to be a promising method for sagittal spine curvature evaluation.

Hypothesis
3D ultrasound imaging could provide repeatable and reliable measurement of sagittal spinal curvature for adolescent idiopathic scoliosis (AIS) patients and comparable results with traditional Cobb angle with good agreement.

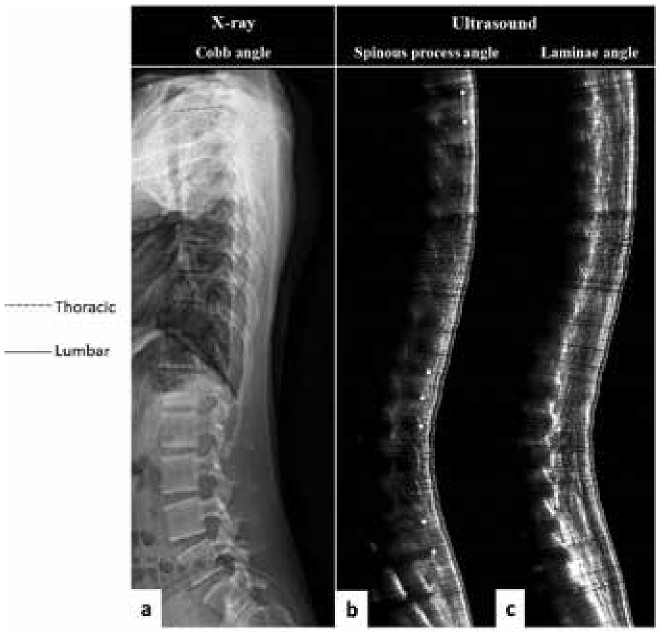
Design
Cross-sectional Study

Introduction
Though Cobb angle is the gold standard for assessing spinal sagittal curvature, X-ray is two-dimensional. Non-ionizing 3D ultrasound had been demonstrated to be feasible in evaluating vertebrae features and coronal curvatures of the spine. Yet no study has reported the reliability and accuracy of 3DUS on sagittal curvature analysis.

Methods
Twenty-one AIS patients, both males and females (Age: 15.7±1.3 years; Cobb's angle range 11.1 to 41.9°), underwent 3D ultrasound and EOS X-ray scanning of the spine. Spinous processes and laminae of the vertebrae were identified from B-mode images. Sagittal images were then generated to measure the thoracic and lumbar ultrasound spinous process angle (USSPA) and ultrasound laminae angle (USLA) respectively. The reliability (intraclass correlation coefficients (ICC) for the intra- and interobserver variability) and validity (linear regression analysis and Bland-Altman method, with mean absolute difference (MAD)) were tested for two ultrasound angles as compared to the Cobb angle (XCA).

Results
The ICC showed very reliable measurements of both ultrasound methods (ICC≥0.941). Moderate and significant linear correlations were seen between the ultrasound methods and XCA (Thoracic (R^2≥0.574) / Lumbar (R^2≥0.635)) and the Bland-Altman plot showed a good agreement between both ultrasound angles and XCA. The MADs of both ultrasound angles, corrected by the linear regression equations, and XCA showed no significant difference (MAD: USSPA 6.4±4.8°/6.1±4.4° and USLA 7.5±4.9°/5.3±4.2°; p≥0.326 for thoracic / lumbar respectively).

Conclusion
Other than coronal deformity, 3D ultrasound is reliable for measuring sagittal deformity for patients with AIS, using either spinous process or laminae method. Due to it being radiation-free and more accessible, 3D ultrasound has potential for clinical applications such as pre- and post-operative and bracing assessment of sagittal profile.



274. Readily Available EOS Functional Outcomes: 6MWT and Step-Activity Monitoring

Kelly Jeans, MS; Wilshaw Stevens Jr, BS; Dong-Phuong Tran, MS; Charles Johnston, MD; Lori Ann Karol, MD

Summary
Outcome measures for early-onset scoliosis patients are limited, and PFT data have reliability and reproducibility uncertainty. The simple 6-minute walk test (6MWT) can be administered during a clinic visit, while quantification of typical weekly activity can be made using a step-activity monitor (SAM), providing objective data on capacity to participate in ADL's and exercise. We found both these simpler tests to correlate with VO2 Rate and walking intensity during formal graded exercise treadmill testing (GXT).

Hypothesis
A significant relationship between oxygen consumption during walking (VO2 Rate), daily activity and the 6MWT will suggest an alternative clinical outcome measure for EOS patients.

Design
A retrospective review of prospectively collected data.

Introduction
Outcome measures for EOS patients are limited to PRO's and PFTs. Recent work has shown the utility of using VO2 Rate during walking along with activity monitoring to assess both exercise capacity and quantify activity. Not all clinicians however have equipment and staff needed to conduct such tests. A simple 6MWT can be conducted in a clinic setting and be useful when other metrics are unavailable. A SAM can be sent home with the patient and mailed back following data collection. Our purpose was to assess correlations between distance traveled in 6 minutes, oxygen consumption measures taken both during the 6MWT and during exercise, and the child's actual activity level (steps and time) collected over a week.

Methods

31 children participated: 17 had EOS (treated with growing rods n=14; early fusion n=3; range (age 8-16yrs), and 14 controls (range 8-15yrs). These participants completed VO2 Rate during over-ground walking, a 6MWT and wore a SAM for one week, recording steps and activity time. All but two EOS patients (early fusion patients with poor ambulation) performed a GXT.

Results

6MWT (224-608m) was significantly correlated to the final VO2 Rate (range 8.1-47.1ml/kg/min; p=.0002) and exercise intensity during GXT (treadmill: speed p<0.001 and incline p=0.046) (Table). VO2 Rate during the GXT correlated to the SAM data (range of total daily steps 2,737-21,658; p=0.006) and average total daily activity time (range 56-347min; p=0.008) and correlated to the 6MWT (p=0.002). The percent of days in which subjects "exercised" for 30min (range 0-100%, i.e. none-everyday) correlated with 6MWT distance (p=0.003), VO2 Rate (p=0.002), and load (speed and incline) achieved during the GXT on the treadmill (p=0.001 and p=0.002).

Conclusion

6MWT with SAM data are excellent objective surrogate outcome measures for EOS patients, and can be administered in essentially any clinic/office setting.

		6MWT distance		Total Daily Steps steps		Total Activity Time min		Exercise Activity Time % of days with 30 min of moderate-long cont' exercise	
		r	p	r	p	r	p	r	p
6MWT				0.609	0.001	0.509	0.009	0.565	0.003
Graded Exercise Test Final Stage	VO_2 Rate ml/kg/min	0.604	0.002	0.497	0.006	0.482	0.008	0.547	0.002
	Speed mph	0.723	<0.001					0.575	0.001
	Treadmill Incline %	0.419	0.046					0.551	0.002

275. Releasing the Tether: Weight Normalization Following Corrective Spinal Fusion in Cerebral Palsy

Christopher DeFrancesco; Daniel Miller, MD; Patrick Cahill, MD; David A. Spiegel, MD; John M. Flynn, MD; Keith Baldwin, MD

Summary

Children with cerebral palsy (CP) and concomitant neuromuscular (NM) scoliosis may experience improved feeding tolerance following posterior spinal fusion (PSF). This is the first published evidence of weight gain in these patients after PSF.

Hypothesis

Children with CP and NM scoliosis who undergo PSF show an upward trend in weight percentile in the first two years after surgery.

Design

Retrospective observational study

Introduction

Under-nutrition is common among patients with cerebral palsy (CP) and concomitant neuromuscular (NM) scoliosis. However, there is little evidence detailing weight following posterior spinal fusion (PSF) in this population.

Methods

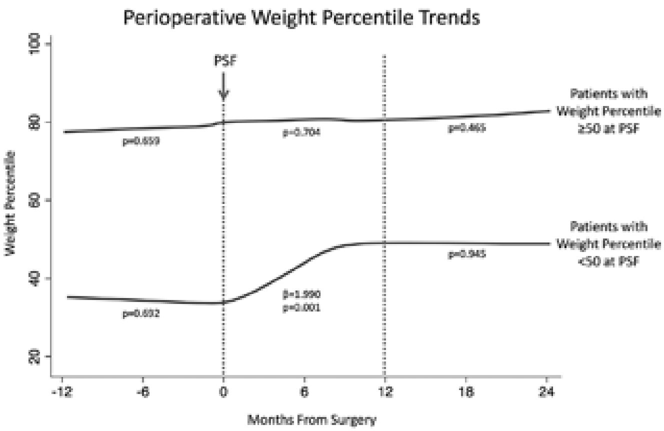
This retrospective observational study included 50 consecutive subjects with non-ambulatory CP who underwent PSF for NM scoliosis. Patient sex, functional level, and gastrostomy tube status were recorded. Age and weight were also recorded for the preoperative year, the day of surgery, 6-month, 1-year, and 2-year follow-up. Weights were converted to weight percentiles using CP-specific growth charts. The weight percentile distributions were compared between time points using descriptive statistics as well as regression analysis.

Results

The average change in weight from the day of surgery to 2-year follow-up was +3.4 percentiles. At 2-year follow-up, 65% (32 of 49) of patients had gained in weight percentile. Patients who started out under the 50th percentile gained an average of 17.3 percentiles in the first year after PSF (p=0.009). Regression analysis showed that patients with baseline weight <50th percentile tended to gain in weight percentile over the first postoperative year (ß=1.990, p=0.001). No trend was present among this group prior to surgery (p=0.692) or during the second postoperative year (p=0.945). No trends were noted prior to or after surgery for patients with baseline weights ≥50th percentile. There was no significant association between curve severity (measured by preoperative Cobb angle) and weight change.

Conclusion

This series is the first to document significant weight gain after PSF for NM scoliosis. This supports the theory that spinal correction allows for improved functioning of the digestive system, although the exact mechanisms accounting for the observed weight gain remain unclear.



276. Restoration of Sagittal Profile in Hypo-Kyphotic Adolescent Idiopathic Scoliosis: Comparison Between Rotational and Translational Techniques.

Cesare Faldini, MD; Fabrizio Perna, MD; Francesco Pardo, MD; Niccolò Stefanini, MD; Antonio Mazzotti, MD; Alberto Ruffilli, MD, PhD

E-Poster Abstracts

Summary
In this study, we compared two different surgical technique for adolescent idiopathic scoliosis (AIS) correction with the aim to evaluate differences on clinical and radiological results. Sagittal plane correction achieved using the simultaneous double rods translation (SDRT) technique were better than using the simultaneous double rods rotation (SDRR) technique.

Hypothesis
SDRT technique improve overall correction rates in patients with AIS.

Design
Retrospective clinical study.

Introduction
Surgical treatment of adolescent idiopathic scoliosis (AIS) is proposed to correct the deformity while maintaining a stable balanced spine. Hypo-kyphosis is a natural consequence of the coronal impairment and it is considered one of the most important parameters predicting long term outcome. Therefore, increased attention has been addressed to physiological sagittal contour restoration. Aim of this study is to compare outcomes of two different corrective techniques for AIS in order to identify the better procedure for sagittal values restoration in hypo-kyphotic patients

Methods
Two group of patients have been identified according to the technique used. The first group of 18 patients undergone simultaneous double rod rotation technique (SDRR) and the second group was subjected to simultaneous double rod translation technique (SDRT). Pre- and postoperative clinical and radiological values were recorded. Analysis of changes in post-procedural values compared to preoperative was performed and differences between the two groups were analysed.

Results
Mean follow-up was 3 years. Mean preoperative Cobb angle was 69.5° in the SDRR group and 66.2° in the SDRT group. Average postoperative Cobb angle was respectively 16.4°±5.9° and 14.3°±4.3° (p=0.22). Mean preoperative kyphosis was 13.8°±4.5° and 13.2°±4.7° respectively in SDRR and SDRT group. Average postoperative kyphosis was respectively 17.5°±3.0° and 21.4°±2.7° in SDRR and SDRT group (p=0.0003). Nor the sagittal or the coronal balance shown a statistically significant difference between the two groups. Rib-hump and SRS-22 scores improved after surgery in both group but without difference between the two techniques.

Conclusion
Both techniques have shown to be effective for AIS correction achieving good clinical and radiological results with low rate of complications. SDRT technique shown to be related with improved sagittal values compared to SDRR technique. Therefore, authors suggest the use of SDRT when planning surgical correction of hypo-kyphotic AIS.

277. Rigo Cheneau-Style Orthosis in Adolescent Idiopathic Scoliosis Lowers Risk of Curve Progression Compared to Boston-Style Orthosis by Achieving Higher In-Brace Correction

Shay Warren, BS; Hiroko Matsumoto, PhDc; Megan Campbell, BA; John Tunney, BOCPO; Nicole Bainton, RN, CPNP; Jennifer Hope, CPNP; Joshua Hyman, MD; David Roye, MD; Benjamin Roye, MD, MPH; Michael Vitale, MD

Summary
This retrospective cohort study compared patients with adolescent idiopathic scoliosis (AIS) treated with Rigo Cheneau-Style Orthosis (RCSO) or Boston-style thoracolumbar sacral orthosis (BSO) bracing at 2-year follow-up. RCSO patients had higher in-brace correction and were less likely to experience curve progression greater than 10°. However, there was no difference in risk of progression when controlled for in-brace correction, suggesting that lower curve progression in the RCSO group is due to higher in-brace curve correction.

Hypothesis
Risk of curve progression will differ between patients treated with Rigo Cheneau-Style Orthosis (RCSO) and Boston-style thoracolumbar sacral orthoses (BSO)

Design
Retrospective Cohort Study

Introduction
Bracing is the mainstay of conservative management for adolescent idiopathic scoliosis (AIS). However, there are many different brace types described in the literature, yet there is little data comparing treatment outcomes among brace types

Methods
This study included AIS patients who began RCSO or BSO bracing. Inclusion criteria included an initial major coronal curve between 20° and 45° and no previous scoliosis treatment. The outcome measure was major coronal curve progression of ≥10⁰ at 2 years.

Results
98 patients (51 RCSO and 47 BSO) were included. There were a higher percentage of Sanders scores 1-4 in the BSO cohort compared to the RCSO cohort (85% vs. 67%, p=0.034). In-brace curve correction was better in the RCSO group (47% vs. 24% p<0.001), and there were a higher percentage of patients who achieved in-brace curve correction ≥30% in RCSO compared to BSO (82% vs. 43%, P<0.001). 38% of patients treated with BSO had >10⁰ curve progression compared to only 16% of patients treated with RCSO (p=0.011). However, after adjusting for in-brace correction and Sanders score, there were no differences in risk of progression between RCSO and BSO (p=0.341). Instead, the risk of progression was 5 times higher when in-brace correction was <30% versus ≥30% adjusting for brace type and Sanders score. This model explains 18% of variance in estimating curve progression.

Conclusion
Although there was no direct effect of brace type on curve pro-

gression, more than 80% of patients with RCSO achieved ≥30% in-brace correction. Therefore, this study supports using RCO as a first-line brace in AIS patients; however, 18% of variance in outcome seems to be driven by unquantified variables and other factors such as sagittal parameters that need to be examined in future studies.

278. Sagittal Malalignment Correction Impact on Health Related Quality of Life

Mitsuru Takemoto, MD, PhD; Louis Boissiere, MD; Derek Cawley, FRCS; Daniel Larrieu, PhD; David Kieser, PhD, MBChB, FRACS, FNZOA; Caglar Yilgor, MD; Ahmet Alanay, MD; Emre Acaroglu, MD; Frank S. Kleinstueck, MD; Francisco Javier Perez-Grueso, MD; Ferran Pellisé, MD; Olivier Gille, MD, PhD; Anouar Bourghli, MD; Ibrahim Obeid, MD, MS; European Spine Study Group

Summary

Health Related Quality of life scores (HRQLs) improvement remains limited after sagittal malalignment corrective surgery. With a comprehensive multivariate analysis, the global alignment variability appears to be poorly correlated to most HRQL subclass scores. Walking and Mental status from SF-36 are the most responsive subclasses to malalignment correction.

Hypothesis

Sagittal alignment restoration impacts a limited number of HRQL subclasses.

Design

Multicenter, prospective study of consecutive ASD patients.

Introduction

Sagittal balance restoration in ASD surgery is related to Health Related Quality of Life scores (HRQLs) improvement. Despite this global benefit, the surgery effectiveness in improving HRQL remains difficult to understand. The aim of this study was to evaluate the HRQL subclass variability after surgical correction of global alignment.

Methods

Inclusion criteria were operated ASD patients, presenting at least one criteria: Cobb ≥ 20°; SVA ≥ 5 cm; TK ≥ 60° or PT ≥ 25°. Exclusion criteria were all 0+ patients regarding Schwab classification and single level or decompressive surgeries. A total of 154 and 87 patients reached 1-year and 2-year follow-up (FU) respectively. The Relative Sagittal Alignment (RSA), which is the difference between the measured Global Tilt and the ideal Global Tilt weighted by pelvic incidence, was measured in preoperative 1 and 2 years FU. The RSA and HRQL variability were calculated with the following formula: dRAS= RSA postop – RSA preop. A multivariate analysis was performed considering dHRQL as the dependent variable and age, BMI, Gender, dRSA 1y/2y as independent variables.

Results

All HRQLs were significantly improved postoperatively (Preoperative ODI was 47 and 2 years-FU ODI was 34). The multivariate analysis reveals that the HRQL subclass variability was consistently correlated to malalignment variability for walking ability and the mental health from SF36. No consistent correlation was found for any ODI and SRS-22 subclass scores.

Conclusion

When HRQLs were validated the sagittal malalignment knowledge was limited. ASD surgery is associated with patient satisfaction but its effectiveness appears limited when comparing HRQLs. This study demonstrates that the global alignment variability impacts a few HRQL subclasses. These results could be used for surgical decision making when sagittal malalignment restoration is prioritized. The patients' locomotion and mental status are most affected with corrective surgery.

Dependent variables	dRSA 1 year Standard beta	P-value	dRSA 2 year Standard beta	P-value
Oswetry Disability Index				
dBack pain	ns	ns	ns	ns
dODI-Walking	**0.22**	**0.0058**	ns	ns
dODI-Standing	**0.18**	**0.0324**	ns	ns
dODI-Sex life	ns	ns	ns	ns
dODI-Traveling	ns	ns	ns	ns
dODI-total score	0.19	0.0207	ns	ns
SRS-22				
d-Function	ns	ns	ns	ns
d-Pain	ns	ns	ns	ns
d-Self image	**-0.33**	**<0.0001**	ns	ns
d-Mental health	ns	ns	-0.31	0.0044
d-Satisfaction with management	**-0.55**	**<0.0001**	ns	ns
d-Subtotal score	-0.19	0.0189	ns	ns
d-Total score	-0.21	0.0091	ns	ns
SF-36 (only significant results)				
3g(9). Walking more than a mile	**-0.25**	**0.0022**	**-0.23**	**0.0436**
3h(10). Walking several blocks	**-0.30**	**0.0002**	**-0.23**	**0.0411**
3i(11). Walking one block.	**-0.30**	**0.0002**	**-0.24**	**0.0360**
9a(23). Feel full of pep.	**0.17**	**0.0392**	**0.25**	**0.0320**

279. Sagittal Profile of Adolescent Idiopathic Scoliosis After Posterior Spinal Fusion: a Systematic Review and Meta-analysis

Saba Pasha, PhD; Keith Baldwin, MD

Summary

Through a systematic review and meta-analysis, we compared 6 variables of the spine and pelvis in sagittal plane between pre- and two-year post-operative Lenke 1 and Lenke 5 AIS and non-scoliotic control cohort. As normal sagittal alignment was achieved for both Lenke types, the duration of the follow-up and the timing of changes in the sagittal alignment can additionally guide the patient-specific monitoring post-operatively for each Lenke type.

Hypothesis

Normal sagittal profile is achieved at two-year post PSF in Lenke 1 and Lenke 5 AIS.

Design

Systematic review and meta-analysis

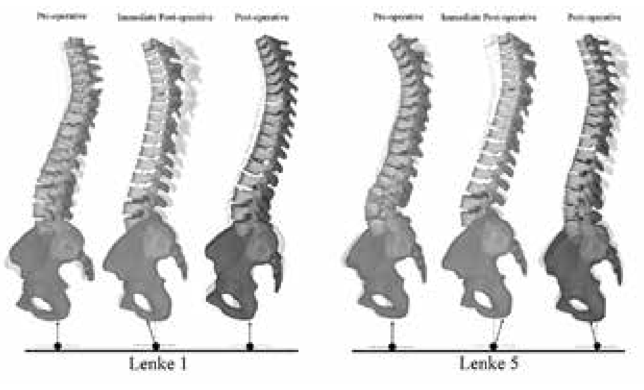
Introduction

The post-operative changes in the sagittal profile of Lenke 1 and 5 AIS at varying time points after posterior spinal fusion (PSF) have not been rigorously demonstrated; studies performed have had conflicting results. To determine the differences in the sagittal spinopelvic parameters between the non-scoliotic controls, pre-operative and different time points post-operative in Lenke 1 and 5 AIS.

Methods
Sagittal spinal and pelvic parameters, T5-T12 thoracic kyphosis (TK), L1-S1 lumbar lordosis (LL), pelvic incidence (PI), sacral slope (SS), and sagittal vertical axis (SVA), for Lenke 1 and 5 pre-operatively, at immediate, less than 2-year, and more than 2-year post-operatively, and for controls were searched. Differences in the sagittal spinopelvic parameters between pre-operative and the follow-ups and between the non-scoliotic and pre- and post-operative AIS subtypes using standardized difference of means meta-analysis was calculated.

Results
through the systematic review, 340 Lenke 1 patients and 224 Lenke 5 with two-year follow-up were found and compared to 1243 non-scoliotic controls. In Lenke 1 SVA was significantly more anterior at the immediate post-operative compared to pre-operative, but continued moving posteriorly up to 2-year post-operative with no significant difference in the SVA position between the final follow-up and pre-operative, $p>0.05$. In Lenke 5 SVA was significantly more posterior at the immediate post-operative and more anterior at the final follow-up compared to the pre-operative measurements, $p<0.05$.

Conclusion
Normalization of the sagittal spinal parameters appears to be the rule after PSF, and watchful waiting appears to be appropriate in this population when viewing the lateral X-ray post-operatively. Continuous changes and ultimate normalization in SVA and sagittal profile in Lenke1 and TK and SVA in Lenke 5 between the short- and long-term follow-ups should be expected.



280. Scoliosis in Association with the 22q11.2 Deletion Syndrome

Jelle Homans, MD; Vyaas Baldew, MD; Rob Brink, MD; Moyo C. Kruyt, MD, PhD; Tom PC Schlösser, MD, PhD; Michiel Houben, MD, PhD; Vincent Deeney, MD; T. Blaine Crowley, ; Donna McDonald-McGinn, MS; René M. Castelein, MD, PhD

Summary
The 22q11.2 Deletion Syndrome (22q11.2DS) is the most common microdeletion syndrome. Our data confirms that scoliosis is definitely associated with 22q11.2DS, with a prevalence of 48-49% of patients who have reached skeletal maturity. In our study scoliosis was not associated with the presence of pre-existent congenital heart disease. Spine surgeons should be aware that patients with what may look like an idiopathic scoliosis may have this underlying syndrome, which warrants further paediatric consultation because of possibly serious concomitant pathology.

Hypothesis
1) The prevalence of scoliosis is increased in the 22q11.2 Deletion Syndrome (22q11.2DS). 2) There is a relation with congenital heart disease (CHD) and scoliosis. 3) A subset of the observed scoliosis in 22q11.2DS are of a biomechanically similar type as observed in adolescent idiopathic scoliosis (AIS).

Design
In the Philadelphia cohort we performed a retrospective analysis, in the Utrecht a cross-sectional.

Introduction
The 22q11.2DS is the most common microdeletion syndrome with an estimated prevalence of 1:4000 new-borns. 22q11.2DS is known to have wide phenotypic variability, including scoliosis. The goal of this study is to assess the prevalence of scoliosis, its characteristics and the association with congenital heart disease (CHD) in patients with 22q11.2DS.

Methods
Two cohorts from specialized 22q11.2DS clinics were included. The prevalence based on physical examination and questionnaires of the world's largest 22q11.2DS database (retrospective, Childrens's Hospital of Philadelphia) was augmented with the scoliosis prevalence based on radiography in a smaller cohort (cross-sectional, University Medical Center Utrecht).

Results
Within the Philadelphia cohort, a total of 1085 patients were included. Scoliosis develops throughout age and therefore, in order to determine the true prevalence of scoliosis, the group of patients older than 16 years (n=317) was used. The prevalence of scoliosis was 48%. A similar prevalence (49%) was shown for the Utrecht cohort (n= 97). In both cohorts gender was not associated with the occurrence of a scoliosis. Scoliosis was not associated with the presence of pre-existent CHD. Sixty-three percent of patients with scoliosis had a scoliotic curve pattern that resembled AIS.

Conclusion
Clinicians should be aware that scoliosis is highly prevalent (48-49%) in patients with 22q11.2DS. The majority of the 22q11.2DS patients have a curve type that resembles the curve pattern of AIS patients. Moreover, gender and CHD is not associated with the occurrence of scoliosis within this study

281. Scoliosis Severity in Cerebral Palsy Patients is Associated with Increased Need for Respiratory Assistive Aids

Christopher De Allie, BS; Megan Campbell, BA; Hiroko Matsumoto, PhDc; Benjamin Roye, MD, MPH; Michael Vitale, MD; David Roye, MD

Summary

This study examined the association between scoliosis severity and pulmonary dysfunction in patients with CP, 25% of whom relied on respiratory aids (RA). A significant difference was found between major coronal curve of patients who use RA and those who do not, and a 10.3x greater risk of RA use with major coronal curve ≥70° when controlling for other factors. This study highlights the need for longitudinal examination of scoliosis and pulmonary function to optimize treatment for this complex population.

Hypothesis

Patients with large spinal curves will demonstrate increased use of respiratory aids compared to those with smaller curves.

Design

Retrospective cohort study

Introduction

Respiratory comorbidities are a leading cause of death among patients with Cerebral Palsy (CP). Many undergo spine surgery to slow the progression of pulmonary decline; however, no consensus has been reached regarding respiratory benefits of spine deformity surgery in this population. The purpose of this study is to examine the association between scoliosis severity and pulmonary dysfunction in patients with CP.

Methods

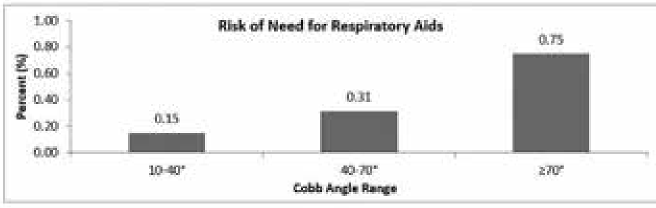
Patients diagnosed with CP and scoliosis seen at a single academic center between July 2005 and November 2016. Clinical data were obtained by chart review and survey. RA included ventilation, tracheostomy, supplemental oxygen, cough assist, or other. Patients who reported use of respiratory aids were compared to those who denied use using chi-square and independent sample t-tests in addition to binomial logistic regression.

Results

94 of 344 surveys were returned. 24 (25%) reported use of respiratory aids, of which 70.8% reported everyday use. Average major coronal curve for patients who rely on RA was 48 ± 28° compared to 33 ± 18° in patients who don't (p=0.031). The risk of RA use was higher for patients with larger curves, highest for patients with a major coronal curve of ≥70° (15% vs. 31% vs. 75% for curves 10°-40°, 40°-70°, and >70°; p<0.001) (Figure 1). In addition, GMFCS 1-3 patients relied on RA significantly less than GMFCS 4-5 patients (8.3% vs. 31.4%, p=0.025). Logistic regression revealed a 10.3 times greater risk of RA use in patients with major coronal curves ≥70° after controlling for GMFCS level and age.

Conclusion

Currently, surgical correction is indicated for patients with curvatures of 50° and above. These results support the hypothesis that coronal plane curvature leads to pulmonary decline and further justifies the current practice of preventing scoliosis progression in efforts to avoid respiratory demise and need for RA.



282. Should Decision Making for Lower Instrumented Vertebra (LIV) Go Beyond Traditional Assessment of Adolescent Idiopathic Scoliosis (AIS) Classification? A Dynamic 3D Gait Assessment of AIS†

Bassel Diebo, MD; Jeffrey Varghese, BS; Neil Shah, MD, MS; John Kelly, BA; Ayman Assi, PhD; Virginie Lafage, PhD; Frank J. Schwab, MD; carl paulino, MD

Summary

While Adolescent Idiopathic Scoliosis (AIS) classification provides a framework in the decision making of AIS surgery, determining LIV is a decision made based on static radiographs. This study showed that while the nature of the spinal curve might indicate a more caudal LIV, the decision needs to take into account the dynamic consequences.

Hypothesis

AIS patients differ in their post-operative walking pattern based on LIV.

Design

Prospective cohort

Introduction

Surgical planning in AIS poses a challenge for surgeons, especially in regard to selection of LIV, which is guided by Lenke classification and based on static radiographs (XR). Postoperative gait outcome data as it relates to LIV remains limited. Therefore, this study examined pre- and postoperative walking patterns to determine if LIV impacted outcomes.

Methods

From 2012 to 2015, preoperative patients underwent spine XRs and gait assessment, which was performed in a 6-DOF motion analysis laboratory. Patients were grouped based on LIV: Cephalad (LIV: T12, L1 or L2) or Caudal (LIV: L3 or L4), and were tagged with reflective markers before performing straight-line walking trials. Demographics, radiographic, and gait parameters were compared between groups at baseline and one year follow-up. Logistic regression model identified independent characteristics of the cohort

Results

No significant demographic differences were identified between the Cephalad group (n=15) and Caudal group (n=21) in terms of age or gender. Mean upper thoracic, thoracic, and lower lumbar curves were similar between cohorts (~26, 53 and 28°, respectively; p>0.05), but thoracolumbar curves were smaller in the Cephalad group (33.1 vs. 55.2°, p<0.01). Postoperatively, the Cephalad cohort had greater pelvic range of motion (ROM) in the horizontal plane (10.6° vs. 7°, p=0.017), knee flexion/extension ROM during the gait cycle (56.9° vs. 46.6°, p=0.043), and plantar flexion in stance (-30.9° vs. -23°, p=0.006). Walking speed was higher (1.2 m/s vs. 1.1 m/s p=0.045) and time spent with knee extension in stance was less (33.1 ms vs. 39.5 ms, p=0.016) in the Cephalad cohort also (Table 1). Increased plantar flexion (OR=1.7) and decreased hip horizontal ROM (OR=0.65) remained characteristic of the Caudal cohort's post-operative walking patterns (p=0.004).

Conclusion
While the nature of the curve may indicate a more caudal LIV, its selection should account for the consequences on postoperative gait dynamics.

Group	TL Curves	Pelvic Horizontal Plane ROM	Knee Flex/Extension ROM	Plantar Flexion	Knee Extension, stance (m/s)	Walking Speed (m/s)
Cephalad (T12-L2)	12.5°	10.6°	56.9°	-30.9°	33.1	1.2
Caudal (L3-L4)	19.9°	7.0°	46.6°	-23.0°	39.5	1.1
p-value	p = 0.025	p = 0.017	p = 0.043	p = 0.006	p = 0.016	p = 0.045

283. Surgery Outcomes of Idiopathic Scoliosis Surgery Related to Age and Length of Follow-up

Glenn Robin Buttermann, MD

Summary
Idiopathic scoliosis patients were followed for pain and function over 10 years postoperatively. AIS had greater pain relative to matched controls but improved to normals postoperatively. AIS patients treated surgically as adults had improvement similar to multilevel lumbar DDD surgery patients. All groups had gradual worsening pain scores 5 to 10 years postoperatively. This late decline may be related to adjacent segment conditions, or aging, as the controls groups, had a slow parallel decline.

Hypothesis
Surgical treatment of AIS and adults with adolescent onset has improved outcomes in addition to deformity improvement.

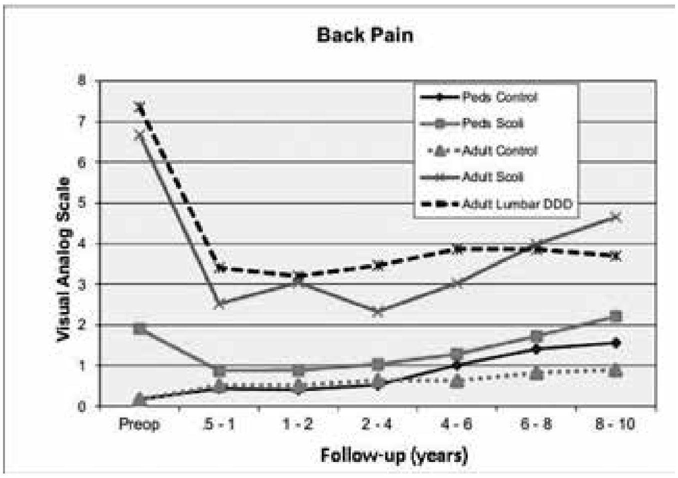
Design
Prospective cohorts (n=30 each) compared by outcomes over 10 years postoperatively.

Introduction
The natural history of back pain in AIS and long-term outcomes of surgical treatment in these pediatric and adult groups have not been fully reported. This study compared the 10-year surgical outcomes of both adolescent and adult with adolescent onset types, relative to normal controls, as well as multilevel lumbar DDD fusion patients.

Methods
Pain and disability were assessed (SRS-22R pain, VAS pain, ODI, pain drawing, VAS deformity) pre-and postoperatively for AIS, adults with AIS, DDD, and gender and age matched control groups (n=30 each).

Results
Preop AIS mean 51° preop curve and adult IS mean 54° preop curve. Postoperative pain outcomes found significant pain improvement for all groups which was stable for the initial 5 yrs postoperatively. During the subsequent 5 yrs, results slowly deteriorated; as did control groups at the 8-10 yr follow-up (p < 0.03). Adult controls trended toward worsening pain scores. Between groups, AIS had worse preoperative scores relative to controls, but postoperatively, there was no difference. Adult AIS relative to controls had worse scores across all time periods. DDD pts had similar scores to the Adult AIS. ODI scores improved significantly for adult surgical groups and remained stable. Deformity scores improved significantly for scoliosis groups and remained improved for >10 yrs.

Conclusion
AIS patients had greater pain compared to matched controls. Postoprative scores were similar and remain improved for the first 5 postoperative years, after which there was a gradual decline in both groups. Adult idiopathic scoliosis patients improved outcomes similar to patients who had multilevel surgery for lumbar DDD and remained stable over the first 5 postoperative years but then declined over the subsequent 5 years. The gradual decline 5 or more years after surgery may be related to adjacent segment conditions but also may be part of normal aging, as the controls also exhibited a slow parallel decline.



284. Surgical Algorithm in Pediatric Tubercular Spondylitis with Myelopathy

Arjun Dhawale, MBBS, MS; Kshitij Chaudhary, MBBS, MS; Avi Shah, MBBS, MS; Abhay Nene, MS

Summary
Tuberculosis (TB) with myelopathy in children is rare. and a single approach may not work in different clinico-radiological situations. An algorithmic approach with consideration of neurology, spinal instability, vertebral body involvement, kyphosis and cord compression is proposed for acute tubercular spondylitis with myelopathy. Mandatory cultures in view of high multi drug resistance (MDR) incidence and appropriate chemotherapy is important. Mulitiple vertebral involvement and MDR TB are risk factors for complications.

Hypothesis
An algorithm based on cord compression, spinal instability,

vertebral involvement, kyphosis with appropriate chemotherapy is useful for the treatment of pediatric tubercular spondylitis with myelopathy.

Design

Retrospective review of prospectively collected data

Introduction

Tubercular spondylitis with resultant compressive myelopathy and kyphosis in children is not common. There are very few reports on the treatment. With increasing incidence of multi-drug resistant tuberculosis (MDR TB), treatment strategies have evolved in tubercular spondylitis and a single approach may not work in different situations.

Methods

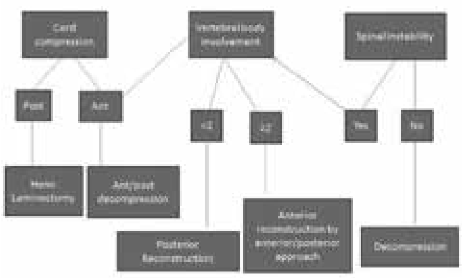
Demographics, clinical details, neurology (Frankel grades), spinal deformity, X-rays and magnetic resonance imaging (MRI) spine were evaluated. Children with myelopathy were surgically treated with biopsy, cultures, decompression and reconstruction as per the algorithm based on neurology, spinal deformity, vertebral involvement and cord compression (figure) with chemotherapy as per sensitivity. Decompression was done for 1 body involvement with no instability and decompression with fusion and reconstruction was done for 2 / >2 body involvement with instability and kyphosis by posterior or combined approach.. Primary outcome measures were postoperative neurology as per Frankel grades and resolution of infection. Secondary outcomes were kyphosis. Complications were recorded.

Results

21 patients, mean age 8.5 years (2–14), and minimum follow-up 24 months after index surgery. All were Frankel B, C or D. Two had multifocal spinal involvement. 47% patients had MDR TB. There was improvement in Frankel grade in 20 cases. There was a significant improvement in kyphosis (<0.05). 4 MDR TB patients needed revision surgery due to implant loosening, wound complications. and 2 patients had kyphosis progression.

Conclusion

An algorithmic approach with consideration of neurology, spinal stability and cord compression, mandatory cultures in view of high MDR incidence and appropriate chemotherapy is important for managing TB spondylitis with myelopathy. Multiple vertebral involvement and MDR TB are risk factors for complications. Further long term follow-up is necessary.



285. T1 Tilt is a Risk Factor for Postoperative Distal Adding-on in Lenke Type 1 Adolescent Idiopathic Scoliosis

<u>Yusuke Sakai, MD</u>; Takahiro Makino, MD; Shota Takenaka, MD; Takashi Kaito, MD, PhD

Summary

Predictors for postoperative distal adding-on after selective thoracic fusion for AIS were investigated including previously reported factors and postoperative residual T1 tilt. Higher MT curve correction rate and large residual T1 tilt were identified as predictors for postoperative distal adding-on in Lenke type 1 AIS. Unconscious correction of T1 tilt to improve head tilt may affect the development of distal adding-on.

Hypothesis

We hypothesized that residual T1 tilt is one of predictors for postoperative distal adding-on after selective thoracic fusion for AIS.

Design

A retrospective study.

Introduction

Selective thoracic fusion (STF) surgery for Lenke 1 idiopathic scoliosis generally achieves good clinical and radiographic results. However, postoperative loss of correction, which is named distal adding-on phenomenon, occurs during postoperative curse. The selection of the lowest instrumented vertebra (LIV) and the reduction of the apical translation of the main thoracic (MT) curve are reported to be important factors to prevent distal adding-on.

Methods

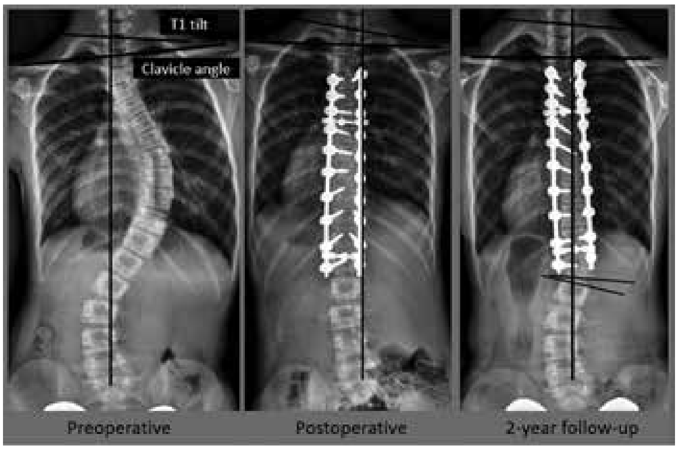
Twenty-six AIS patients (all Lenke type 1 and convex to the right, all female, mean age 16.9 [range; 12-29]) who received STF after 2012 were included. The minimum follow-up period is 2 years. The patients were classified into two groups (adding-on group vs. non-adding-on group) at 2-year follow-up. The two groups were compared in age, Risser grade, Lenke lumbar modifier at the time of surgery, and the following radiographic parameters in the early postoperative period; Cobb angle, apical translation, and correction rate of MT curve, fusion mass Cobb angle (FMC), trunk shift, LIV deviation from CSVL, radiological shoulder height, and T1 tilt. The positive value of T1 tilt was defined as the inclination to the right side.

Results

Distal adding-on occurred in 7 of 26 cases (27%), but no case received additional operation. In the early postoperative period, adding-on group had higher MT correction rate (78.9 ± 8.5 vs 67.5 ± 9.4%, p = 0.007), smaller FMC (2.2 ± 7.2 vs 11.1 ± 6.3°, p = 0.011), and larger T1 tilt (9.3 ± 3.7 vs 4.0 ± 4.6°, p = 0.011) than non-adding-on group. There was no significant difference between the two groups in age, Risser grade, Lenke lumbar modifier, apical translation, trunk shift, LIV deviation and radiological shoulder height.

Conclusion

Higher MT curve correction rate and large residual T1 tilt were the risk factors for postoperative distal adding-on in Lenke type 1 AIS.



286. The "Risser +" Grade. The "Risser +" Grade: A New Grading System to Classify Skeletal Maturity

Michael Troy, BS; Patricia Miller, MS; Nigel J. Price, MD; Vishwas Talwalkar, MD; Fabio Zaina, MD; Sabrina Donzelli, MD; Stefano Negrini, MD; <u>*Michael T. Hresko, MD*</u>

Summary

This study aims to propose and validate a new unified "Risser+" grade that combines the North American (NA) and European (EU) variants of the classic Risser score. The "Risser+" is a reliable scale to classify patients based on skeletal maturity when clinical data is known for participants in scoliosis research studies.

Hypothesis

The "Risser+" grade (RP) can effectively combine the North American and European Risser Classifications for skeletal maturity with adequate intra-rater/inter-rater reliability and agreement.

Design

Comparative study

Introduction

The Risser Plus (RP) scale is an 8 point system which combines the versions and assesses the triradiate cartilage (TRC) maturity; RP 0-(open TRC), 0+ (Closed TRC), 1, 2, 3, 3/4, 4 and 5.

Methods

Agreement and reliability were evaluated for 6 raters (3-NA, 3-EU) who assessed 120 pelvic radiographs from the BrAIST trial, all female, average age 13.4 (range 10.1-16.5 years). Blinded raters reviewed x-rays at two time-points. Intra- and inter-rater agreement (RA) were established with Krippendorff's alpha (k-alpha), while intra- and inter-rater reliability (RR) were established with intraclass correlation coefficients (ICC). Acceptable agreement and reliability were set a priori at 0.80.

Results

Inter-RA of RP sign for the 1st and 2nd readings was k-alpha of 0.72 (0.63-0.79) and 0.86 (0.81-0.90) respectively, and overall RA was alpha of 0.79 (0.74-0.84). EU raters exhibited slightly better agreement then NA Raters for both the first (EU: 0.78 vs NA: 0.66) and second readings (EU: 0.88 vs NA: 0.87) Intra-rater agreement was sufficient for 4 out of the 6 raters in the study (all k-alpha > 0.80). One rater from each of EU and NA presented subpar intra-rater agreement (k-alpha = 0.64 and 0.74, respectively). Graded response modeling determined reducing the number of categories in the RP scale increased intra-RA substantially with coefficients ranging from 0.87 to 0.96. 16 readings were identified in which 1 rater recorded a rating that was more than 4 units from the other 5 raters. After removing these values, agreement improved substantially with interRA at alpha 0.85. Most variability occurred at Risser 2-4. The EU raters had a slightly higher reliability, EU: ICC = 0.93 (0.91 – 0.95), NA: ICC = 0.91 (0.88 – 0.93).

Conclusion

The Risser+ system showed excellent reliability across multiple reads and raters and demonstrated 79% agreement over all reads and ratings. Agreement increased to over 85% when raters could distinguish Risser 0+ from Risser 5.

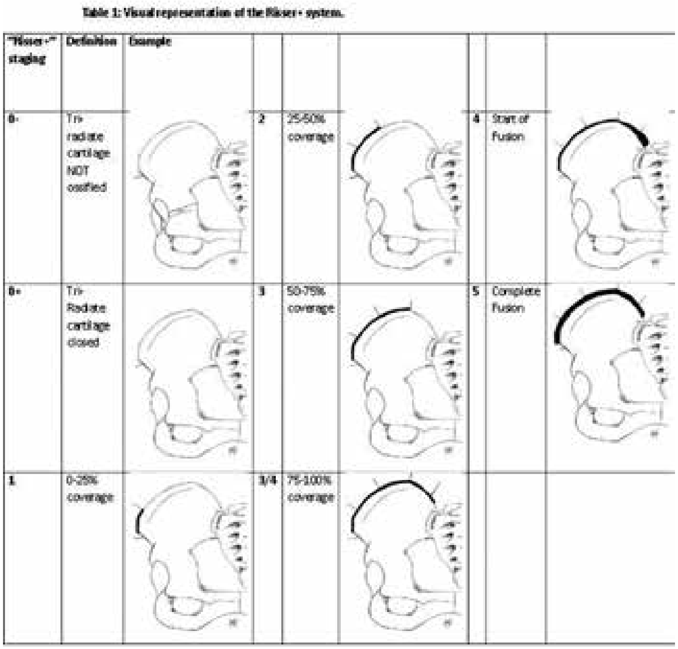


Table 1: Visual representation of the Risser+ system.

"Risser+" staging	Definition	Example						
0-	Tri-radiate cartilage NOT ossified		2	25-50% coverage		4	Start of Fusion	
0+	Tri-Radiate cartilage closed		3	50-75% coverage		5	Complete Fusion	
1	0-25% coverage		3/4	75-100% coverage				

287. The Contribution of the Rib Deformity to the Pulmonary Dysfunction in Congenital Scoliosis

<u>*Wenbo Li*</u>; Shifu Sha, MD; Enze Jiang, MD, PhD; Zezhang Zhu, MD

Summary

The effect of rib deformity on the pulmonary has not been well described previously in the setting of congenital scoliosis(CS).

Hypothesis

The rib deformity could have various influences on the pulmonary function in CS patients on the basis of different complexity.

Design

Retrospective Cohort.

Introduction

Congenital scoliosis is usually accompanied with the rib deformity. Cobb angle and the rib deformity are both important factors to the pulmonary dysfunction. The effect of the cobb angle was well researched. However, no prospective studies have been reported regarding the importance of the rib deformity when it comes to the pulmonary dysfunction. Thus, the purpose of this study was to investigate how much the rib deformity may contribute to the pulmonary dysfunction in congenital scoliosis.

Methods

A total of 108 adolescent patients with thoracic CS were reflected in the present study. They were divided into three groups. As a control group(N), CS patients without any rib deformity were included. The simple group(S) was consisted of 14 patients (mean age 13.21±3.92) with localized fusion or bifurcation of ribs or increased or decreased one or two ribs. The complex group was defined as patients with extensive fusion or bifurcation of ribs or a decrease of more than two ribs. All of these patients were evaluated by a standard test of pulmonary function.

Results

The group N (n=11,mean age 14.36±1.91) and group S (n=14, mean age 13.21±3.92)have similar pulmonary function on the basis of different pulmonary parameters(ERV:0.847±0.298 vs 1.138±0.482, p=0.094; FVC:2.779±0.847 vs 2.860±0.920, p=0.823; FEV1: 2.427±0.728 vs 2.512±0.798, p=0.786; MVV: 84.955±25.484 vs 87.932±27.839, p=0.786).Group C(n=11, mean age 13.36±2.29) was proved to have worse pulmonary function compared to group N(ERV:0.461±0.174 vs 0.847±0.298, p=0.001; FVC:1.896±0.637 vs 2.779±0.847, p=0.012; FEV1:1.606±0.589 vs 2.427±0.728, p=0.009; MVV:56.190±20.618 vs 84.955±25.484, p=0.009).

Conclusion

The simple rib deformity with localized fusion or bifurcation of ribs or increased or decreased one or two ribs has little effect on the pulmonary function. Those CS patients with complex rib deformity may experience about 30% more pulmonary dysfunction compared to those without rib deformity.

288. The Effect of Magnetically Controlled Growing Rod Lengthening on Kyphosis

Michelle Welborn, MD; Nikolas Baksh, MD; Joseph Ivan Krajbich, MD, FRCS(C);

Summary

In this study we found that MCGR did induce kyphosis with serial lengthening compared to initial postop images in halo gravity traction (HGT) pts but not compared to their preop kyphosis and not in nonHGT pts. We did find that patients are subject to diminishing returns after 2yrs

Hypothesis

We hypothesize that because the MCGR actuator is straight as it lengthens, the kyphosis at final follow up would not be significantly different from the kyphosis at initial curve correction. But rather the distribution of the kyphosis would be affected

Design

IRB approved retrospective cohort study of prospectively collected data. Patients with EOS treated with MCGR with or without preop halo gravity traction (HGT) were included in the database

Introduction

Sankar et al established the law of diminishing returns with dual growing rod constructs. Subsequently Spurway et al established the concept of Sagittal Spine Length and that rather than diminishing returns these constructs were inducing kyphosis so patients continued to gain length but that it was predominately in the sagittal plane

Methods

Radiographs and clinical records for EOS patients treated with MCGR at a single institution were reviewed. Demographics and radiographic measures, preop, post HGT, postop and most recent sagittal and coronal measurements and actuator length were recorded

Results

42 EOS patients underwent MCGR at a single site between 2014-2017,12 patients with prior growing constructs, and 10 with inadequate follow up were excluded. Neither group had a significant change in kyphosis vs preop at most recent follow-up. HGT patients had a temporary change in kyphosis at initial preop imaging but returned to preop levels at most recent follow-up. The avg actuator length gain for patients with >2yr fu avg .03mm/day, >1yr .04 mm/day, <1 yr .05mm/day. Length gained over time did show diminishing returns p=.006 when <1yr, >1 yr and >2yrs were compared, but did not show diminishing returns, p=.12 if >2yr followup was excluded

Conclusion

MCGR treatment did not result in increased kyphosis at most recent follow-up vs preop kyphosis. HGT pts had a temporary change in kyphosis at initial postop follow-up but returned to preop kyphosis at most recent follow-up. Unlike Sankar et al we did not see diminishing returns at 1yr, but we did see it at >2 yr follow-up. Unlike other forms of growth friendly surgery MCGR is not kyphogenic. Longer follow-up is needed to determine the full extent of diminishing returns

	Preop Kyphosis	Postop Kyphosis	Pre op Kyphosis vs post op p- value	Kyphosis at most recent follow-up	Pre op Kyphosis vs most recent p-value	Actuator length gain averaged over time	Duration follow-up
HGT	**29.58±30.75**	15.75±16.8	.027	**31.55±13.85**	**.811**	**.03 mm/day (.02-.04)**	712 days
Non HGT	**21.86±33.64**	19.64±11.16	.783	**27.34±23.39**	**.576**	**.04 mm/day (.01-.06)**	561 days
Total	20.75±29.02	15.15±13.14	.312	30.31±19.14	.177	.036 mm/day	621 days

289. The Fiber-Type Composition and the Occurrence of Adolescent Idiopathic Scoliosis: New Evidence for an Old Question†

Feng Zhenhua, MS; Lei-Lei Xu, PhD; Zezhang Zhu, MD; Jack C.Y. Cheng, MD; Yong Qiu, MD

Summary

In adolescent idiopathic scoliosis (AIS) patients, the proportions of type I fibers in paraspinal muscles are lower about 18.6 % on the concave side and lower about 16.2 % on the convex side when compared to the two sides of Congential Scoliosis (CS). Therefore, there should be a primary muscular disorder in AIS patients.

Hypothesis

Whether there is primary musculature abnormal in AIS patients?

E-Poster Abstracts

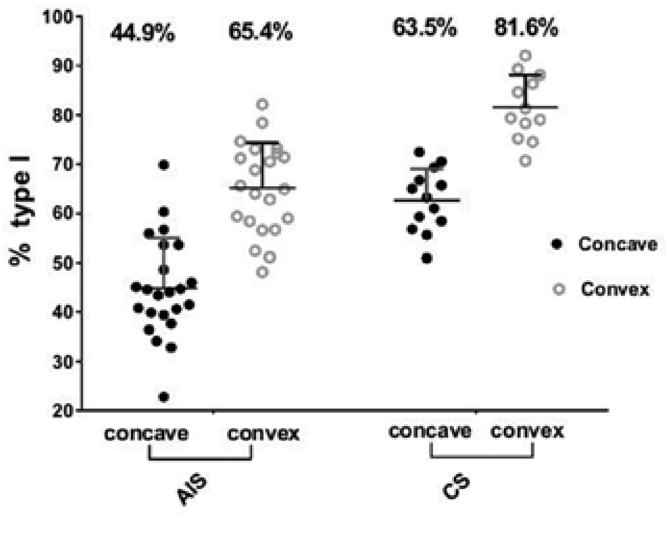
Design
A case-control study

Introduction
The etiology of AIS remains unknown in spite of extensive investigations. The paraspinal muscles function as vertebral segment stabilizers and lower percentage type I fibers in concavity than in convexity has been reported. For the lack of scoliotic curve-matched control, the asymmetry is primary or secondary still a controversial issue. In congenital scoliosis (CS), the differences in fiber composition between the convex and concave sides are considered secondary.

Methods
Twenty-five AIS patients (23 females, 11-18 years) and 14 CS patients (6 females, 12-16 years) were included. Muscle samples were taken bilaterally from the deep paraspinal muscles at the apex. The muscle fibers classified as type I (slow-twitch oxidative) and type II (glycolytic fast-twitch) by ATPase staining. Real time-polymerase chain reaction was used to detest the transcription level of the encoding type I myosin Myh7 and type II myosin gene Myh4 in muscles.

Results
There was a significantly lower proportion of type I fibers on both sides of paraspinal muscles in AIS patients compared to CS patients (concave, 44.9± 10.1% versus 63.5% ± 10.4%, p = 0.004; convex, 65.4% ± 9.0% versus 81.6% ± 9.7%, p=0.005), Figure 1. Accordingly, RT-PCR revealed a lower Myh7 expression in AIS than CS muscles.

Conclusion
Our results showed that the spinal musculature of AIS patients is different from CS patients. Therefore, the change in fiber-type composition in AIS should be primary in the pathogenesis of the spinal curve. In AIS patients, the change could be interpreted as that the muscles adopts a "faster", or more "glycolytic" profile , which is consistent with a reduced fatigue-resistant capacity and causing the occurrence of the scoliosis. In conclusion, the study supports fiber-type composition of paraspinal muscle involve in the etiology of AIS risk.



290. The Influence of Optimizable Patient Factors on Baseline Frailty in Adult Spinal Deformity

Frank Segreto, BS; Peter Passias, MD; Renaud Lafage, MS; Justin Smith, MD, PhD; Breton G. Line, BS; Bassel Diebo, MD, ; D. Kojo Hamilton, MD; Gregory Mundis, MD; Richard Hostin, MD; Jeffrey Gum, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher Shaffrey, MD; Christopher Ames, MD; Virginie Lafage, PhD; International Spine Study Group

Summary
Frailty, a more accurate measure of physiological age, has been associated with adverse post-operative outcomes. Optimizable patient factors may significantly influence preoperative frailty status and treatment outcomes. Depending on a patient's age, our analysis identified baseline(BL), BMI, drug/alcohol abuse, smoking status, osteoporosis, and anemia to influence as much as a 30% change in baseline frailty.

Hypothesis
Optimizable patient factors may significantly influence preoperative frailty status.

Design
Retrospective review of prospective multicenter ASD database.

Introduction
Given the clinical impact of a patient's frailty status, the next step is to determine optimizable patient factors that contribute to a patient's frailty. Optimizing a patient's preoperative health-state may impact frailty status and treatment outcomes.

Methods
ASD Patient's ≥18 y/o treated operatively or non-operatively, and complete BL frailty scores were included. ASD was defined as: coronal scoliosis ≥20°, SVA ≥5cm, pelvic tilt ≥25° and/or thoracic kyphosis >60°. Descriptive analysis determined cohort demographics. Patients were then stratified by age (<40, 40-65, and 65< years old), and controlled stepwise linear regression models determined significant predictors of BL frailty utilizing only the potentially modifiable patient factors.

Results
1,583 patients were included (Mean Age: 57.5, 77.1% F, 91% white, CCI: 1.53, Frailty score: 0.29). 242 patients were <40 y/o, 754 were 40-65 y/o, and 587 were >65 y/o. Regression models found increased BL BMI (B=0.387), drug/alcohol abuse (B=0.272), and osteoporosis (B=0.160) as the most significant optimizable predictors of increased baseline frailty in patients <40 y/o (R2=0.259), all p<0.001. For patients 40-65 y/o, increased BL BMI (B=0.425), smokers with increased # of pack years (B=0.201), and osteoporosis (B=0.228) were the most significant optimizable predictors of increased baseline frailty (R2=0.296), all p<0.05. For patients >65 y/o, increased BL BMI (B=0.196), osteoporosis (B=0.163), and anemia (B=0.096) were the most significant optimizable predictors of increased baseline frailty (R2=0.066), all p<0.05.

Conclusion
Optimizable patient factors such as osteoporosis, BMI, drug/al-

cohol abuse, smoking status, and anemia could influence change in baseline frailty by as much as 30%, depending on an ASD patient's age. Physicians and patients alike should be aware of the potentially modifiable drivers of a patient's baseline frailty status for preoperative optimization.

291. The Influence of Diffuse Idiopathic Skeletal Hyperostosis on Physical Function in Elderly Populations

Tomohiro Banno, MD, PhD; Daisuke Togawa, MD, PhD; Tomohiko Hasegawa, MD, PhD; Yu Yamato, MD, PhD; Go Yoshida, MD, PhD; Sho Kobayashi, MD, PhD; Tatsuya Yasuda, MD; Hideyuki Arima, MD, PhD; Shin Oe, MD; Yuki Mihara, MD; Hiroki Ushirozako, MD; Yukihiro Matsuyama, MD, PhD

Summary
A total of 504 elderly volunteers were enrolled. DISH subjects showed greater body weights, BMIs, blood pressures, and BMD compared to age and sex matched non-DISH controls while no inter-group differences were observed in physical function, HRQOL and spinopelvic parameters. However subjects with thoracic and lumbar DISH had significantly lower values of sit-and-reach and functional reach than those with thoracic DISH.

Hypothesis
DISH affects the physical function, spinal deformity, and HRQOL in elderly populations.

Design
A cohort study.

Introduction
DISH is associated with increasing age, obesity, and diabetes mellitus. However, little is known about the clinical impacts of DISH on physical function and spinal deformity in elderly populations. The purpose of this study was to elucidate the influence of DISH on physical function, spinal deformity, and HRQOL in elderly populations.

Methods
The study population included healthy Japanese volunteers over 50 years of age, who attended a local government's basic health screening. Height, weight, body mass index (BMI), blood pressure, grip strength, one-leg standing time, sit-and-reach, functional reach, and bone mineral density (BMD) were measured. Using whole spine standing x-rays, the prevalence, location, and numbers of fused vertebra of DISH, and spinopelvic parameters were measured. HRQOL measures, including the Oswestry Disability Index and the EuroQuol-5D were also obtained. We compared DISH subjects with control subjects, four times age and sex matched subject without DISH selected randomly. We compared the subjects with DISH in the thoracic spine (T-DISH) to those with DISH in the thoracic and lumbar spines (TL-DISH).

Results
The study enrolled 504 volunteers (187 men and 304 women, mean age 74.0 years). DISH occurred more frequently in men (15.5%) than in women (4.1%). The mean age was significantly higher in subjects with DISH than those without DISH. The mean number of fused vertebra by DISH was 5.5 ±1.5, and T-DISH was observed in 57% cases. DISH subjects showed greater body weights, BMIs, blood pressures, and BMD in the lumbar spine compared to controls. No inter-group differences were observed in physical function, HRQOL and spinopelvic parameters. Subjects with TL-DISH had significantly lower values of sit-and-reach and functional reach than those with T-DISH.

Conclusion
DISH did not affect physical function, spinal alignment, or HRQOL in elderly subjects. However, DISH in the lumbar region could be an indicator of physical function impairments and postural instabilities.

292. The One Stage Surgery Outcomes of Spinal Deformity with Syrinx With and Without Chiari Malformation: A 5-Year Follow-up Study

Yingsong Wang, MD; Jingming Xie, MD; Tao Li, MD; Zhi Zhao, MD; Ni Bi, MD; Ying Zhang, MD; Zhiyue Shi, MD

Summary
The long term outcomes of one stage surgery treating spinal deformity with syrinx was satisfactory.

Hypothesis
Neurosurgical decompression prior to correction for spinal deformity with syrinx was not always necessary, one stage surgery could correct the deformity, help to improve syrinx and neurological status.

Design
Retrospective study.

Introduction
There is few long term follow-up study that focus on using one stage surgery to correct spinal deformity with syrinx, especially for the patients with and without Chiari malformation(CM).

Methods
Spinal deformity patients with syrinx received one stage spinal correction surgery at our institution were reviewed, the minimum follow-up was 5 years. Patients with swelling syrinx and severe neurological deficits were excluded. The patients with a good flexibility (> 30%) and small main curve (< 80°) were received posterior correction surgery, otherwise, received PVCR. Demographics, morphological, surgical outcomes were recorded and syrinx were assessed by MRI.

Results
Twenty-eight patients met inclusion criteria, 12 patients received PVCR and 16 received posterior surgery. 20 patients were associated with CM. Nine syrinx located at the cervical, 5 at the main curve, 14 were mix. Scoliosis was corrected from 75.9° to 26.5°, and 27.8° at final follow up. Kyphosis was corrected from 50.4° to 26.4°, and 27.9° at final follow-up. Preop mild neurological deficits were observed in 3 and improved after surgery. No spinal cord injury from surgery. Syrinx decreased in 8. Male, severe curve, PVCR and syrinx located in whole spinal cord were more common in patients with CM, but surgical outcomes had no different between patients with and without CM.

Conclusion

The one stage surgery outcomes of spinal deformity with syrinx with a 5-year follow-up was satisfactory. Neurosurgical decompression prior to correction was not always necessary, spinal surgery can help to improve the syrinx and neurological deficits. The surgery outcomes were the same in patients with and without CM.

	Idiopathic Syringomyelia (n=8)	Syringomyelia + Chiari malformation (n=20)	P
Age (yr)	15.8 ± 2.0	15.8 ± 3.1	P>0.05
Sex (M/F)	4/4	14/6	P>0.05
Neurological deficits	1 (12.5%)	2 (10%)	P>0.05
Pre coronal Cobb(°)	61.9 ± 18.9	81.5 ± 27.0	P<0.05
Post coronal Cobb(°)	21.4 ± 10.5	28.6 ± 17.9	P>0.05
Final coronal Cobb (°)	22.8 ± 11.6	30.1 ± 19.1	P>0.05
Pre sagittal Cobb(°)	37.6 ± 24.4	55.5 ± 33.1	P<0.05
Post sagittal Cobb(°)	26.0 ± 3.7	26.6 ± 14.4	P>0.05
Final sagittal Cobb (°)	27.0 ± 4.8	27.8 ± 15.6	P>0.05
Surgery			
PVCR	1	9	P<0.05
Posterior correction only	7	11	
Maximal syrinx/cord ratio	0.49 ± 0.16	0.64 ± 0.22	P<0.05
Syrinx Location			
Cervical	4	5	P>0.05
Main curve region	2	3	
Mix	2	12	
Chang of the Syrinx			
Decrease	2	6	P>0.05
Increase	0	0	
No change	6	14	

293. The Role of Traditional Growing Rods in the Era of Magnetically-Controlled Growing Rods for the Treatment of Early-Onset Scoliosis*

Eric Varley, MD; Burt Yaszay, MD; Jeff Pawelek, BS; Gregory Mundis, MD; Matthew Oetgen, MD; Peter Sturm, MD; Behrooz Akbarnia, MD; Growing Spine Study Group

Summary

While enthusiasm for less invasive distraction-based treatment for early-onset scoliosis (EOS) has grown, the utility of traditional growing rods (TGR) in the magnetically-controlled growing rod (MCGR) era has yet to be defined. The purpose of this study was to describe the clinical and radiographic profiles of patients treated with TGR in the MCGR era to define the continued role of TGR.

Hypothesis

There is a continued role for TGR in the surgical treatment of EOS in the MCGR era.

Design

Multicenter retrospective review.

Introduction

While enthusiasm for less invasive distraction-based treatment for early-onset scoliosis (EOS) has grown, the utility of traditional growing rods (TGR) in the magnetically-controlled growing rod (MCGR) era has yet to be defined. The purpose of this study was to describe the clinical and radiographic profiles of patients treated with TGR in the MCGR era to define the continued role of TGR.

Methods

A multicenter EOS registry with 19 U.S. based centers was used. TGR patients were enrolled into this study after the approval and use of at least one MCGR at the respective centers. Of the 19 centers 8 performed at least one TGR surgery after performing their first MCGR. 25 TGR patients met inclusion criteria. Patient demographics and pre-op radiographic data were summarized for each TGR and clinical notes were reviewed in detail to determine the specific underlying clinical decision making.

Results

The reported clinical decision making for utilizing of TGR included: 1) sagittal plane profile, 2) trunk height, 3) co-morbidities requiring either pacemaker or repeat MRI, and 4) other including behavioral issues, parental concerns, and limited remaining growth. Four patients had a combination of indications 1) and 2) with 1) listed as the primary factor. All EOS etiologies were represented. Mean pre-op radiographic parameters for TGR (n=25) and the MCGR patients performed during the same time period at the same sites (n=125) are listed in Table 1. For TGR patients whose reported indication was short trunk height, mean pre-op T1-S1 and T1-T12 were 214 and 117 mm, respectively, compared to 273 and 174 for MCGR patients.

Conclusion

TGR continues to be utilized in the current MCGR era. In this study the most commonly reported indications for TGR was surgeon concerns of sagittal plane profile and trunk height not providing adequate space for the MCGR actuator. As further experience is gained with MCGR, these indications for TGR will likely be refined.

Table 1

Surgeon-Reported Indications for TGR		N
Sagittal Profile		11
Short Trunk		6
MRI/Pacemaker		4
Other (behavioral issues, parental concerns, limited remaining growth)		4
Demographic & Radiographic Parameters	**TGR**	**MCGR**
Mean Pre-op Age (years)	6.9 (range, 2.8-13.8)	7.5 (range, 2.7-11.7)
Etiologies		
Congenital:	40%	12%
Idiopathic:	28%	20%
Neuromuscular:	8%	51%
Syndromic:	24%	17%
Mean Major Curve (°)	78 (range, 33-127)	77 (range, 7-141)
Mean T1-S1 (mm)	240 (range, 161-356)	273 (range, 166-4250)
Mean T1-T2 (mm)	149 (range, 79-230)	174 (range, 84-242)
Mean Max Kyphosis (°)	48 (range, 2-110)	55 (range, 3-104)

294. The Smartphone as a Tool to Screen for Scoliosis, Applicable by Everyone

Hanneke van West, MD; Julie Herfkens, BSc; Max Reijman, PhD

Summary

The accuracy and precision of a cheaper and more available screening tool for scoliosis is evaluated in 50 adolescent patients with scoliosis. Both medical professionals and patient's parents performed the axial trunk rotation (ATR) measurement during the Adam Forward Bending Test (AFBT) comparing the gold standard (scoliometer) to the smartphone with app and casing. The smartphone with app and casing can be used as a screening tool, even by the patient's parent.

E-Poster Abstracts

Hypothesis
A minimum correlation coefficient of 0.8 between the smartphone with app and casing (index tool) and Scoliometer (reference tool). A minimum of 0.8 intraclass correlation coefficient (ICC); both intra-observer and inter-observer among the measurements with smartphone with app and casing.

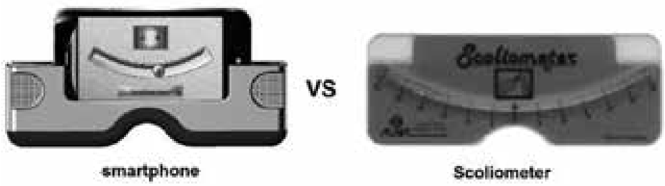
Design
diagnostic accuracy

Introduction
Abandoning standard school screening for scoliosis in the Netherlands has led to discovering scoliosis in children at a later age. We believe it is important to find these patients at an earlier phase in order to be able to prevent large spinal surgery. Scoliometers are not easily available and therefore not routinely used in screening. This is why a new tool was developed using the smartphone, a device owned by the majority. Adding a casing that is designed to adapt to the spine creates a better available alternative to the currently used scoliometer. With this tool everyone, even non physicians, should be able to accurately obtain the ATR.

Methods
50 consecutive patients which visited the outpatient clinic of an University Medical center with idiopathic scoliosis were asked to perform the AFBT. The ATR was measured 6 times , namely twice by an orthopaedic surgeon, twice by a medical student and twice by the patient's parent using the smartphone with app and scolioscreen casing. The orthopedic surgeon and the student also measured the ATR with the scoliometer. Accuracy was measured using the Pearson correlation coefficient between smartphone with app and casing and scoliometer. Precision was defined analyzing the inter- and intra-observer variability.

Results
6 boys and 44 girls were included at mean age of 14 years and Cobb angle of 38.5degree (SD14,7degree). The smartphone vs. scoliometer measurement showed a Pearson correlation coefficient of 0.97. All the intra class correlations, both intra- and inter-observer reached a value over 0.92. So all predefined hypotheses were confirmed.

Conclusion
The smartphone with application and casing (scolioscreen) has the same diagnostic accuracy and precision as the scoliometer in measuring the Axial Trunk Rotation (ATR). Patient's parents were capable of performing the test with comparable accuracy.



295. The Vertebral Rotation Caudal to Major Thoracic Curve as a Supplementary Determinant to Lenke type 1&2A Adolescent Idiopathic Scoliosis (AIS)

Yuan-Fuu Lee, MD; Chih-Wei Chen, MD; Ming-Hsiao Hu, MD; Shu-Hua Yang, MD, PhD

Summary
The vertebral rotation caudal to major thoracic curve could further delineate the treatment prognosis of AIS, especially combined with 1AR/L modification. Thus, the vertebral rotation caudal to major thoracic curve is an valuable supplementary determinant in Lenke type 1&2A AIS patients. RS may play a supplementary determinant in determining LIV of 1&2A, may be applied with/without AR/AL. RO in1&2A patient, the curve patterns act like lumbar modifier B/C.

Hypothesis
The vertebral rotation caudal to major thoracic curve (EV+1) cause different adding-on rates.

Design
Lenke type 1&2A adolescent idiopathic scoliosis (AIS) patients were divided by selective fusion and the vertebral rotation caudal to major thoracic curve. Selective fusion or not were further marked as SF(selective fusion) and NSF(non-selective fusion). The vertebral rotation caudal to major thoracic curve was defined as same direction as thoracic curve(RS) and opposite direction(RO). The data of four groups were further analyzed including correction rate, adding-on rates.

Introduction
The vertebral rotation in thoracolumbar/lumbar curves has been mentioned in several studies. The rotation grade of lumbar curves may influence the decision of lowest instrumented level (LIV). In previous studies, some authors established a suggestion based on the L4 tilt direction. Our aim is to find out whether the directions of vertebral rotation in thoracolumbar/lumbar curves affect the surgical outcomes of Lenke type 1&2 adolescent idiopathic scoliosis (AIS) patients.

Methods
The patients classified as Lenke type 1&2A adolescent idiopathic scoliosis (AIS) collected from 2 medical centers. The patients underwent operation during 2005/6~2015/7 were enrolled. The follow-up time all beyond 2 years. The data were reviewed by 2 spinal specialists retrospectively. The standing whole spine plain films and bending views were reviewed.

Results
The results showed incidence of adding-on in all patients is 12.5%. Adding-on in 1AR patients with selective fusion is 28%, while in RS patients with selective fusion is 50%. Further more, the adding-on rates increased to 62% in patients have both 1AR and RS characteristics underwent corrective surgery.

Conclusion
RS may play a supplementary determinant in determining LIV of 1&2A, may be applied with/without AR/AL. RO in 1&2A patient, the curve patterns act like lumbar modifier B/C.

Adding-on rate in selective fusion

L4 tilt	R	L
RS	8/13(62%)	0/3
RO	0/15	0/11

296. Thoracic Spinal Deformities Affected Cardiopulmonary Function in Patients with Scoliosis

Youxi Lin, MD; Tianhua Rong, MD; Zheng Li, MD; Wangshu Yuan; Hui Cong, MS; Jinmei Luo, MD; Jianxiong Shen, MD

Summary
Prior studies of static pulmonary function test indicated that scoliosis had the potential to impair respiratory function. However, little is known about its impact on the exercise capacity. Our studies of dynamic cardiopulmonary function testing revealed that although exercise tolerance seemed not affected, severe or congenital scoliosis negatively influenced patients' breathing pattern while exertion.

Hypothesis
Severity and etiology of scoliosis affected exertion tolerance in scoliotic patients.

Design
A prospective study.

Introduction
Prior studies of static pulmonary function test(PFT) indicated that scoliosis impaired respiratory function. However, little is known about its impact on the exercise capacity. The aim of our study is to investigate whether the severity and etiology of scoliosis affected exertion tolerance.

Methods
187 patients were included in this study from 2014 to 2018. Radiographic parameters of the spine were measured, and results of PFT and cardiopulmonary exercise testing(CPET) was collected. Pearson and Spearman correlation test were performed. Student-t test was used to analyze differences between groups.

Results
113 females and 74 males aged 19.0 years averagely, with mean main thoracic curvature(MTC) of 58.9°, were included. In PFT, MTC and apical vertebral translation were significantly correlated with forced expired volume in one second(FEV1)(P<0.05), forced vital capacity(FVC)(P<0.01), total lung capacity(TLC) (P<0.01), but not with FEV1 /FVC(P>0.05). In CPET, radiographic parameters were significantly correlated with 3 of 4 parameters of ventilation, including tidal volume(Vt)(P<0.01), respiratory rate(RR)(P<0.01) and breathing reserve(BR) (P<0.05), but not with minute ventilation(VE)(P>0.05). Blood oxygen saturation(SpO2)(P<0.05) and its decrease(P<0.05) were also significantly correlated with radiographic parameters. No correlation was found between radiographic data and oxygen intake(VO2), oxygen pulse(O2/pulse) and maximal heart rate(HR) (P>0.05). Patients were divided into 2 groups(A congenital, 61 patients and B idiopathic, 126). No significant difference was discovered between the two groups in FEV1, FVC, TLC and FEV1/FVC, whereas in CPET, Group A had significantly higher RR(P<0.01), lower Vt(P<0.01) and lower SpO2(P<0.05). There was no difference in VE, VO2, O2/pulse and HR between groups.

Conclusion
Exercise capacity seemed not correlate to the severity of the thoracic deformities. However, CPET revealed abnormal breathing pattern and decompensation of ventilation and gas exchange in patients with severe or congenital thoracic spinal deformity.

297. Timing of Surgical Treatment in Adolescent Idiopathic Scoliosis: A Retrospective Analysis

Jamal McClendon Jr, MD; Judson W. Karlen, MD; Gregory R. White, MD

Summary
The progression of adolescent idiopathic scoliosis (AIS) has been defined for curves approaching 45 degrees, however the rate or progression and timing of surgical treatment from the decision point has yet to be clarified. Our study examined the time from surgical scheduling to actual intervention, and whether this impacted last touched vertebrae or distal fusion level. Only Lenke lumbar B and C modifiers predicted distal decompensation at last follow-up.

Hypothesis
Skeletally-immature patients who delay treatment greater than 90 days will significantly change radiographic parameter of maximum Cobb angle and last touched vertebrae, and potentially change distal fusion level.

Design
A level III retrospective analysis

Introduction
Natural history studies have demonstrated progression of AIS for Cobb angles approaching 45 degrees. Furthermore, studies showed curves will progress substantially if patients wait >6 mo for surgery if deemed a surgical candidate. No study has evaluated the progression of the last touched vertebra (LTV), nor evaluated the impact on distal fusion level during this time.

Methods
After IRB approval, all pediatric patients undergoing posterior spinal fusion at a single-institution between 1/1/2008 and 12/31/2013 for adolescent idiopathic scoliosis were retrospectively analyzed. Patients with congenital scoliosis, neuromus-

cular scoliosis, or early-onset scoliosis with prior growing-spine constructs were excluded. Descriptives and bivariate analysis were performed. Mean follow-up 2.2 (SD=1.6)

Results

181 patients (160F:21M) between 10-24 years (mean=14.9 years, SD=2.1) met inclusion criteria. Mean time from scheduling to actual surgery was 4.5mo (SD=2.6), and 121 patients scheduling >3mo out. Mean maximum Cobb angles were 53.6 (SD=11.4), 57.8 (SD=12.0), and 14.4 (SD=9.2) for time of decision for surgery, pre-surgery, and postoperatively, respectively. Thirty-nine patients changed LTV. There was no statistical significance waiting >3mo with LTV or altering distal fusion levels, p>.05. Risser (0-2) did not predict change in LTV or distal fusion level waiting > 3mo for surgery. Having Lenke B or C lumbar modifier predicted distal junction decompensation independent of skeletal maturity, p=.024

Conclusion

This is the first study to examine progression of the LTV from time of surgical scheduling to intervention with no correlation with time >3 mo. This did not impact distal fusion levels. Thus, children waiting til end of school to have surgery for AIS may progress clinically and radiographically, however will not alter distal fusion level. Lenke B and C modifiers predict distal decompensation with time.

298. Tranexamic Acid Inhibits Plasminogen in Adolescent Idiopathic Scoliosis Surgery†

Susan M. Goobie, MD, FRCPC; David Zurakowski, PhD, MS; Michael T. Hresko, MD

Summary

Tranexamic acid (TXA), a potent antifibrinolytic, is a competitive inhibitor of plasminogen. In this randomized controlled trial, the efficacy in decreasing blood loss has been reported. We now define TXA efficacy in a direct manner; measuring biological markers of fibrinolysis. A significant decrease in plasminogen over time in the TXA group and a corresponding rise over time in the placebo group is reported. Plasminogen may be used as a marker of the antifibrinolytic efficacy of TXA in future investigations.

Hypothesis

Biological markers of fibrinolysis differ during AIS surgery in TXA patients compared to placebo patients.

Design

Randomized controlled double blind trial.

Introduction

We previously reported the efficacy of tranexamic acid (TXA) in decreasing blood loss for patients undergoing Adolescent Idiopathic Scoliosis (AIS) Surgery by an overall average of 27% compared to placebo (primary aim)(1). The secondary aim; to better define efficacy of TXA in a direct manner using a novel marker of fibrinolysis, is reported here.

Methods

This Internal ethics review board approved prospective randomized trial of TXA (50 mg/kg loading dose and 10 mg/kg/h infusion) included 68 successive (of 119 enrolled) AIS surgery patients (clincaltrials.gov NCT01813058) in this secondary analysis. Plasma was analyzed for plasminogen levels and the other presumed predetermined markers of fibrinolysis before surgery and after surgery. We measured the following markers; plasminogen, plasmin-antiplasmin complex (PAPC), plasminogen activator inhibitor , tissue plasminogen activator and alpha2-antiplasmin.

Results

Demographics and variables did not differ in TXA cohort (n=34) compared to placebo controls (n=34). There was no difference in hemostatic laboratory values between groups (PT, PTT, INR, Fibrinogen). A difference between the groups in the change in plasminogen levels is reported; TXA shows a mean reduction and placebo an increase(p < 0.001), see Table 1. No other group differences were observed, except an increase in the change in mean PAPC with TXA compared to placebo (p = 0.03).

Conclusion

The biological mechanism of TXA is to inhibit plasminogen and to inhibit the conversion of plasminogen to plasmin (competitive inhibitor) at therapeutic levels. We report in AIS surgery that plasminogen levels in the TXA group decreased over time while in the placebo group plasminogen increased over time indicating inhibition of the fibrinolytic cascade by tranexamic acid during scoliosis surgery. Plasminogen may be used as a biological marker of the antifibrinolytic effects of TXA in future investigations.

Ref: 1. SRS Meeting 2017 HIBBS Clinical Research award. Dose response relationship of Tranexamic Acid in AIS Surgery.

Comparison of Treatment Groups Based on Biological Markers of Fibrinolysis

	Pre Mean Levels			Post Mean Levels			Δ (Pre-Post) Levels	
Biomarker	Placebo	TXA	p-value	Placebo	TXA	p-value	F-test	p-value
Plasminogen (pg/dl)	2160	2095	0.58	2670	1944	<0.001*	19.4	<0.001*
PAPC (mg/ml)	407	382	0.42	625	751	0.13	4.8	0.03*
PAI-1 (ng/ml)	20	22	0.65	24	29	0.38	0.2	0.67
tPA (pg/ml)	2262	2388	0.69	3004	3193	0.65	0.3	0.59
alpha2 AP (ug/ml)	78	89	0.25	61	62	0.83	1.0	0.32

Data are mean values. Groups compared using repeated-measures ANOVA. * Statistically significant difference between the two groups. Evidence indicates a difference between the groups in the change in plasminogen levels where TXA shows a mean reduction and placebo an increase in level (p < 0.001). No other group differences were observed, except a somewhat larger mean increase in the change in PAPC with TXA compared to placebo (p = 0.03). PAPC =plasmin-antiplasmin complex, PAI-1 =Plasminogen activator inhibitor , tPA =tissue plasminogen activator and alpha2 AP =alpha2-antiplasmin

299. Transcranial Motor Monitoring is Possible and Protective in Charcot-Marie-Tooth Disease Spinal Deformity Surgery

Jeffrey Peck, MD; Kiley Poppino, BS; Daniel J. Sucato, MD, MS; Steven Sparagana, MD; Patricia Rampy, CNIM

Summary

The ability to obtain IONM in the CMT population has previously been reported to be difficult. In a series of 23 CMT patients, SSEPs were obtainable only 20% of the time. However, following the introduction of TcMEPs, IONM was obtained in

83% (p<0.001), with 8.3% demonstrating critical changes but no new post-operative neurologic deficits occurred. Addition of this modality to the IONM regimen has allowed for more reliable monitoring in the CMT population.

Hypothesis
The addition of TcMEPs will enhance the ability to obtain baseline IONM in CMT patients undergoing spinal deformity surgery.

Design
Retrospective chart review

Introduction
Intraoperative neuromonitoring (IONM) has historically been difficult to perform in pediatric patients with CMT disease. Transcranial motor evoked potentials (TcMEPs) have been found to be safe and effective for patients with idiopathic spinal deformity. There are no studies analyzing the effectiveness of TcMEP monitoring in patients with CMT.

Methods
A retrospective analysis of a consecutive series of patients with CMT undergoing spinal deformity surgery at a single institution. A 2:1 matched cohort of idiopathic spinal deformity patients was used as a control group. The IONM records and overall outcomes were reviewed. Standard statistical analysis was defined as p<0.05.

Results
Twenty-three CMT patients with 26 surgical cases were identified. Patients were a mean age of 14.1 years and a mean maximum preoperative cobb angle of 63°. When compared to SSEP, TcMEP use improved the ability to obtain baseline IONM (20% vs 83%; p<0.001). Baseline monitoring was obtained less often in CMT patients for both SSEP (20% vs 100%; p<0.001) and TcMEP (83% vs 100%; p=0.11) compared to idiopathic patients. In CMT patients, the tibialis anterior muscle trended towards being the most robust lower limb signal (p=0.059). A mean TcMEP sweep length of 150 msec (100-200 msec) was seen in cases with IONM not obtained while the mean was 300 msec (100-1000 msec) in cases in which baseline TcMEPs were obtained. There was one CMT patient and no idiopathic patients in whom critical IONM changes were noted. In this patient, release of intraoperative traction led to resolution of the IONM changes. No patients had new postoperative neurologic deficits.

Conclusion
Obtaining IONM in CMT patients undergoing spinal deformity surgery has been previously viewed as an often impossible achievement. The addition of TcMEP monitoring significantly improves the ability to provide reliable IONM for this patient population. Utilizing longer sweep lengths when obtaining TcMEPs may enhance the ability to attain baseline readings.

300. Unplanned Return to Operation Room (OR) following Growing Spinal Constructs(GSCs) in Early Onset Scoliosis (EOS): A Multi-Centric Study

Saumyajit Basu, MD, FRCS; Anil Solanki, MS, DNB; Ankur Goswami, MD; Govindaraja Perumal Vijayaraghavan, MD; Abhishek Srivastava, MBBS, MS; Ajoy Prasad Shetty, MS, DNB; S. Rajasekaran, PhD; Arvind Jayaswal, MS

Summary
Growing spinal constructs (GSCs) in early onset scoliosis (EOS) require a frequent visit to operation room (OR) which includes a significant number of unplanned surgeries regardless of implant type and initial Cobb angle. This should be well understood by the surgeon, patient and care-takers. Syndromic aetiology and age at primary surgery <5 years are associated with higher risk of unplanned surgeries. Implant failure (rod/screw breakage & anchor pull-out) and wound healing problems/infection are the common causes of unplanned surgeries.

Hypothesis
GSCs in EOS are associated with an extremely high rate of unplanned surgeries independent of implant type and Cobb angle but is significantly higher with syndromic cases and age at index surgery <5 years

Design
Multi-centric retrospective study

Introduction
GSCs in EOS require repeated planned expansion procedures. Studies have reported variable rate of complications requiring an unplanned return to OR which demands extra resources.The purpose of this study is to evaluate the incidence and risk factors associated with the same.

Methods
Medical records of 51 patients of EOS operated at 3 different centres using various types of GSCs were evaluated for complications requiring unplanned surgeries. Data were analysed to find out rate of unplanned surgeries in relation to the aetiology, age at index surgery, type of implant and Cobb angle at presentation. The cause of unplanned surgery and management were also analysed.

Results
Out of 51 patients, 3 expired in the early post-op period. 48 patients of EOS operated by GSCs with a mean age of 6.7 years (range 2 to 12 years) with an average follow-up of 67.3 months were studied. There were 30 congenital, 10 idiopathic, 4 syndromic and 4 neuromuscular cases. 39 out of 48 patients had 1 or more unplanned surgeries on follow-up (81.25%). Out of total 248 surgeries following index procedure, 82 were unplanned surgeries (33.06%), including 53 implant revisions, 12 implant removal, 14 debridement and 2 flaps.The common complications were 24.14% rod/screw breakage, 42.53% anchor pull-out, 16.09% infections, 6.90% wound dehiscence and 4.6% neuro-deficits.Unplanned surgeries were significantly higher in syndromic(58.8%) compared to neuromuscular(52.9%), congenital(27.2%) and idiopathic(37.8%) cases(p<0.05). Patients with age at index procedure of <5 years showed higher unplanned surgeries than age >5 years(2.5 and 1.23 per patient respectively, p<0.05). Type of implant and initial Cobb angle did not significantly affect the rate of unplanned surgeries(p >0.05)

Conclusion
GSCs in EOS requires a frequent unplanned return to OR and

is more common with syndromic cases and age at index surgery <5 years.

	Planned	Unplanned	Total Surgeries	Percentage of Unplanned	No of patients	Unplanned surgery per patient
Syndromic	7	10	17	58.82%	4	2.5
Non syndromic	159	72	231	31.17%	44	1.63
p <0.05						
Age <5 years	73	45	118	38.14%	18	2.5
Age >5 years	93	37	130	28.46%	30	1.23
p <0.05						
Spine to spine	119	62	181	34.25%	35	1.77
Rib to Spine	47	20	67	29.85%	13	1.54
p>0.05						
Cobb >70	56	23	79	29.11%	19	1.21
Cobb <70	96	43	139	30.94%	29	1.48
p >0.05						

301. Whole Exome Sequencing of Monozygotic Twins Discordant for Congenital Scoliosis

Zheng Li, MD; Chong Chen, MD; Haining Tan, MD; Tianhua Rong, MD; Youxi Lin, MD; Xingye Li, MD; Jianxiong Shen, MD

Summary

The exact etiology of congenital scoliosis remains unknown as yet. It seems that its development may be influenced by both genetic predisposition and environmental factors, at varying degrees. Whole exome sequencing and PCR analyzing of monozygotic twins discordant for congenital scoliosis (4 twins) and then the gene mutations were identified. This is the first research to comprehensively identify gene mutations by using whole exome sequencing and PCR analyzing in monozygotic twins discordant of Congenital Scoliosis.

Hypothesis

The gene mutations involved in development of monozygotic twins discordant for congenital scoliosis (CS)

Design

Based on monozygotic twins discordant of CS to identify and investigate gene mutations between monozygotic twins and relationships related to pathogenesis of CS.

Introduction

Congenital scoliosis is the abnormal development of the spine resulting in combination of missing portion, partial formation, or lack of separation of the vertebras. Susceptibility loci have been identified for CS, yet a large part of the genetic variance remains unexplained.

Methods

Whole exome sequencing and PCR analyzing was performed to determine the genetic differences between monozygotic twins discordant for congenital scoliosis (4 twins). Quantitative real-time polymerase chain reaction (RT-PCR) was performed to validate the expression of selected gene mutation.

Results

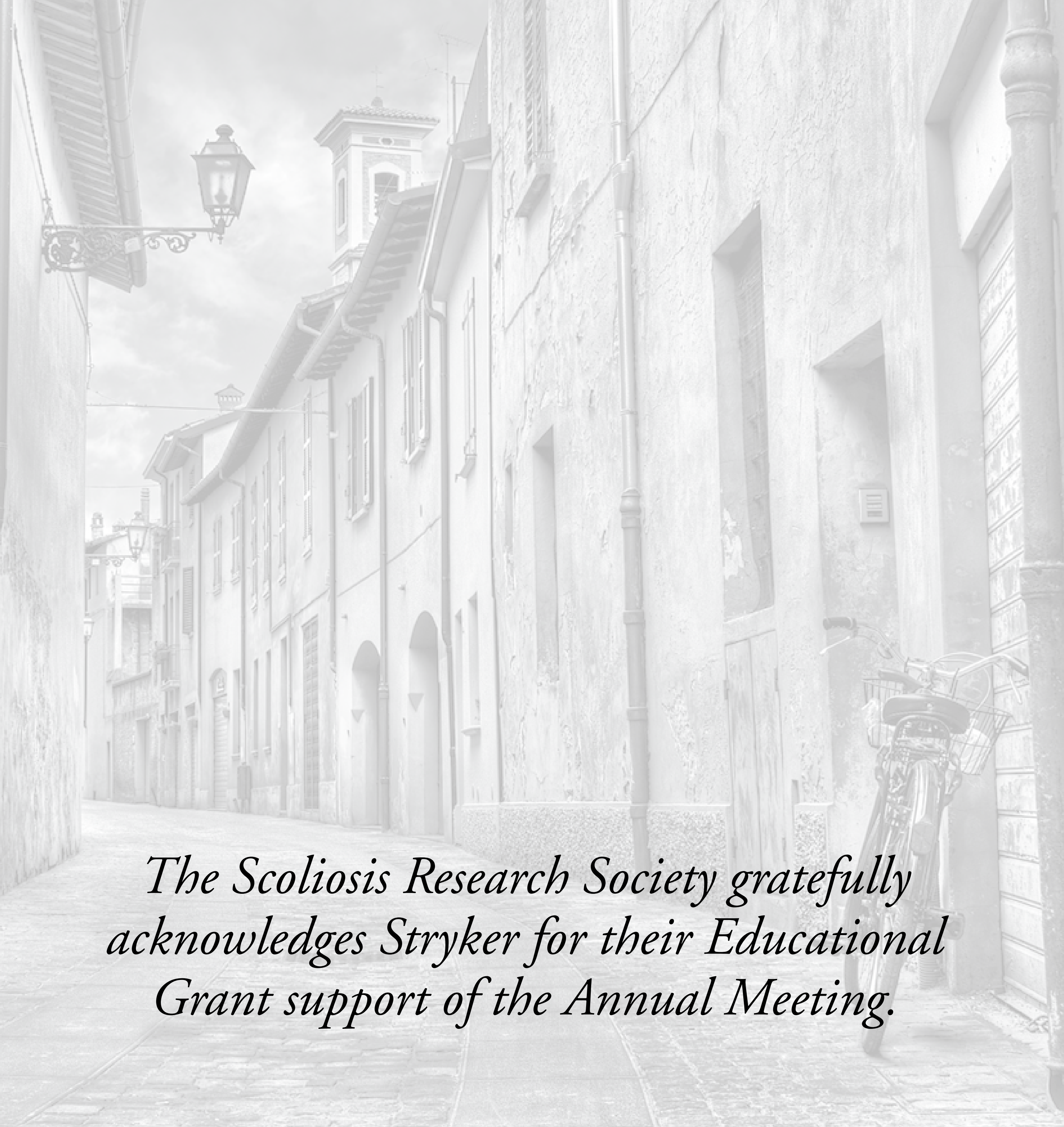
GARS, SDHC, KIAA0586, SMARCA2, MED25, B3GLCT, TBX1, EXT1, SPG11, ERCC6 and PIEZO2 mutations were identified and confirmed by RT-PCR. The most significantly involved pathways in CS pathogenesis were Wnt, PI3K-ATK, FoxO and mTOR signaling pathways. These results illustrate the relationship between gene mutation between monozygotic twins in the pathogenic mechanism of CS.

Conclusion

This is the first study to comprehensively identify gene mutation of monozygotic twins discordant of congenital scoliosis by using whole exome sequencing and PCR analyzing. This information will provide a valuable reference dataset for future studies.

Notes

E-Presentation Abstracts



The Scoliosis Research Society gratefully acknowledges Stryker for their Educational Grant support of the Annual Meeting.

The E-Presentations will be recorded onsite at the Annual Meeting and will be available for attendees to view online approximately two weeks after the meeting.

151. Cautions for Anterior and Posterior Combined Long Level Fusion in Adult Spinal Deformity: Perioperative Surgical Complications Related to Anterior Procedure (Oblique Lumbar Interbody Fusion)

Whoan Jeang Kim, MD, PhD; Jae Won Lee, MD; Shann Haw Chang, MD; Dae Geon Song, MD; Kun Young Park, MD, PhD

Summary

OLIF has more end plate injury than we expect in treatment modalities for ASD accompanied sagittal imbalance. - Thus surgeon should be cautious about end plate injury during OLIF procedure. - It is difficult to enough lordosis correction only by OLIF, so do not try an impractical correction goal and insert immoderate cage.

Hypothesis

We aimed to determine the perioperative complications of oblique lumbar interbody fusion (OLIF) as first staged procedure of anterior and posterior combined surgery for adult spinal deformity (ASD) accompanied sagittal imbalance; what kinds of perioperative surgical complications occur in radiological and clinical aspect, what factors affect complications occur.

Design

Retrospective, single center study.

Introduction

Current trend of operative treatment for ASD accompanied degenerative sagittal imbalance is combined anterior-posterior staged surgery. Recently, oblique lumbar interbody fusion (OLIF) get more popularity and there are many reports about good results of OLIF technique. However, there are only a few studies on the complications and limitation of the OLIF, especially, there are scanty studies focusing on perioperative surgical complications of ASD accompanied sagittal imbalance that needs multi-level interbody fusion and long level posterior arthrodesis.

Methods

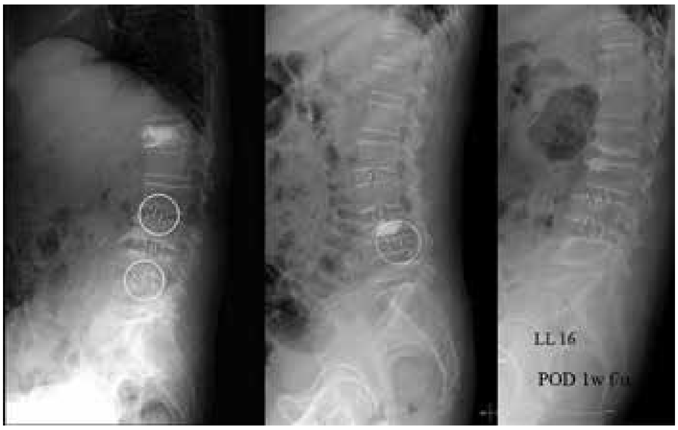
Perioperative period was defined 1 week interval of anterior and posterior procedure. All patients take the preoperative and postoperative simple radiography and MRI. Cage placement was evaluated. Cage placement included displacement (sinking down, migration) and vertebral body fracture. During 1 week, clinical complaints of patients were evaluated.

Results

A total fusion segments were 138. 1 week after OLIF, 14 patients/33 segments (30.4/23.9%) underwent end plate injury associated cage placement change. Sinking down was most common cage placement-related complications. Large correction angle was showed significant different, and using bigger height cage than height of full extension lateral view show significant different following end plate injury.

Conclusion

OLIF has more end plate injury than we expected in treatment modalities for ASD accompanied sagittal imbalance. Thus surgeon should be cautious about end plate injury during OLIF procedure. It is difficult to enough lordosis correction only by OLIF, so do not try an impractical correction goal and insert immoderate cage.



152. Adult Spinal Deformity Surgical Decision-Making Score: Development and Internal Validation

Ibrahim Obeid, MD, MS; Takashi Fujishiro, MD; Louis Boissiere, MD; Derek Cawley, FRCS; Daniel Larrieu, PhD; Olivier Gille, MD, PhD; Jean-Marc Vital, MD; Ferran Pellisé, MD; Francisco Javier Perez-Grueso, MD; Frank S. Kleinstueck, MD; Emre Acaroglu, MD; Ahmet Alanay, MD; European Spine Study Group

Summary

In this study, we developed and internally validated a score specific to the decision-making process for patients with adult spinal deformity (ASD).

Hypothesis

The scoring system, we developed in this study, specific to the decision-making process for ASD patients has an internal validation.

Design

Multicenter, prospective study of consecutive ASD patients

Introduction

The decision-making process in patients with adult spinal deformity is highly complex. To date, there have been no published decision-making algorithms for ASD patients. The aim of this study is to develop and validate a scoring system specific to the decision-making process of ASD.

Methods

A total of consecutive 1018 patients with ASD from a multicenter database were included in this study, and randomly divided into a derivation (80%) and validation (20%) set. Demographic, HRQoL measures and radiographic variables significantly associated with the surgical treatment in multivariate analysis were incorporated into the scoring system. The scoring systems were developed separately in younger (≤40 years) and older (>40 years) patients, and subsequently validated in the validation set.

Results

The resultant scoring system consisted of 4 parameters: SRS-22 self-image domain; coronal Cobb angle; PI-LL mismatch; and relative spinopelvic alignment (RSA), and ranged from 0 to 10 in the younger age group, and consisted of 5 parameters: leg pain evaluated using a numerical rating scale; SRS-22 pain and self-image domains; coronal Cobb angle; and RSA, and ranged from 0 to 12 in the older age group. In the validation set, the surgical rate was 21.1% in the bottom tertile of the score and 80.0% in the top tertile in the younger age group; 23.7% and 80.4% in the older age group. The area under the receiver operating characteristic were 0.79 (95% CI: 0.66-0.88; P<0.001) in the younger age group and 0.80 (95% CI: 0.71-0.86; P<0.001) in the older age group.

Conclusion

The scoring system specific to deciding on surgery for ASD patients was developed and internally validated, and may be helpful for the decision-making process. Further refinement is necessary to establish the universal surgical indications for ASD.

153. The Consequence of Non-Operative Management in Adult Spinal Deformity: Long-Term Durability of Alignment in Non-operative and Operative Patients

Peter Passias, MD; Cole Bortz, BA; Renaud Lafage, MS; Justin Smith, MD, PhD; Breton G. Line, BS; Gregory Mundis, MD; Munish C. Gupta, MD; Jeffrey Gum, MD; Samantha Horn, BA; Frank Segreto, BS; Daniel M. Sciubba, MD; Eric O. Klineberg, MD; Douglas C. Burton, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher Shaffrey, MD; Virginie Lafage, PhD; International Spine Study Group

Summary

Compared to non-operative intervention, operative adult spinal deformity (ASD) treatment is associated with superior long-term alignment outcomes. Still, differences in alignment durability between operative and non-operative ASD patients remain understudied. This study demonstrates that for ASD patients with similar baseline deformity, frailty status, and comorbidity burden, non-operative treatment is associated with progressive decline in lumbo-pelvic alignment and increased frailty rates. Additionally, compared to operative patients, non-operative patients developed increased rates of hypertension and pulmonary comorbidities over the 2-year study period.

Hypothesis

Non-operative ASD patients have less durable 2-year alignment outcomes than similar operative patients

Design

Retrospective review

Introduction

The literature is sparse in comparing durability of alignment between non-operative and operative ASD patients.

Methods

ASD patients(scoliosis≥20°, SVA≥5cm, PT≥25°, or TK≥60°)>18yr with baseline(BL)/1-year(1Y) radiographs. Operative(Op) and non-operative(N-Op) ASD patients were propensity score matched(PSM) for BL PT, PI-LL, SVA, age, Charlson comorbidity index(CCI), and frailty(ASD-FI). Kaplan-Meier analyses assessed durability of SVA, PI-LL, and PT alignment beginning at 1Y postop for Op patients, and BL for N-Op. Alignment was durable if maintained within +1 standard deviation of age-adjusted ideal. Log Rank tests compared Op/N-Op survival distributions.

Results

394 ASD patients(53±17yrs, 83%F) were included in the PSM analysis(197 Op, 197 N-Op). For Op patients, fusions spanned 11±4 levels, and surgical approach included 71% posterior, 2% anterior, and 28% combined. No differences were observed in age, sex, or BMI between groups(all P>0.05). Table 1 shows alignment and comorbidity differences between Op and N-Op groups at BL, 1Y, and 2Y intervals. N-Op patients showed less durable PI-LL alignment at 1Y(Non-Op: 63.5% vs Op: 73.6%) and 2Y(52.3% vs 65.3%,P=0.026). Cumulative durability of SVA(P=0.153) and PT(P=0.708) did not differ between groups. Despite no BL differences, N-Op patients had higher rates of lung disease(4.2% vs 0%,P=0.016) and hypertension(22% vs 10%,P=0.006) at 2Y Despite no differences in BL frailty, a greater proportion of N-Op patients were considered frail(ASD-FI >3) at 1Y(24% vs 12%,P=0.003) and 2Y(25% vs 13%,P=0.007). Non-Op patients also showed inferior BL-2Y changes in frailty score(1.2 vs -0.4,P=0.001).

Conclusion

Unlike operative, non-operative ASD patients showed progressive decline in spinopelvic alignment and inferior clinical outcomes over a 2-year period. As compared to operative, non-operative patients also developed higher rates of pulmonary comorbidities and hypertension.

Patient Factor	Baseline		1 Year Interval		2 Year Interval	
	Op	N-Op	Op	N-Op	Op	N-Op
Radiographic						
PT (°)	20.6	20.7	18.9	20.4	19.1	21.1
PI-LL (°)	6.1	6.3	***0.3**	***6.5**	-0.4	7.1
LL (°)	47.3	49.3	***54.2**	***49.0**	***54.2**	***48.5**
C7-S1 SVA (mm)	24.4	23.9	9.2	28.7	***11.0**	***30.0**
T4-T12 TK (°)	33.5	33.5	***39.5**	***32.5**	***40.9**	***34.4**
C2-C7 SVA (mm)	27.4	27.0	28.8	26.7	27.2	25.9
Comorbidity						
Frailty	19.3%	22.3%	***12.1%**	***23.8%**	***12.8%**	***25.2%**
Hypertension	24.9%	22.3%	***13.5%**	***21.4%**	***9.6%**	***21.5%**
Lung Disease	2.5%	6.1%	1.6%	2.6%	***0.0%**	***4.2%**
Depression	18.3%	12.2%	10.4%	15.8%	8.8%	15.3%
Diabetes	3.6%	2.0%	1.6%	3.1%	**2.9%**	**4.2%**
Heart Disease	7.6%	7.1%	5.2%	5.6%	**2.2%**	**6.3%**

Table 1. Differences in radiographic sagittal alignment and comorbidity status between operative (Op) and non-operative (N-Op) adult spinal deformity patients at baseline, 1-year, and 2-year study intervals. Bolded and asterisked values indicate statistically significant difference to p<0.050.

154. Influence of the Change in Back extensor Strength on the Natural History of Sagittal Spino-Pelvic Deformity in Postmenopausal Women

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Summary

The influence of the change in back extensor strength on the

deterioration of spino-pelvic sagittal alignment was analyzed. The change in PT was the significant variable on the change in back extensor strength after adjusting for age and BMI. \The results suggest that the decrease in back extensor strength contributed to the increase in pelvic retroversion.

Hypothesis
The change in back extensor strength may influence on the development of spinal deformity.

Design
Prospective cohort study

Introduction
Kyphosis progresses with advancing age. Back extensor strength is known to deteriorate with aging. Kyphotic spinal deformity is significantly associated with back extensor strength, however the relationship between progression kyphosis and muscle strength are still unclear. This study aimed to assess the influence of the change in back extensor strength on the change of spino-pelvic sagittal alignment.

Methods
Eighty-six postmenopausal women with the longitudinal records of muscle strength and radiographs for more than 2 years were included in the study. The average age was 67 years. Lateral standing radiographs of the whole spine were evaluated for TK, LL, SVA, PT, TPA, and the incidence of vertebral fractures. Isometric back extensor strength and grip strength were measured. The participants were categorized according to the change in back extensor strength into increased group (I-group, n=42) and decreased group (D-group, n=44). Then multivariable analysis was conducted to find the spinal factors affecting the change in back extensor strength with stepwise variable selection.

Results
Average follow-up period was 3.2 years (2-5y). Back extensor strength was 12.2±6.4 kg at baseline, and decreased to 11.6±6.2kg at follow up. D-group showed significant increase in PT (p=0.01) and PI-LL (p=0.04) compared with I-group and no significant difference in SVA and TK. Multivariate analysis revealed that the change in PT was the significant variable on the change in back extensor strength after adjusting for age and BMI (β=0.394, p<0.001).

Conclusion
The change in spino-pelvic sagittal alignment, especially in PT overtime was influenced by the change in back extensor strength. The results suggest that the decrease in back extensor strength contributed to the increase in pelvic retroversion. Evaluation of the change in PT may be valuable for the assessment of the effect of exercise intervention.

155. Risk Factors for Proximal Junction Kyphosis (PJK) in Scheuermann's Kyphosis (SK)

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Summary
A large number of SK patients have postop PJK. Higher incidence of PJK is seen with all pedicle screw fixation and UIV below T3.

Hypothesis
The incidence of PJK in SK is higher in pedicle screw fixation than hybrid

Design
Ambispective review

Introduction
PJK has been well documented with pedicle screws in AIS patients. In Scheuermann's kyphosis (SK), PJK has been reported with hybrid fixation in the presence of shorter fusions. The literature is deficient about PJK in SK with all pedicle screw constructs.

Methods
XR and chart review of all SK patients operated with all pedicle screw (PS), hybrid fixation (HF), and anterior/posterior fusions with hybrid fixation (AP) were reviewed. Number of fusion levels, percent correction, UIV, LIV, pre and postop PJK, sagittal balance, and demographic data was collected. PJK was defined as more than 10 degrees. Fisher's exact test, Kruskal-Wallis, Wilcoxon ranked sum test were used.

Results
84 total patients: PS (n=29), HF (n=24), and AP (n=31). Median preop kyphosis was significantly higher in the AP compared to PS and HF (89 vs 77 vs 81.5, p<0.001). Median postop kyphosis was significantly higher in the PS cohort (50.3 vs HF: 45.5 vs AP: 43, p=0.048). Median percent correction was highest in the AP cohort (51.8 vs HF: 43.8 vs PS: 32.9, p<0.001). Pre and post sagittal balance was similar across the three cohorts. Overall, at postop 47.6% of patients had PJK, and at final 70.2%. Immediate postop-PJK was significantly higher in PS 13.4 vs HF: 7.8 vs AP: 8, p =0.008). However, final PJK was similar across the three groups (PS: 19 vs HF: 15 vs AP:14, p=0.07). T2 was the most common UIV for AP (71%) and HF (71%) compared to T3 for PS (59%), p<0.001). Overall, significantly higher postop-PJK was seen with UIV below T3 (13.7 vs 9.4, p =0.043).

Conclusion
Incidence of PJK appears to be higher in SK compared to that reported in AIS. Patients with pedicle screw fixation appear to be at the highest risk. UIV at T3 or proximally has significantly lower PJK.

156. Correlation of General Validated Frailty Instrument (Edmonton) to Disease Specific Frailty (ASD-FI) and Objective Physical Strength in Adult Deformity Population

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Summary

Frailty is an important predictor of outcomes and complications following adult spinal deformity (ASD) surgery. This study correlated the Edmonton Frailty Scale (EFS) with the ASD Frailty Index (ASD-FI), Oswestry Disability Index (ODI), strength testing, and age. Preoperative EFS correlated moderately with ASD-FI, but poorly with ODI and objective strength measures. Age showed no correlation with ASD-FI or EFS. These findings underscore the complexity of frailty assessment and support the use of standardized frailty assessment tools.

Hypothesis

The Edmonton Frailty Scale (EFS) correlates with the Adult Spinal Deformity Frailty Index (ASD-FI) and other preoperative measures of sarcopenia in adult spinal deformity (ASD) patients.

Design

Prospective clinical study of preoperative ASD patients at a single center

Introduction

Patient frailty is an important preoperative characteristic for predicting surgical outcomes and complications in spinal deformity patients. Few frailty tools have been validated in ASD patients. Our aim was to prospectively evaluate the EFS and ASD-FI in our ASD cohort.

Methods

Consecutive ASD patients at a single institution were offered enrollment in our frailty study from July 2017 to January 2018. Patient demographics and history were collected, as were standardized health-related quality of life surveys, the EFS and the ASD-FI. Patients also underwent strength testing as a functional assessment of frailty. Coefficients of determination were calculated using least-squares regression analysis comparing EFS, ASD-FI, Oswestry Disability Index (ODI), strength tests, and age.

Results

39 patients were consented, with 31% men and mean age of 65.7 years (range: 47 to 85 years). EFS scores ranged from 0 to 11, with a mean of 4.51. Mean ASD-FI was 0.41 (range: 0.15 to 0.69). Mean ODI was 25.7 (range: 12 to 39), mean grip strength was 24.0 kg (range: 6.6 to 44), mean sit-to-stand time (STS) was 5.8 seconds (range:0.85 to 27), and mean 4-meter walk time (4MW) was 7.5 seconds (range: 3.45 to 30). EFS correlated moderately with ASD-FI, with an R^2= 0.44. R^2 for EFS and ODI was 0.19, and for ASD-FI and ODI 0.42. Grip strength, STS and 4MW correlated poorly with both EFS and ASD-FI. Age correlated poorly with EFS, ASD-FI, ODI, grip strength, STS, and 4MW (Table).

Conclusion

Preoperative EFS correlates moderately with ASD-FI, but poorly with ODI and strength tests. Age showed no correlation with ASD-FI or EFS. Collectively, these findings underscore the complexity of frailty assessment, suggest that age alone is not a sufficient surrogate for frailty, and support the use of standardized frailty assessment tools for ASD patients.

Coefficient of Determination ("R-squared")

	ASDFI	ODI	Grip	STS	4MW	Age
EFS	0.44	0.19	0.09	0.08	0.02	0.005
ASDFI		0.42	0.16	0.0006	0.12	0.004
ODI			0.08	0.03	0.003	0.0005
Grip				0.02	0.19	0.004
STS					0.12	0.07
4MW						0.003

157. Correlation Between Sagittal Alignment and Muscle Mass in Patients with Lumbar Spine Disease

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Summary

We investigated the correlation between sagittal plane alignment and trunk and lower limb muscle mass in patients with lumbar spine disease. In result, this study showed that only PT was correlated with trunk and lower limb muscle masses in lumbar disease patients, suggesting its usefulness as a surface alignment parameter.

Hypothesis

The sagittal alignment parameters are correlated with trunk and lower limb muscle masses in lumbar disease patients

Design

Retrospective study

Introduction

The number of patients with lumbar spine disease has increased rapidly in recent years, and the number of patients with osteoporosis continues to increase as society ages. In recent years, the muscles have attracted attention as essential elements in maintaining alignment. Obviously, the muscles are the posterior elements supporting the spinal column (body trunk muscles), and the lower limb muscles are critical to maintaining trunk balance. However, the correlation between spinal column alignment and the muscles . Here we investigated the correlation between sagittal plane alignment and trunk and lower limb muscle mass in patients with lumbar spine disease.

Methods

A total of 187 subjects with lumbar spine disease who were being followed up at our hospital were targeted. The main sagittal plane alignment parameters (LL, SS, PI, PT) were determined on stereotactic X-ray images in these patients. The body trunk and lower limb muscle masses were measured using the impedance method. A statistical analysis was used to determine the correlation coefficient between each sagittal plane alignment parameter and muscle mass.

Results

Of the sagittal plane alignment parameters, only PT was correlated with trunk muscle mass and lower limb muscle mass (body trunk muscle mass, -0.3227; $p < 0.01$; lower limb muscle mass,

-0.2819; $p < 0.01$), whereas no correlation was found between LL, SS, or PI and muscle mass.

Conclusion
This study showed that only PT was correlated with trunk and lower limb muscle masses in lumbar disease patients, suggesting its usefulness as a surface alignment parameter.

158. Is a Higher Dose Range of Tranexamic Acid More Superior in Reducing Blood Loss in Scoliosis Surgery?

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Summary
The optimal dose of tranexaemic acid is unknown. We divided 173 AIS patients into two groups –High dose TXA (>20 mg/kg, n=115) and Low dose TXA (<20 mg/kg, n=58). The differences for mean absolute intraoperative blood loss (827.8 vs 909.4mls; p=0.26) and percentage of blood volume loss (28.5 vs 24.9%; p=0.11), did not achieve statistical significance. When given as a single dose, a higher dose of TXA (>20 mg/kg) was not superior in reducing blood loss.

Hypothesis
We hypothesize that different dose range of TXA in posterior spinal fusion (PSF) surgery will affect intraoperative blood loss.

Design
Retrospective study

Introduction
Scoliosis surgery is often associated with extensive blood loss. Published studies consistently demonstrate the efficacy of tranexamic acid (TXA) to reduce intraoperative blood loss compared to placebo. However, the optimal dose to maximize its anti-fibrinolytic properties without increasing thrombotic complications is controversial.

Methods
173 patients diagnosed with adolescent idiopathic scoliosis (AIS) who underwent PSF in 2015 and 2016 were retrospectively studied. All patients received 1 gram bolus of intravenous TXA at the start without maintenance infusion. They were divided into two groups – Group A- High dose TXA (>20 mg/kg, n=115) and Group B- Low dose TXA (<20 mg/kg, n=58). Cell salvage technique was employed in all patients.

Results
Mean age, weight, blood volume, Cobb's angle and number of levels fused were 15.4 years, 41.8 kg, 2914.8 ml, 66.4o, 11.2 levels and 18.2 years, 57.5 kg, 3652.8 ml, 65.7o, 10.8 levels in Groups A and B respectively. In terms of mean absolute intraoperative blood loss (827.8 vs 909.4mls; p=0.26) and percentage of blood volume loss (28.5 vs 24.9%; p=0.11), the differences between the high and low dose groups did not achieve statistical significance. Total blood loss per segment (72.2 vs 81.1mls; p=0.08) and per screw (56.8 vs 63.8mls; p=0.14) also did not differ significantly between the groups and so did duration of hospital stay (3.4 days vs 3.4 days, p=0.96). No patients received allogenic blood transfusion and none developed thrombotic complications.

Conclusion
A higher dose of TXA (>20 mg/kg), failed to demonstrate superiority in reducing blood loss compared to a lower dose of (<20 mg/kg) when given as a single dose in PSF for AIS. Prospective studies to investigate the optimal dose range and regimen of TXA are needed.

159. Craniovertebral Junction Tuberculosis (CVJ-TB) With AtlantoAxial Instability(AAI): Is Surgery Necessary?

Saumyajit Basu, MD, FRCS; *Aditya Banta, MS, DNB*; Amitava Biswas, MS; Anil Solanki, MS, DNB; Rohan Gala, MS; Naveen Agrawal, MS; Trinanjan Sarangi, MD

Summary
Retrospective study of 24 consecutive CVJ-TB cases with AAI was done from 2003-2015. Transoral biopsy, immobilization in Halovest and Full course Anti-Tubercular Treatment(ATT) was done for all. Radiologically 9 cases were Goel Stage2 and 15 were Stage 3. At final follow up all patients were painfree, cervical ROM was well preserved in 15 and moderately restricted in 9. Final CT, MRI showed healed disease in all. Bone reformation was seen in patients with odontoid erosion. No patient had residual instability.

Hypothesis
Atlantoaxial Instability with CVJ-TB tuberculosis can be managed conservatively with excellent & predictable functional & radiological outcomes.

Design
Retrospective Descriptive Study

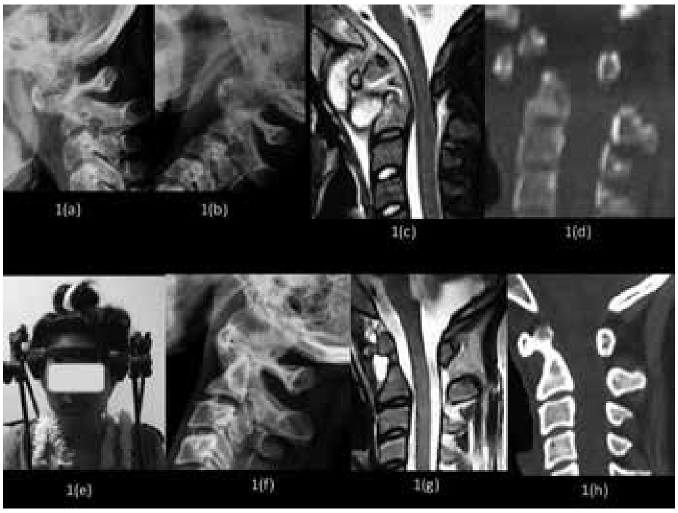
Introduction
CVJ-TB accounts for 0.3 -1% of all spinal tuberculosis cases. Presence of AAI is considered an indication of surgery. Present study aims to observe the clinoradiological outcome of conservative management in such patients

Methods
24 consecutive cases of CVJ-TB with AAI presenting to our institute from 2003-2015 were reviewed. All patients were Frankel grade D/E. Patients underwent dynamic Xrays, MRI and CT scan at diagnosis and were treated with transoral biopsy/aspiration and immobilized in Halo Vest. Full course ATT was given. Ambulation was encouraged in all patient, Monthly Follow up was done for 3 months followed by 3 monthly visits till end of treatment. Duration of ATT was decided by an infectious disease specialist. MR Imaging was done at 6 monthly intervals and CT scan was done at final followup

Results
24 patients (10m & 14f) had an average age of 34.67(Range13-71) & average follow up of 7.87years (Range 2y-13.5y). All patients had severe restriction of Neck ROM, torticolis was seen in 5. 50% of patients had paraesthesia in upper

limbs at time of presentation, 4 patients showed neurological signs of pyramidal tract involvement. Radiologically 9 cases were Goel Stage 2 and 15 were Stage 3. Average duration of ATT was 14.1 months (range12-18) & Average duration of external immobilization was 8.2 months (range 6-12). The NDI scores improved from 65.5(range 64-86) at first visit to 23.9(range 10-36) at end of treatment. At last follow up all patients were pain free, Cervical ROM was near normal in 3, Restricted terminally in 12 and moderately in 9. MRI showed healed disease in all cases. CT scan showed evidence of bone reformation in patients with dens erosion, those with facet joint affection showed sclerotic changes, 3 of these had fusion of facet joints. None of the patient had any residual instability

Conclusion
AAI in CVJ-TB without major neurodeficit should not be considered an indication of surgery as results of conservative management are excellent



160. Neither Thoracic Height nor True Spine Length Predict Thoracic Volume in Rabbit Model of Early Onset Scoliosis +/- Expansion Thoracoplasty

J. Casey Olson, PhD; Vincent Ruggieri, BS; Michael P. Glotzbecker, MD; Patrick Cahill, MD; Robert M. Campbell, MD; Brian D. Snyder, MD, PhD

Summary
Thoracic height is a common clinical indication for thoracic hypoplasia used to guide treatment in thoracic insufficiency syndrome. Thoracic height likely misrepresents true spine length as growth can significantly deviate from the longitudinal axis, nevertheless it may serve as an accessible correlate for thoracic volume. In this study we individually explore suitability of thoracic height, true spine length, and thoracic curvature as predictors of thoracic volume using established rabbit models of early onset scoliosis and expansion thoracoplasty.

Hypothesis
Thoracic height and true spine length are ineffective proxies for thoracic volume in early onset scoliosis.

Design
In an established rabbit model of early onset scoliosis (EOS), we previously demonstrated that spine orientation (curvature) predicted thoracic and pulmonary hypoplasia at maturity. Using this model apparent thoracic height, true spine length and 3D spine curve are correlated to thoracic volume for EOS rabbits, EOS rabbits treated with expansion thoracoplasty, and normal rabbits.

Introduction
Thoracic height is a common clinical indication of thoracic hypoplasia used to guide treatment in thoracic insufficiency syndrome, it may misrepresent true spine length as growth can significantly deviate from the longitudinal axis. Nevertheless there is no objective study on whether thoracic height or length is a suitable proxy for thoracic volume.

Methods
EOS was surgically induced in 3-week old rabbits (n=24) by tethering the right rib cage; a subset was sequentially treated with expansion thoracoplasty (n=14) and the remainder left as EOS control (n=10). CT recons of the thorax at maturity (28-weeks) were evaluated for apparent thoracic height (A-P projection), true spine length (trace length T1-13), thoracic curvature and thoracic volume. Length and volume values were scaled to age matched normal controls (n=8) and compared. Thoracic height, spine length, and curvature were correlated to volume within each group.

Results
Thoracic height was less than normal in EOS control group (80%, $p<0.01$), there were no differences in true spine length across groups. Thoracic volume was less than normal for EOS control (84%, $p<0.05$) and expansion groups (80%, $p<0.05$). Neither thoracic height or true spine length correlated with thoracic volume in any groups, curvature correlated with thoracic volume in EOS group only ($R^2=0.63$, $p<0.01$).

Conclusion
Both EOS and expansion thoracoplasty influence spine orientation but do not alter spine growth as determined by true spine length. Neither thoracic height nor true spine length were useful proxies of thoracic volume, whereas spine orientation was strongly predictive in EOS.

161. Risks for Revision in Growth Friendly Treatment for Early Onset Scoliosis (EOS)

Jaime Gomez, MD; Regina Hanstein, PhD; Jason Anari, MD; Patrick Cahill, MD; Michael Vitale, MD; John M. Flynn, MD

Summary
Thirty percent of patients undergoing growth friendly treatment for EOS are still requiring additional revision surgery. Patients with larger postop Cobb angles, higher BMI, increased pre and postop kyphosis and less proximal anchor points are more likely to require additional revisions.

Hypothesis
Certain perioperative conditions (Kyphosis, Cobb angle, BMI, etc.) increase the risk of having additional surgical procedures in patients with EOS.

Design
Retrospective Cohort

Introduction
The frequency, and type of complications vary widely among subtypes of patients with early onset scoliosis. This study aims to determine which perioperative patients' characteristics increase the risk of additional revision surgery during "growth friendly" treatment.

Methods
Retrospective review of a prospective multi-center database, patients from 2012-2016 with minimum 2 year follow up were included. We evaluated all revisions performed that could not be addressed at a scheduled procedure. The patients that had additional revision surgery were evaluated for their diagnosis, ambulatory status, BMI, pre and post radiographic measurements, laterality of devices, anchor points and comorbidities.

Results
Of 389 patients, 117 (30%) required additional revision surgery. For the patients that were classified within C-EOS groups, the frequency within the study population was compared to the frequency of additional revision surgery. Of the patients having additional revisions, C3N (10.3%) and M3+ (13.7%) patients had a higher representation than the expected for our population. Patients requiring additional revisions had a larger Cobb angle at last follow up (47° vs. 55°;p=.001) as well as larger pre-kyphosis (41° vs 50°;p=.001) and postop-kyphosis (45° vs 53°;p=.001). Similarly, additional revisions occurred more frequently in patients with higher adjusted BMI (54 vs 45;p=.027) and with decreased number of proximal anchors (4.2 vs 3.7;p=.029). There was no difference between ambulatory status, comorbidities and inferior attachment groups.

Conclusion
30% of patients undergoing growth friendly treatment for EOS required unexpected revision surgery. Large neuromuscular and congenital curves are more likely to require additional revisions. Patients with larger postop Cobb angles, higher BMI, increased pre and postop kyphosis and less proximal anchor points are more likely to undergo additional revisions. Surgeons should consider these perioperative factors to counsel parents and guide their management.

162. Unplanned Return to OR (UPROR) for Early Onset Scoliosis (EOS) Children: A Comprehensive Evaluation of all Diagnoses and Instrumentation Strategies

Jason Anari, MD; John M. Flynn, MD; Patrick Cahill, MD; Michael Vitale, MD; John Smith, MD; Jaime Gomez, MD; Sumeet Garg, MD; Keith Baldwin, MD; Children's Spine Study Group

Summary
UPROR is very common in EOS surgery (23%), and varies with patient characteristics & surgical implant type/strategy. True UPROR, requiring an unexpected anesthetic for the child, is most common in hyperkyphotic neuromuscular deformities (M3+), & when surgical strategies not requiring surgical lengthening techniques are employed. These results are valuable for accurate informed consent and for improving surgical planning and execution, especially for patients with the highest risk UPROR deformities.

Hypothesis
The rate of UPROR is based on both patient specific factors and surgical strategy.

Design
Retrospective Cohort

Introduction
Growing concerns over the impact of multiple anesthetic events on the young brain have focused attention on limiting unplanned return to the OR (UPROR) in early onset scoliosis (EOS). EOS occurs in a heterogeneous patient population, and many instrumentation strategies are deployed for its management. Our goal was to study true UPROR (a post-operative complication that could not be treated without an additional anesthetic) as a function of C-EOS diagnosis and implant type.

Methods
We performed a retrospective analysis of a large, prospective multi-center database, studying all patients with a diagnosis of EOS who had surgical implantation of growing instrumentation from 10/4/10 to 9/27/15. Among the complications requiring surgical treatment (revision for implant or anchor failure, infection, or implant removal), we analyzed all true UPROR events--those that required a separate anesthetic (could not be treated as part of a planned surgical lengthening) within the first 2 years after initial implantation. UPROR was analyzed by diagnosis, deformity type, and implant strategy using the C-EOS classification.

Results
369 patients met inclusion criteria. 85 of the 369 (23%) required true unplanned trips to the operating room for various reasons. The C-EOS group at highest risk of an unplanned trip to the operating room is the M3+ (14/85) cohort, followed closely by the M3N (9/85) & C3N (9/85) groups. Implant strategy was significantly related to risk of UPROR (p=0.009; Table 1), with traditional techniques (VEPTR/TGR) being less likely to have a true UPROR event.

Conclusion
Growing instrumentation to treat EOS, when considered com-

prehensively in 2018, results in a true unplanned reoperation rate within 2 years of implantation of 23% (85/369). UPROR events are contingent on C-EOS diagnosis (hyperkyphotic neuromuscular deformities) and implant strategy. Families should be counseled that unplanned anesthetics are common with any implant strategy available today.

2 Year "True UPROR"			
	n	Total	%
MCGR	22	61	36%
VEPTR	55	258	21%
SHILLA	2	5	40%
TGR	5	43	12%
Combination	1	2	50%
Total	85	369	23%

163. Improvements in Spinal Alignment and Balance in the Treatment of AIS with Anterior Vertebral Tethering: A Seven Year Experience.

John T. Braun, MD

Summary

Spinal alignment and balance were analyzed in 20 AIS patients treated with Anterior Vertebral Tethering (AVT). Scoliosis correction from 45.8° pre-op to 16.8° final at 3.5 years (2-7years) was significant at 63.3% with maintenance of thoracic kyphosis (36.6°) and lumbar lordosis (62.5°) within a normal range. Measures of corornal balance (proximal and distal) both improved significantly whereas sagittal balance remained within a normal range throughout.

Hypothesis

Significant scoliosis correction will be achieved with AVT for AIS with more modest improvements in other measures of spinal alignment and balance.

Design

Retrospective review of consecutive patients (2010-2015).

Introduction

Although Anterior Vertebral Tethering (AVT) has demonstrated significant scoliosis correction in AIS patients, long-term improvements in spinal alignment and balance have not been evaluated.

Methods

Twenty consecutive AIS patients with >2 year F/U after AVT for curves in the 33-60° range were analyzed. Pre-op and final radiographs were used to measure spinal alignment (scoliosis, thoracic kyphosis and lumbar lordosis) with the Cobb method and spinal balance using differentials between C7 plumb/CSL (proximal coronal), T12 centrum/CSL (distal coronal) and C7 plumb/S1 (sagittal balance).

Results

Twenty AIS patients (18F/2M) were treated with AVT. Seventeen patients with 24 curves (age14+6, R=2.6) demonstrated significant scoliosis correction from 45.8° pre-op to 16.8° final at 3.5 years (2-7years). Changes in thoracic kyphosis from 32.8° to 36.6° and lumbar lordosis from 64.6° to 62.5° were modest but remained in a normal range. Changes in coronal balance were significant with improvements both proximally (2.2 pre-op to 1.4cm final)(p=0.029) and distally (3.2 pre-op to 2.1 post-op) (p=0.034). Sagittal balance remained in a normal range but did trend from negative to positive (-0.9 pre-op to +0.2 final). Three patients with 6 curves had additional procedures after their 2 year F/U (2 requiring tether removal for overcorrection and 1 requiring PSF for lumbar decompensation below a tether) making their spinal alignment and balance assessments suboptimal for inclusion.

Conclusion

Anterior Vertebral Tethering (AVT) demonstrated significant scoliosis correction from 45.8° to 16.8° at 3.5 years (2-7years) F/U. Additional measures of spinal alignment (thoracic kyphosis and lumbar lordosis) changed little over this time but remained in a normal range. Measures of coronal spinal balance improved significantly both proximally and distally whereas sagittal balance changed little but remained in a normal range.

164. Redefining Guidelines for Brace-Weaning in Adolescent Idiopathic Scoliosis Based on Standardized Skeletal Maturity Parameters

Jason Pui Yin Cheung, MBBS, FRCS, MS; Prudence Wing Hang Cheung, BDSc (Hons); Keith DK Luk, FRCS

Summary

This is a prospective analysis of 145 adolescent idiopathic scoliosis (AIS) patients who underwent brace weaning. Patients were followed-up for 2-years after brace weaning to identify any curve progression. Risser, distal radius and ulna (DRU) and Sanders (SS) grading systems were used for maturity assessment. Risser was inaccurate, SS8 still had risk of progression, and the ulna grading provides the best prediction for avoiding post-weaning progression in incompletely closed radial physes.

Hypothesis

Utilizing the DRU grading scheme provides better indication of brace weaning.

Design

Prospective study.

Introduction

There is no standard criteria for brace weaning in AIS patients but most clinicians agree to wean when patients are Risser 4 and have no growth between 2 visits. However, patients have been shown to experience curve progression despite following these guidelines for brace weaning. Due to the wide variations with Risser sign and possible mismatches in growth and curve progression rates, the weaning criteria should be further refined.

Methods
145 consecutive AIS patients who fulfilled the SRS criteria for brace weaning were prospectively recruited from June 2014 to March 2016. Patients were followed-up for 2 years post-brace weaning to observe for any curve progression. All patients were assessed by Risser, DRU and SS at the time of brace weaning. Odds ratio (OR) was calculated for maturity indices.

Results
The baseline mean age was 14.6±1.0 years and mean Cobb angle was 35.4±7.3 degrees at brace weaning. Those with larger curve magnitudes was associated with curve progression after weaning (p=0.041). A total of 43 patients (29.7%) had curve progression after brace weaning and was more prevalent in curves >40 degrees (p=0.018). There were no differences in progression risk with brace-weaning at Risser 4 (38%), 4+/5- (28%) or 5 (20%). SS7 had significantly higher risk (46.2%) of post-weaning progression than SS8 (16.3%). For DRU, at R10, the progression risk dropped from 24% for U8 to 10% for U9. At R11, there were no risk of curve progression regardless of ulna grade. OR drops from 4.42 to 0.23 for SS7 to SS8, from 3.73 to 0.47 for R9 to R10, and from 1.06 to 0.144 for U8 to U9.

Conclusion
The Risser sign is inaccurate for guiding brace-weaning. Patients should not be weaned at SS7 and SS8 still has risk of progression. The DRU provides finer grading at the end of growth and can be used independently to determine the best timing for brace weaning. For radial physes that are not fully closed, the ulna grade is the main determinant and indicates the earliest and lowest rate of post-weaning progression.

165. The Top 100 Classic Papers on Adolescent Idiopathic Scoliosis In the Past 25 Years: A Bibliometric Analysis

Jared Newman, MD; Neil Shah, MD, MS; Bassel Diebo, MD; Ariana Goldstein, BA; Marine Coste, BA; Jeffrey Varghese, BS; Daniel Murray, BS; Qais Naziri, MD; Carl Paulino, MD

Summary
The most classic paper is from 1999 by Lenke et al. and describes the development of the Lenke Classification System for AIS. Most studies originated from the United States (n=67) and were published in SPINE (n=77). The proportion of studies clearly defined as prospective (18%) among the top 100 classic papers on AIS reflects an area of future improvement.

Hypothesis
Over the past 25 years, studies pertaining to AIS are becoming more impactful

Design
Bibliometric analysis

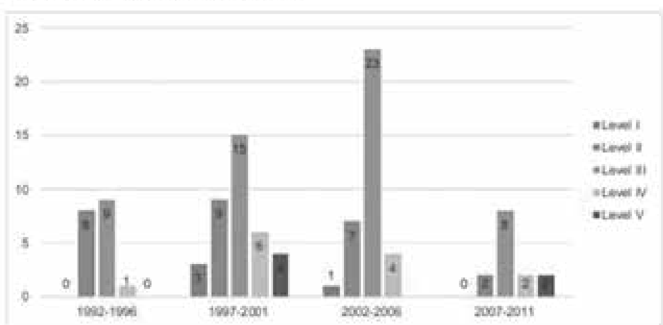
Introduction
Adolescent idiopathic scoliosis represents a 3-dimensional deformity that drives a significant number of investigations. Though available evidence continues to grow, truly impactful studies have not been identified.

Methods
A review was performed to identify the top 1,000 cited studies published between 1992 and 2018 related to AIS using Thomson ISI Web of Science. Articles were organized in descending order by number of citations, and the study titles and abstracts were screened for relevance. After excluding unrelated studies, the top 100 articles by number of citations were identified. Additionally, all studies were reviewed to identify the study type, country, level of evidence, and journal impact factor.

Results
Among the top 100 articles, 42 studies were cited ≥100 times. The mean number of authors and citations of the 100 most cited studies were 5.64 and 118.3, respectively. The study types included retrospective (n=54), prospective (n=17), cross-sectional (n=13), systematic review/meta-analysis (n=7), review (n=5), longitudinal (n=2), animal (n=1), basic science (n=1). The topics covered in the studies included clinical/patient outcomes (n=51), methodology/validation (n=22), basic science (n=14), radiographic analyses (n=9), and gait/biomechanics (n=4). Most studies originated in the USA (n=67) and were published in SPINE (n=77), with 8,561 total citations. Most studies were of level III (n=55) and level II (n=26) evidence (Figure 1). Mean impact factor was 3.47.

Conclusion
Although recent studies had shorter time frames, citations of AIS research have progressively increased over the past 25 years. The top 100 most cited articles on AIS originated in the USA, were published in SPINE, and focused on clinical/patient-reported outcomes. Most of the top 100 cited studies were level II or III, retrospective, non-randomized studies, and therefore, are subject to multiple biases. This underscores the need for higher quality studies to support our practice.

Figure 1. Study levels of evidence by years



166. Reference Centile Curves for 3D True Spine Length T1-S1 in Healthy Children

Marie Beausejour, PhD; Félix Thibeault, MS; Paul Dallaire, PhD; Ron El-Hawary, MD, MS; James Sanders, MD; Burt Yaszay, MD; Behrooz Akbarnia, MD; Marjolaine Roy-Beaudry, MSc; Patrick Tohmé, MD; Stefan Parent, MD, PhD

Summary
The current study is the first to provide centile curves for 3D spinal dimensions in asymptomatic patients under the age of 11, using 3D reconstructions of the spine. The reference values obtained will help physicians better assess their patients' growth

potential. This data could eventually be used to predict spinal length at maturity or spinal length changes in pathologic conditions as well as to assess the impact of growth friendly interventions.

Hypothesis
3D reconstruction techniques provide precise reference values for 3D spinal dimensions and centile curves in asymptomatic patients under the age of 11.

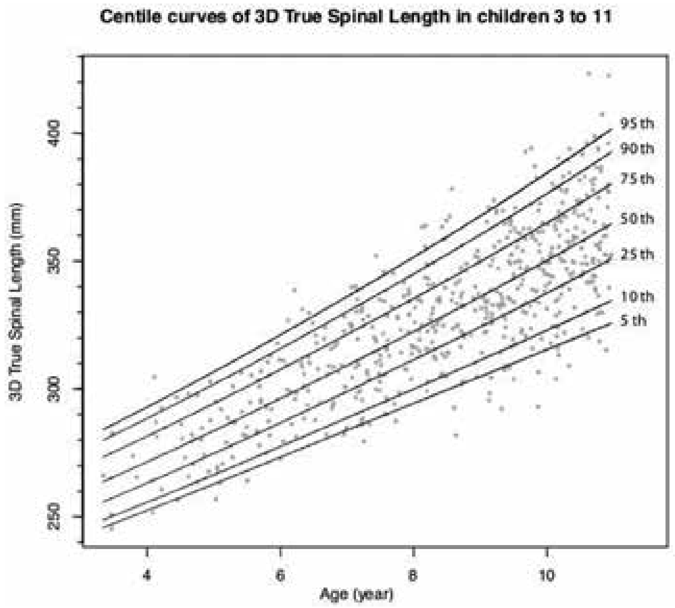
Design
Retrospective study.

Introduction
The objectives of this study are to document precise 3D reference values for spinal dimensions and to estimate centile curves for 3D True Spine Length T1-S1 (3DTSL) in healthy children under the age of 11.

Methods
Radiographic spine examinations of healthy children conducted to rule out scoliosis were reviewed in 4 scoliosis referral centers in North America. All consecutive children aged 3 to 11 years old with EOS biplanar good quality x-rays, but without diagnosed growth-affecting pathologies, were included. PA and Lateral calibrated x-rays were used for spine 3D reconstruction and computation of vertebral body heights and spine length. Three age groups were defined: 3-6, 6-8 and 8-11 years. Median and interquartile range were calculated from cross-sectional data. Lambda-Mu-Sigma method was used to fit smooth 3D indices calibrated centile curves using Box-Cox Power Exponential distribution as a function of age (GAMLSS package for R). Centiles were then predicted from the computed model for selected ages.

Results
A total of 435 full spine examinations from asymptomatic patients were reconstructed in 3D. Mid-vertebral body 3DTSL (T1-S1) medians and interquartile ranges are: 284 (27) mm, 314 (25) mm and 349 (28) mm, respectively for the 3-6, 6-8 and 8-11 y.o. groups. Figure 1 shows the derived centile curves for the 3DTSL (T1-S1) for the 5, 10, 25, 50, 75, 90 and 95th centiles. Model diagnostic tests (normally distributed residuals, adequate wormplots and |Z statistics|<2) confirmed adequacy of the model and the absence of significant misfit.

Conclusion
Precise reference values were derived for spinal dimensions in healthy children. Spinal dimension charts showed that the 3DTSL (T1-S1) changed relatively constantly across the age groups closely resembling WHO total body height charts.



167. Clinical Outcomes Research in Spine Surgery: What are Appropriate Follow-Up Times?

Oliver Ayling, MD, MSc; Charles Fisher, MD, MS, FRCS(C); Tamir Ailon, MD, FRCS(C), MPH

Summary
There has been a generic dictum in spine and musculoskeletal clinical research that 2 year follow-up is necessary for patient reported outcomes (PRO); however, the rationale for this duration is not evidence based. Individual PROs after surgery for lumbar spine pathologies follow specific time-courses to plateaued recovery indicating a two-year follow-up may not be required for all outcomes to be accurately assessed.

Hypothesis
Individual PROs after surgery for lumbar spine pathologies follow specific time-courses to plateaued recovery that occur before two years.

Design
Analysis of a prospective national multi-center clinical spine registry.

Introduction
here has been a generic dictum in spine and musculoskeletal clinical research that 2 year follow-up is necessary for patient reported outcomes (PRO); however, the rationale for this duration is not evidence based. The purpose of this study is to determine the PRO follow-up time necessary to ensure that the effectiveness of a lumbar surgical intervention is adequately captured.

Methods
Using PROs from the Canadian Spine Outcomes and Research Network (CSORN) prospective database the time-course to recovery plateau after lumbar spine surgery was assessed for lumbar disc herniation, degenerative spondylolisthesis, and spinal stenosis. One-way ANOVAs with post-hoc testing were used to compare the following standardized PROs at baseline, three, twelve, and twenty-four months post-operatively: Disability Scale

(DS), Visual Analogue Scale (VAS) leg and back pain, and Short form (SF-12) mental and physical component summary (MCS/PCS) scores .

Results
There were significant differences determined by one-way ANOVAs for all spine pathologies and specific PROs (p<0.0001). Time to plateaued recovery after surgery for lumbar disc herniation and lumbar spondylolisthesis followed the same course for the following PROs: VAS back and leg pain, 3 months; DS, 12 months; PCS, 12 months; and MCS,3 months. After surgery for lumbar stenosis recovery plateaued at 3 months on all PROs. Beyond these time points no further significant improvements in PRO were seen.

Conclusion
Individual PROs after surgery for lumbar spine pathologies follow specific time-courses to plateaued recovery indicating a two-year follow-up may not be required for all outcomes to be accurately assessed. Ultimately the clinical research question should dictate follow-up time and the outcome measure utilized, however there is now evidence to guide the specific duration of follow-up for each PRO.

168. Outcomes of Spinal Fusion in Children with Cerebral Palsy: Are We Getting Better?

Derek Nhan, BS; Amit Jain, MD; Paul D. Sponseller, MD; Brian Sullivan, BS; Suken Shah, MD; Amer F. Samdani, MD; Burt Yaszay, MD; Oussama Abousamra, MD; Patrick Cahill, MD; Michelle Claire Marks, MS, PT; Peter Newton, MD; Harms Study Group

Summary
We reviewed the trends in process measures, operative factors, and clinical outcomes data in a prospectively maintained cerebral palsy (CP) scoliosis registry over a 10-year period. There was a significant decline in major medical complication rates, blood loss, and length of postoperative intubations over the study period but not in deep wound infection rates. Surgeons were more apt to use antifibrinolytics and intra-wound antibiotics during this period.

Hypothesis
With increasing emphasis on surgical safety & adoption of best surgical practices over the past decade, there have been significant improvements in care of children with cerebral palsy undergoing spinal fusion.

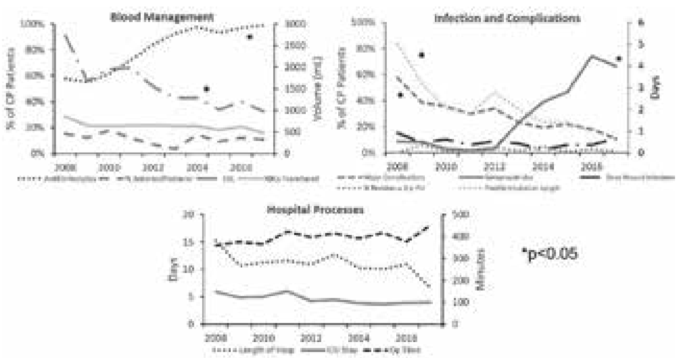
Design
Retrospective review of a prospective registry

Introduction
Our study analyzed the trends over a decade in process measures (op time, length of stay, postop intubation time), operative (op) factors (EBL, EBL/unit blood vol), and clinical outcomes in children with CP treated with spinal fusion.

Methods
A multicenter CP registry was queried to identify all patients ≤ 21 yrs who underwent spinal fusion from 2008-2017 (n=407). We evaluated op data in all patients, and deformity correction & major complications in those with ≥2 yr follow-up (n=238).

Results
From 2008-2017, there was no variation in age (14.4±2.9 yrs, p=0.66) or gender (44% female, p=0.94) at time of surgery. Avg. major curve & pelvic obliquity correction was 66% and 64%, respectively. Op Factors: No variation over time was found in op time (393±126 min, p=0.15), length of hospitalization (11.3±8.8 days, p=0.41), ICU stay (4.7±5.4 days, p=0.16), unit rod use (14%, p=0.36), or %ant/post approach (11%, p=0.41). However, significant decline was seen in EBL (P<0.001, mean decline 159mL/yr, from 2.7±2.0L in 2008 to 0.97±0.66L in 2017), length of postop intubation (2.2±1.4d, p=0.04), and EBL/unit blood volume (p<0.001) with an increase in use of intraop antifibrinolytics (p<0.001, from 58% in 2008 to 100% in 2017). Re-op rate (non-infection) was 2.7% (Fig 1) overall. Outcomes: There was a decline over time in major complication rate (58% in 2008 to 11% in 2017, p=0.008). An increase in intra-wound gentamycin- not vancomycin- was seen (9% in 2008 to 67% in 2017, p<0.001) but no change with time occurred in the early (1 yr) deep wound infection rate (7.9%, p=0.83). The mean improvement in CPCHILD score over the 2 yr follow-up was on avg. 6.1±13.7 points (p=0.36)

Conclusion
Over the past decade, significant improvements occurred in blood loss management and in overall periop complication rates in children with CP undergoing spinal fusion. However, rates of deep wound infection and HRQL scores have remained stable.



Notes

Author Index

The Scoliosis Research Society gratefully acknowledges Globus Medical for their overall support.

Author Index

PRESENTATION KEY: 1-147 = Paper/ Podium Presentations, 151-168 = E-Presentations, 200-301 = E-Posters, PMC= Pre-Meeting Course, CASE= Case Discussion, LTS= Lunchtime Symposium, HDC= Half-Day Course

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About SRS

Founded in 1966, the Scoliosis Research Society is an organization of medical professionals and researchers dedicated to improving care for patients with spinal deformities. Over the years, it has grown from a group of 37 orthopaedic surgeons to an international organization of more than 1,300 health care professionals.

Mission Statement

The purpose of the Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

Membership

SRS is open to orthopaedic surgeons, neurosurgeons, researchers and allied health professionals who have a practice that focuses on spinal deformity.

Active Fellowship (membership) requires the applicant to have fulfilled a five-year Candidate Fellowship and have a practice that is 20% or more in spinal deformity. Only Active Fellows may vote and hold elected offices within the Society.

Candidate Fellowship (membership) is open to orthopaedic surgeons, neurosurgeons and to researchers in all geographic locations who are willing to commit to a clinical practice which includes at least 20% spinal deformity. Candidate Fellows stay in that category for five years, during which time they must demonstrate their interest in spinal deformity and in the goals of the Scoliosis Research Society. Candidate Fellows may serve on SRS committees. After five years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Candidate Fellowship does not include the right to vote or hold office.

Associate Fellowship (membership) is for distinguished members of the medical profession including nurses, physician assistants, as well as orthopaedic surgeons, neurosurgeons, scientists, engineers and specialists who have made a significant contribution to scoliosis or related spinal deformities who do not wish to assume the full responsibilities of Active Fellowship. Associate Fellows may not vote or hold office, but may serve on committees.

Senior Candidate Fellowship (membership) is limited to senior surgeons, neurosurgeons and to non-physicians members of allied specialties. This candidacy is a path to SRS Active Fellowship. Senior surgeons have the opportunity to become Active Fellows of SRS in two years and not 5 years like the regular Candidate Fellowship track. They must have 20 years of experience (time spent with fellowship and training does not count), be a full professor, head of spine unit or chief of spine division, and clinical practice which includes 20% spinal deformity. After two years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Senior Candidate Fellowship does not include the right to vote or hold office.

Visit www.srs.org/professionals/membership for membership requirement details.

SRS Membership Information Session

Prospective members and new candidate members are invited to attend a membership information session on Thursday, October 11 from 18:00 – 18:30 in Sala Italia.

Don't miss the opportunity to learn more about SRS!

Programs and Activities

SRS is focused primarily on education and research that include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Conferences, a Global Outreach Program, the Research Education Outreach (REO) Fund which provides grants for spine deformity research, and development of patient education materials.

Website Information

For the latest information on SRS meetings, programs, activities, and membership please visit www.srs.org. The SRS Website Committee works to ensure that the website information is accurate, accessible, and tailored for target audiences. Site content is varied and frequently uses graphics to stimulate ideas and interest. Content categories include information for medical professionals, patients/public, and SRS members.

For more information, please visit the SRS website at www.srs.org.

Social Media

Follow SRS online. Join the conversation online about the 53rd Annual Meeting.

Share your experience and stay up-to-date with SRS during and after the meeting.

Share and search public posts with: #SRSAM18

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If you need assistance finding the SRS social media or using the hashtag (#SRSAM18), please see Shawn at the registration desk.

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Scoliosis Research Society

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www.srs.org

Meeting Outline

Monday, October 8, 2018	
8:00-16:00	Board of Directors Meeting*
Tuesday, October 9, 2018	
7:00-17:00	SRS Committee Meetings*
12:00-17:00	Registration Open
13:00-17:00	Hibbs Society Meeting*
19:00-22:00	SRS Leadership Dinner* (by invitation only)
Wednesday, October 10, 2018	
7:30-19:00	Registration Open / E-Posters* Open
7:30-20:00	Presentation Upload Area Open
9:00-13:00	Pre-Meeting Course
13:15-14:15	Lunchtime Symposia
14:30-17:20	Scientific Program
17:30-18:30	Case Discussions
18:45-20:00	Opening Ceremonies*
20:00-22:00	Welcome Reception*
Thursday, October 11, 2018	
7:00-8:30	2018-2019 Committee Chair Breakfast* (by invitation only)
7:30-17:00	Registration Open / E-Posters* Open
7:30-18:00	Presentation Upload Area Open
8:55-13:30	Scientific Program
13:30-14:45	Member Business Meeting & Lunch*
13:45-14:45	Non-Member Lunch Session*
15:00-18:00	Half-Day Courses
18:00-18:30	Member Info Session*
Friday, October 12, 2018	
7:30-8:45	Member Business Meeting & Breakfast*
7:30-17:00	Registration Open / E-Posters* Open
7:30-18:30	Presentation Upload Area Open
8:55-12:45	Scientific Program
13:00-14:00	Lunchtime Symposia
14:15-18:14	Scientific Program
20:00-23:00	Farewell Reception*
Saturday, October 13, 2018	
7:30-13:30	Presentation Upload Area Open
7:45-11:00	Registration Open / E-Posters* Open
8:55-13:30	Scientific Program
14:00-16:30	Board of Directors Meeting*

**denotes non-CME*

Wireless Internet: *Network* = **srs2018** *Password* = **scoliosis**

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