FINAL PROGRAM

www.srs.org *Sponsored by the Scoliosis Research Society*

Scoliosis Research Society

48th Annual Meeting & Course

SEPTEMBER 18–21, 2013 • CITÉ CENTRE DE CONGRÈS

Lyon, France

SCOLIOSIS RESEARCH SOCIETY • FOUNDED 1966

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General Meeting Information

The Scoliosis Research Society gratefully acknowledges Medtronic for their support of the Pre-Meeting Course, Half-Day Courses, Welcome Reception, Beverage Breaks and overall support of the 48th Annual Meeting & Course.

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SRS Executive Office
555 East Wells Street, Suite 1100
Milwaukee, WI 53202
P: 414.289.9107
F: 414.276.3349
info@srs.org • www.srs.org

President's Message

Dear Colleagues,

On behalf of the 2013 Local Organizing Hosts, I would like to personally welcome you to the 48th Annual Meeting & Course in Lyon, France, a historic city designated as a UNESCO World Heritage Site. Enjoy the rich history of the city including the tradition of silk weaving and why Lyon is considered the "birthplace" of cinema. While you immerse yourself in the culture of Lyon, don't forget to enjoy the cuisine and wine of the gastronomic capital of the world. Lyon promises to be an unforgettable experience.

I would like to personally thank our Local Organizing Hosts Pierre Roussouly, MD, Daniel Chopin, MD, and Nobert Passuti, MD. All have added their own personal touches to the meeting to help ensure a unique French experience.

The Program and Education Committees have worked hard to present another exceptional program. Wednesday's Pre-Meeting Course, organized by the Education Committee lead by Chair John Dimar, MD explores a Global Perspective of the Management of Spinal Disease & Deformity, with Lyon being the perfect venue for the topic. Following the Pre-Meeting Course will be four exciting Case Discussion Sessions: Cervical, Complications and Congenital Scoliosis, Kyphosis and Neurological Complications. Wednesday evening will round out with the Opening Ceremonies and Welcome Reception. We are delighted to welcome this year's Howard Steel Lecturer, Guillaume d'Angerville, to educate us on the famous Vineyards of Burgundy.

Thursday will kick off the three-day Scientific Program which will feature 129 podium presentations and over 100 E-Posters selected from a record year for abstract submissions. Program Committee Chair Suken Shah, MD and the entire committee have worked hard to ensure the program is fresh and has an increasingly global perspective, a theme of my presidency. Over 30 percent of the podium presentations have come from our international colleagues, and faculty and moderators from around the world can be found throughout the entire program.

In addition to the abstract-based poster and podium presentations, the program will feature six Lunchtime Symposia on Wednesday and Friday as well as three Half-Day Courses on Thursday afternoon; Non-Operative Management, Sagittal Balance and Myelomeningocele. We hope you will choose to join us for these informative and innovative courses.

I am honored to welcome Daniel Henri Chopin, MD as my Harrington Lecturer whose talk is entitled "The Pelvic Vertebrae: A French Obsession?" This year we will also honor Ian A.F. Stokes, PhD and George H. Thompson, MD as our 2013 Lifetime Achievement Award recipients and Bettye A. Wright, PA, RN as the Walter P. Blount Humanitarian Award recipient. Such deserving recipients truly represent the greatness of our Society.

French culture will be incorporated into the meeting from the social events to the guest activities. Friday night's Farewell Reception at "Les Halles de Lyon-Paul Bocuse" is unique to Lyon and its reputation as the gastronomy capital of the world. This covered market opened in 1971 and is home to over 55 different vendors including wine, chocolate, cheese and traditional dishes. All guests will be invited to sample offerings from each vendor at no additional cost, guaranteeing satiety!

Finally I would like to thank the Board of Directors, council chairs, and committee and task force chairs and members for making my year as the 43rd President of this Society successful and memorable. I would especially like to thank the members of the Presidential Line, Steve Richards, MD, Steve Glassman, MD and John Dormans, MD, for their time and commitment each week to help me achieve my goals as president this year.

Thank you for the opportunity and honor of being the president of this wonderful Society.

Sincerely,

Kamal N. Ibrahim, MD, FRCS (C), MA
SRS President, 2012-2013

Board of Directors - 2012-2013

Kamal N. Ibrahim, MD, FRCS(C), MA
President

Steven D. Glassman, MD
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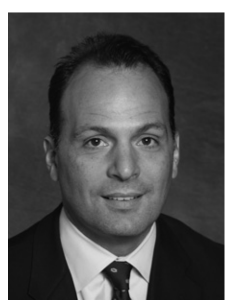
Research Council Chair



Daniel J. Sucato, MD, MS
Education Council Chair

Annual Meeting Committees

2013 SRS President
Kamal N. Ibrahim, MD, FRCS(C), MA

2013 Local Organizing Hosts
Daniel H. Chopin, MD
Nobert Passuti, MD
Pierre Roussouly, MD

2013 SRS Education Committee
John R. Dimar, II, MD, Chair
Mark B. Dekutoski, MD, Past-Chair
Lori A. Karol, MD, Chair-Elect

Terry D. Amaral, MD
Christopher P. Ames, MD
Sigurd H. Berven, MD
Michael S. Chang, MD
Robert H. Cho, MD
John C. France, MD
Daniel W. Green, MS, MD, FACS
Brian Hsu, MD
Andrew H. Jea, MD
Elias C. Papadopoulos, MD
S. Rajasekaran, MD, FRCS, MCh, PhD
Scott S. Russo, MD
Frank J. Schwab, MD
Suken A. Shah, MD
Kit M. Song, MD, MHA
Paul D. Sponseller, MD
Mark Weidenbaum, MD
Adam L. Wollowick, MD
Lukas P. Zebala, MD

2013 SRS Program Committee
Suken A. Shah, MD, Chair
Daniel J. Sucato, MD, MS, Past-Chair
James O Sanders, MD, Chair-Elect

Jahangir K. Asghar, MD
Theodore J. Choma, MD
Daniel W. Green, MS, MD, FACS
Stanley S. Lee, MD
Ronald A. Lehman Jr., MD
Timothy S. Oswald, MD
Frank J. Schwab, MD
John G. Thometz, MD

2013 SRS Program Reviewers
Neel Anand, MD
Patrick Cahill, MD
Charles H. Crawford, III, MD
Geoffrey A. Cronen, MD
Mohammad El-Sharkawi, MD
James T. Guille, MD
Lawrence L. Haber, MD
Jeffrey S. Kanel, MD
Khaled Kebaish, MD
D. Raymond Knapp, Jr., MD
Michelle Marks, PT, MA
Jwalant S. Mehta, FRCS(Orth)
Hani Mhaidli, MD
Mohammad Mossaad, MD
Matthew E. Oetgen, MD
Clifford B. Tribus, MD
Stewart K. Tucker, FRCS
Juan S. Uribe, MD
Kota Watanabe, MD, PhD
Mark Weidenbaum, MD
Hee Kit Wong, MD
Muharrem Yazici, MD

General Meeting Information

VENUE INFORMATION

The Cité Centre de Congrès is the location for the 48th Annual Meeting & Course:

50 Quai Charles de Gaulle, 69006 Lyon, France
+33 4 72 82 26 26
http://www.ccc-lyon.com/home

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 times inside the Cité Centre de Congrès, 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

The Half-Day Courses on Thursday, September 19 require a ticket for admission. Tickets for these sessions are not included in the meeting's base registration fees, but are available for an additional $30. Tickets will be collected by ushers in exchange for lunch prior to the sessions. Tickets may be purchased at the Registration Desk. In addition, tickets will be required for admission to the Farewell Reception. The Farewell Reception will take place at Les Halles de Lyon, for an additional $25 fee per ticket for registered delegates and registered guests. If you pre-registered, tickets may be found in your registration packets behind your name badge. A limited number of tickets may be available at the Registration Desk.

ABSTRACT VOLUME

All abstracts accepted for presentation at the 48th Annual Meeting have been published in the Final Program (pages 208-279). Each attendee will receive one copy of the program along with their registration materials. The Final Program has also been posted online to the Program tab of the SRS Annual Meeting website (www.srs.org/professionals/meetings/am13/program)

ATTIRE

Business casual (polo or dress shirts, sport coats) is appropriate for all Annual Meeting & Course sessions and events. Casual attire is appropriate for the Farewell Reception.

SRS 48th Annual Meeting & Course Mobile App

A mobile and online app will be available to all delegates during the 48th Annual Meeting & Course. The app is designed to provide all the information about the Annual Meeting & Course and Lyon in one convenient location and can be accessed from any smart phone or computer with an internet connection. To download the app visit:

http://eventmobi.com/srsam13
or scan the QR code below with your smart phone.

Download all abstracts and the Final Program right from the app!

The app includes:

- An offline mode will allow delegates to access all static content, including the agenda, speaker listing and info booth, on the app without an internet connection.
- A detailed Annual Meeting agenda that allows delegates to create a personalized schedule.
- An information booth featuring everything you need to know about the Annual Meeting & Course and its host city of Lyon, including scientific and social program details, information on the Cité Centre de Congrès, as well as downtown Lyon dining and attractions.
- Live audience polls during the Pre-Meeting Course and a Hibbs Award voting poll on Friday, September 20.
- Maps of the Cité Centre de Congrès and meeting space.
- An alert system for real-time updates from SRS - program changes, tour and social event notifications, and breaking news as it happens.
- A complete list of Annual Meeting faculty and podium presenters, including presentation titles, times, dates, and locations.

To learn more about the app or how to use the QR code, please refer to the insert in your registration bag or visit www.srs.org/professionals/meetings/am13.

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

General Meeting Information

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 Cité Centre de Congrès 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.

EVALUATIONS

Please take time to complete the online evaluation forms provided for each session you attend. Your input and comments are essential in planning future Annual Meetings.

GUEST HOSPITALITY PROGRAM

Registered guests of Annual Meeting & Course are welcome to attend the Welcome Reception for the base registration fee on Wednesday, September 18 and the Farewell Reception on Friday, September 20 for the additional cost of $25. Registered guests are also welcome to take part in the Guest Hospitality Program on Friday, September 20 which will feature a hands-on, interactive cooking class at L'atelier des Chefs. Guests will be welcomed with breakfast and viennoiseries (French pastries) followed by a private cooking class. All guests will help to create a traditional French menu including a first course, main course and, of course, dessert, which will be enjoyed over French wine!

L'atelier des Chefs
Thursday, September 19, 2013 (sold out)
& Friday, September 20, 2013
9:30am-1:30pm
8 Rue Saint Nizier F-69002 Lyon
www.atelierdeschefs.frw

*Registration is limited. Please see the Registration Desk for more information.

LANGUAGE

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

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.

MESSAGES

A self-service message board (non-electronic) will be available in the Registration Area for attendees to post notes or leave messages for other attendees. Please remember to check for any messages that may be left for you.

This message center is supported, in part, by a grant from K2M.

PHOTOGRAPHY POLICY

SRS will be taking photographs throughout the Annual Meeting & Course. 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.

SMOKING POLICY

Smoking is not permitted during any meeting activity or event.

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.

INTERNET KIOSKS

Location: Bellecour Level Lobby

Attendees can search the Internet and check email at the Internet kiosks, supported, in part, by a grant from K2M and Orthofix.

Wednesday, September 18	6:30am – 6:00pm
Thursday, September 19	6:30am – 4:30pm
Friday, September 20	6:30am – 5:30pm
Saturday, September 21	6:30am – 12:45pm

Wireless Internet access is available throughout the meeting space in the Cité Centre de Congrès on the Forum Level, Bellecour Level and Salle-Gratte Level.

E-POSTERS

There are over 100 E-Posters available for your review on the E-Poster kiosks in the Forum Level Foyer. The E-Posters are also available on the CD-ROM included with your registration materials.

E-Poster Kiosks are supported, in part, by grants from K2M and Orthofix.

E-Poster CD-ROMs are supported, in part, by a grant from K2M.

REGISTRATION DESK

Location: Bellecour Level Lobby

Tuesday, September 17	2:00pm – 6:00pm
Wednesday, September 18	6:30am – 6:00pm
Thursday, September 19	6:30am – 4:30pm
Friday, September 20	6:30am – 5:30pm
Saturday, September 21	6:30am – 12:45pm

General Meeting Information

SPEAKER UPLOAD AREA

Location: Forum 5/6, Forum Level

Presenters may upload their PowerPoint Presentations in the Speaker Upload Area, located at the back of the general session room, Forum 5/6, Forum Level. **New this year: presentations may not be uploaded in individual rooms but must be uploaded in the Speaker Upload Area.**

Wednesday, September 18	6:30am – 6:00pm
Thursday, September 19	6:30am – 4:30pm
Friday, September 20	6:30am – 5:30pm
Saturday, September 21	6:30am – 12:45pm

MEMBERS BUSINESS MEETINGS

Location: Forum 4, Forum Level

All SRS members are invited to attend the Members Business Meetings, held Thursday, September 19 through Saturday, September 21 from 6:30 – 7:45am in Forum 4 on the Forum Level of the Cité Centre de Congrès. Agendas will include reports from the various SRS committees, presentations by the 2013 Travelling Fellows and Edgar Dawson Scholarship recipients, and updates on SRS activities and programs. A hot breakfast will be served.

NON-MEMBERS CONTINENTAL BREAKFAST

Location: Forum Level Foyer

All non-member delegates to the SRS Annual Meeting are invited to meet with their colleagues, view posters and network over coffee and a continental breakfast served Thursday, September 19 through Saturday, September 21 from 6:30 – 7:45am in the Forum Level Foyer of the Cité Centre de Congrès.

SRS MEMBERSHIP TABLE

Location: Forum Level Foyer

SRS Membership Manager, Nilda Toro, will be available at the SRS membership table throughout the week to answer any questions related to membership requirements for existing members, or how to apply for membership. Don't forget to also stop by for information on upcoming SRS meetings and different SRS programs such as the E-Text, REO and *Spine Deformity: The Official Journal of the Scoliosis Research Society.*

INTERNET ACCESS

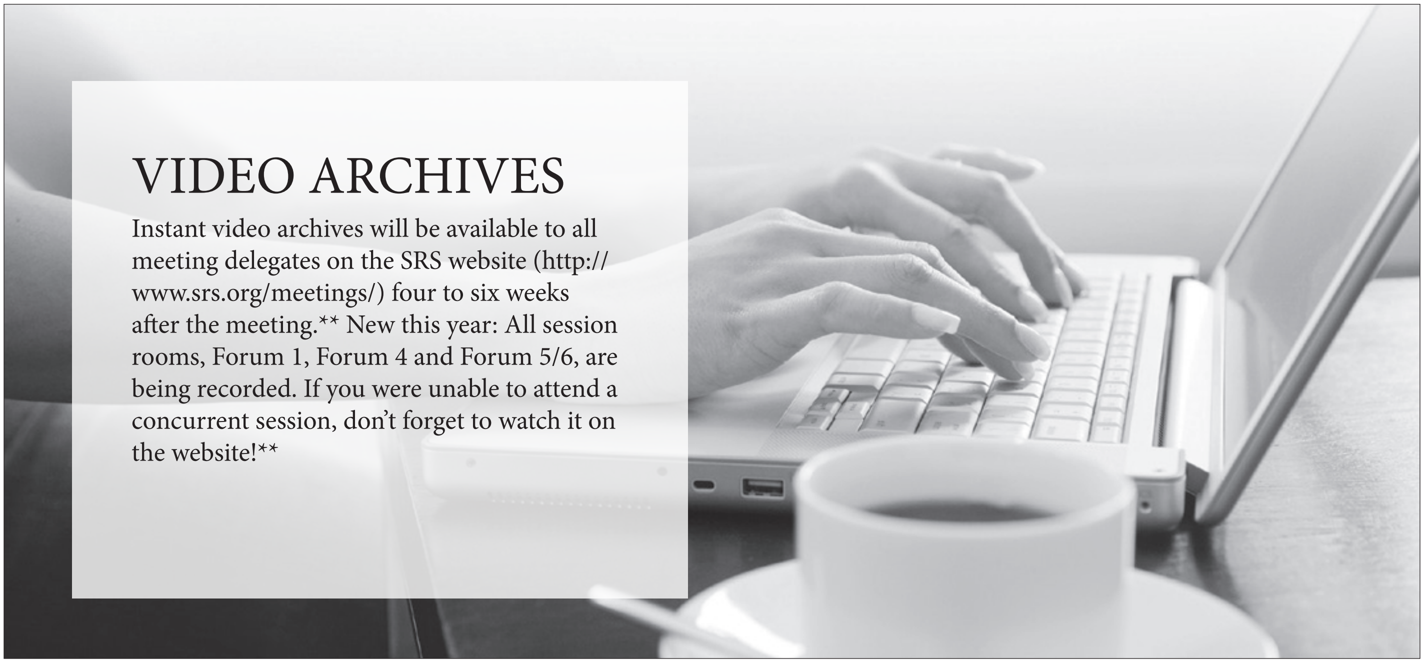
Wireless Internet access is available throughout the meeting space in the Cite Centre de Congres on the Forum Level, Bellecour Level and Salle-Gratte Level.

To log on select…
Network = SRSAM2013
Password = spine2013

Wireless Internet is supported, in part, by a grant from NuVasive.

Delegates without laptops may access complimentary Internet kiosks in the Forum Level Foyer

Internet Kiosks are supported, in part, by grants from K2M and Orthofix.



VIDEO ARCHIVES

Instant video archives will be available to all meeting delegates on the SRS website (http://www.srs.org/meetings/) four to six weeks after the meeting.** New this year: All session rooms, Forum 1, Forum 4 and Forum 5/6, are being recorded. If you were unable to attend a concurrent session, don't forget to watch it on the website!**

CME Information

Meeting Description

The Scoliosis Research Society (SRS) Annual Meeting & Course is a forum for the realization of the Society's mission and goals, the improvement of patient care for those with spinal deformities. Over 125 papers will be presented on an array of topics, including adolescent idiopathic scoliosis, growing spine, kyphosis, adult deformity, trauma, neuromuscular scoliosis and tumors. Upon completion of the Annual Meeting, participants should be able to:

- Detect factors which may contribute to higher complication rates or risk of re-operation and incorporate pre-and peri-operative steps that help to avoid complications in spinal deformity surgery.
- Assess clinical and radiographic factors that contribute to positive or negative outcomes in spinal deformity surgery and utilize this knowledge to prevent adverse outcomes.
- Describe new techniques for the treatment of patients with spinal deformity.
- Indentify the short- and long-term effect of fusion for patients with spinal deformity using a variety of correction strategies and implants.

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 credits (8.25 for Pre-Meeting Course, 19.75 for Annual Meeting) *AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

CME Certificates

CME Certificates will be available immediately upon the close of the meeting at www.srs.org/professionals/meetings/am13.

Delegates should log onto the website listed above and enter their last name and the ID# listed at the top of your Annual Meeting registration confirmation form. The system will then ask delegates to indicate which sessions they attended, to complete evaluation forms for each of those sessions, and then generate a PDF certificate which may be printed or saved. Session attendance and evaluation information are saved in the database, and certificates may be accessed again, in the event the certificate is lost or another copy is required.

Please note that certificates will not be mailed or emailed after the meeting. The online certificate program is the only source for this documentation. If you have any questions, please visit the registration desk, or email the SRS office at meetings@srs.org.

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

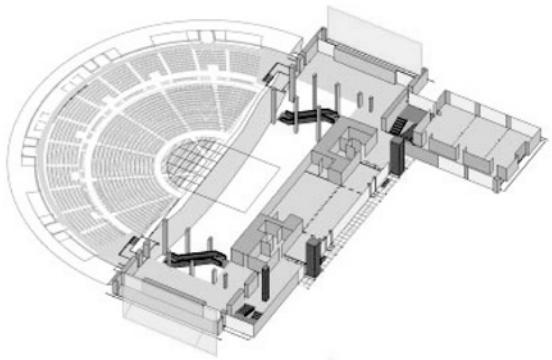
SRS will not be held liable for personal injuries or for loss or damage to property incurred by participants or guests at the Annual Meeting & Course including those participating in tours and social events. Participants and guests are encouraged to take out insurance to cover loss incurred in the event 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 & Course 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.

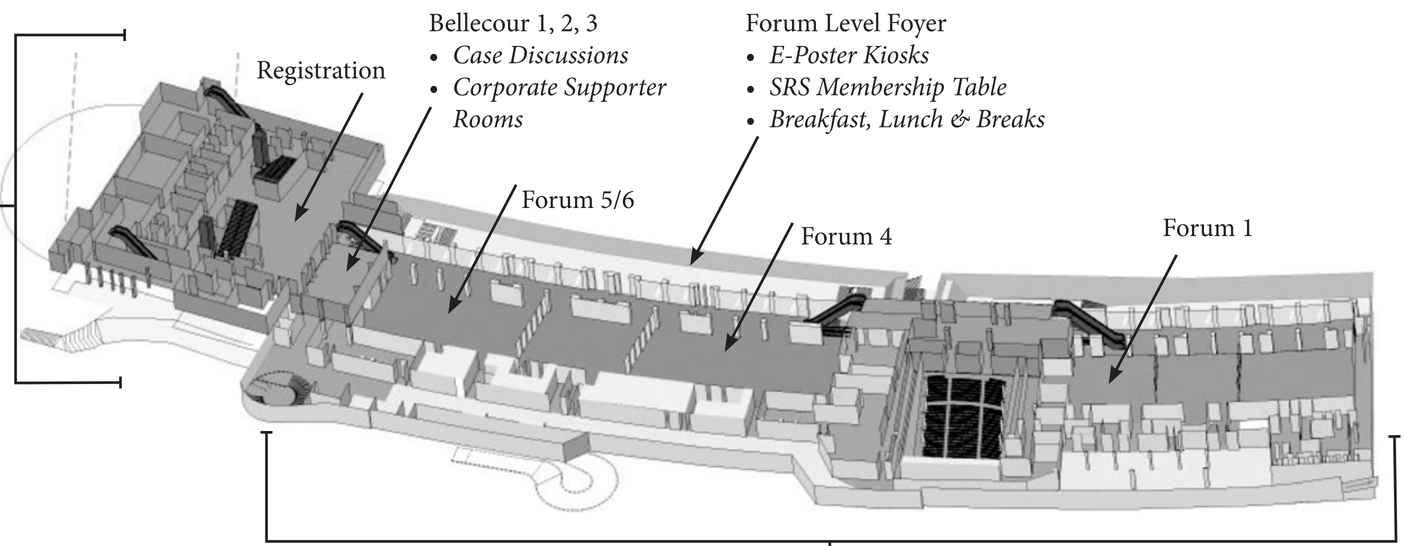
SRS disclaims any and all liability for injury or other damages resulting to any individual attending a scientific meeting and for all claims that may arise out of the use of techniques demonstrated therein by such individuals, whether these claims shall be asserted by a physician or any other person.

Cité Centre de Congrès Floorplans



Level 2, Gratte-Ciel Level

- *Committee Meetings*
- *Corporate Supporter Rooms*



Level -1, Bellecour Level

- *Registration*
- *Internet Cafe*
- *Bellecour 1, 2, 3, (Case Discussions, Corporate Supporter Rooms)*

Level -2, Forum Level

- *Forum 5/6, Forum 4, Forum 1 (Pre-Meeting Course, Scientific Program, Educational Program)*

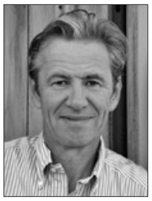
Meeting Outline

Meeting Overview

Monday, September 16, 2013		**Location**
12:00-6:00pm	Board of Directors Meeting	Hilton Lyon
Tuesday, September 17, 2013		
7:00am-5:00pm	SRS Committee Meetings	Gratte-Ciel Level
1:00-5:00pm	Hibbs Society Meeting	Forum 1
2:00-6:00pm	Registration Open	Bellecour Level Lobby
7:00-10:00pm	SRS Leadership Dinner (by invitation only)	
Wednesday, September 18, 2013		
6:30am-6:00pm	Registration Open/ Internet Kiosks E-Posters Open	Bellecour Level Lobby Forum Level Foyer
7:45am-12:20pm	Pre-Meeting Course – Morning Sessions	Forum 5/6; Forum 1
12:35-1:35pm	Lunchtime Symposia Neuromonitoring Lifelong Radiology Exposure to Patients Research Grant Outcomes	 Forum 5/6 Forum 4 Forum 1
1:45-4:30pm	Pre-Meeting Course – Afternoon Sessions	Forum 5/6
4:45-5:45pm	Case Discussions	Bellecour 1, 2, 3; Forum 1
6:00-7:30pm	Opening Ceremonies	Forum 5/6
7:30-9:00pm	Welcome Reception	Forum Level Foyer
Thursday, September 19, 2013		
6:30am-4:30pm	Registration Open/ Internet Kiosks E-Posters Open	Bellecour Level Lobby Forum Level Foyer
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast	Forum 4 Forum Level Foyer
7:55am-12:30pm	Scientific Program	Forum 5/6
9:30am-1:30pm	Guest Hospitality Program	
12:30-1:30pm	Lunch & Networking for Half-Day Course Participants Member Information Session	Forum Level Foyer Forum 1
1:30-4:30pm	Half-Day Courses Myelomeningocele Non-Operative Techniques Sagittal Plane Deformity	 Forum 1 Forum 4 Forum 5/6
Friday, September 20, 2013		
6:30am-5:30pm	Registration Open/ Internet Kiosks, E-Posters Open	Bellecour Level Lobby
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast	Forum 4 Forum Level Foyer
7:55-11:50am	Scientific Program	Forum 5/6; Forum 4
9:30am-1:30pm	Guest Hospitality Program	
12:00-1:00pm	Lunchtime Symposia Culture of Safety in Your Operating Room Global Outreach Update Research Planning	 Forum 1 Forum 4 Forum 5/6
1:15-5:15pm	Scientific Program	Forum 5/6
7:45-11:00pm	Farewell Reception	Les Halles de Lyon - Paul Bocuse
Saturday, September 21, 2013		
6:30am-12:45pm	Registration Open/ Internet Kiosks E-Posters Open	Bellecour Level Lobby Forum Level Foyer
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast	Forum 4 Forum Level Foyer
7:55-12:45pm	Scientific Program	Forum 5/6
1:00-3:30pm	Board of Directors Meeting	Hilton Lyon

Guest Lecturers & Award Recipients

Howard Steel Lecture
Wednesday, September 18, 2013



Guillaume d'Angerville
Owner of Domaine Marquis d'Angerville
"The Vineyards of Burgundy and Their Famous Climates: A Brief Encounter"

Guillaume d'Angerville owns and runs Domaine Marquis d'Angerville, a winery and estate located in the tiny village of Volnay, in the heart of world famous Côte de Beaune in Burgundy. Guillaume is the sixth generation of the family dynasty that has been running the Domaine since it was acquired by his ancestor in 1804. The estate, totalling about 15 hectares (37 acres), comprises the most famous "Premier Crus" (first growth) of Volnay: Clos des Ducs, Champans, Taillepieds, Caillerets... which were once part of the estate of the Dukes of Burgundy.

Guillaume d'Angerville is the grandson of Sem, Marquis d'Angerville, who was one of the founding members of the Institut National des Appellations d'Origine (INAO, a regulatory body that controls the names and origins of classified wines in France), and one of the pioneers of estate bottling in the 1920s. Guillaume's father, Jacques d'Angerville, also a well-known figure on the Burgundian scene, was for many years the President of the Bureau Interprofessionnel des Vins de Bourgogne (Burgundy Wine Board) and of the French Wine Academy.

Guillaume spent the first 30 years of his professional career in investment banking, most notably with J.P. Morgan. Never out of touch with the Domaine's activities during his father's tenure, he nonetheless pursued an international career, living for more than 10 years in New York and London before returning to Paris to run the investment banking arm of J.P. Morgan in France.

Upon his father's death in July 2003, he decided, together with his family, to resign from J.P. Morgan and return to Burgundy in order to maintain Domaine Marquis d'Angerville in family hands.

Since then, he has worked to continue to enhance the Domaine's reputation while respecting the winemaking philosophy and style of his predecessors. This means, inter alia, a sharp focus on viticulture - a good wine starts with a perfectly kept vineyard - combined with minimal human intervention during vinification, to let each terroir express itself. An advocate of natural treatments, Guillaume decided and supervised the conversion of the Domaine to biodynamic viticulture, a re-discovered method first invented by Rudolf Steiner in the 1920s, designed to fight vine diseases without using fertilizers or pesticides. The conversion was completed in 2009.

Guillaume is the current President of Domaines Familiaux de Bourgogne, an association of family-owned domaines of Burgundy, and is President-Delegate of the Association pour l'inscription des climats du vignoble de Bourgogne au Patrimoine mondial.

Guillaume d'Angerville is 56. He is married and has four children. He graduated from Ecole Supérieure des Sciences Economiques et Commerciales (ESSEC) in 1981 and earned a Diplôme de Technicien en Oenologie at the University of Dijon in 2004.

Harrington Lecture
Thursday, September 19, 2013

Daniel H. Chopin, MD
"The Pelvic Vertebrae: A French Obsession?"

Daniel Henri Chopin, MD currently resides in Burgundy, France and is a member of the University of Lille Neuro-Orthopedic Spine Unit. Prior to his current position, Dr. Chopin was the Director of the Spine Center of the Institut Calot Berck sur Mer from 1977 to 2010. Dr. Chopin received his medical degree from the University of Paris in 1969 and pursued a fellowship in neurosurgery, orthopedic surgery adult and pediatric, at the Paris University Hospital from 1970-1977.

Dr. Chopin has been active in many orthopedic associations. He has been president of the French Scoliosis Society, and founding member and president of the French Spine Society. Additionally, he is a member of the College of Orthopedic Surgeons, Scoliosis Research Society, Spine Society of Europe, International Group for Advance Spine Science, British Scoliosis Research Society, Australian Spine Society, Quebec Scoliosis Society, and Turkish Spine Society. He has been a guest speaker at 19 different societies, faculty at many international spine courses and a visiting professor at various hospitals around the world.

Research has also played a large role in Dr. Chopin's career working on deformity correction simulation, bone substitutes implant design for CD Instrumentation (transverse plate, pelvic fixation), co-conceptor of Colorado Instrumentation, specific pelvic fixation design and InterbodyTelemanon cage.

Dr. Chopin was born May 9, 1944 in Autun, France.

Guest Lecturers & Award Recipients

Walter P. Blount Humanitarian Award Recipient

The 2013 Walter P. Blount Humanitarian Award will be presented on Wednesday, September 18, acknowledging outstanding service to those with spinal deformity, and for generosity to the profession and Society.

Bettye A. Wright, PA, RN

Bettye Wright was born in Platte City, Missouri, or as Marc Asher, MD affectionately says, she is a "Missouri Mule." Ms. Wright is the oldest of two children, mother of three (Michael, Michelle and Monique), grandmother to five and a great-grandmother to one. In addition to her small immediate family, Ms. Wright has numerous adopted children and family members in Ghana.

Being diagnosed with idiopathic scoliosis as an adolescent, Ms. Wright always had a desire to work with teens with the same diagnosis. As a physician's assistant (PA) at Henry Ford Hospital in Detroit, Michigan in the early 1980s, this desire was realized when she was assigned to work with Alvin Crawford, MD and Chuck Schock, MD. Ms. Wright worked as Dr. Crawford's PA until he relocated to Cincinnati, although they continued to work together. After Dr. Crawford's departure, Ms. Wright began working with Dale Hoekstra, MD when he assumed the Directorship of Henry Ford's spine program. The two worked together for 30 years.

After retiring in 2007, Ms. Wright joined Oheneba Boachie-Adjei, MD in his Manhattan office in addition to continuing to volunteer with the Foundation of Orthopedics and Complex Spine (FOCOS) mission trips to Ghana. This transition was after years of mission trips to Ghana including the very first mission trip when it was just the two of them.

According to Ms. Wright, she never felt that the small role she played in FOCOS was significant and is simply honored to be a part of the FOCOS journey, and a fabulous journey it has been. During her 15-year involvement, she truly feels she has received far more than she has given.

Lifetime Achievement Award Recipients

The 2013 Lifetime Achievement Awards will be presented on Thursday, September 19. 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.

Ian A.F. Stokes, PhD

After graduating in Engineering Science from Cambridge University in 1971, Ian Stokes worked on the biomechanics of the forefoot affected by diabetic neuropathy and hallux valgus for his PhD in 1975. He then studied spinal motion and thoracic shape in patients with spinal deformity using biplanar X-ray and stereo-photogrammetric methods and moved to the University of Vermont in 1980. Tackling the question "If spinal biomechanics is the answer, then what is the question?" led him to identify scoliosis progression (not etiology) as offering opportunities to make useful contributions. The spine scoliosis of critical magnitude (independent of initiating causes) may grow asymmetrically during rapid skeletal growth, apparently because bone growth and disc wedging are sensitive to applied forces. The research involved clinical studies and analyses of paraspinal muscle activation, as well as research into the biomechanics of the growth plate and intervertebral disc with extensive use of animal models.

George H. Thompson, MD

George H. Thompson, MD is Professor of Orthopaedic Surgery and Pediatrics at Case Western Reserve University in Cleveland, Ohio and the Director of Pediatric Orthopaedics at Rainbow Babies and Children's Hospital, University Hospitals Case Medical Center (1987-present).

He graduated from Oklahoma State University (BS in Physiology) in 1966 and the University of Oklahoma School of Medicine in 1970. He did a surgical internship and orthopaedic surgery residency at the University of California Los Angeles Medical Center (1970-1972, 1974-1977) followed by a fellowship in pediatric orthopaedics at the Hospital for Sick Children in Toronto, Ontario (1978) under the supervision of Robert B. Salter, MD, FRCS(C). He then joined the faculty at Case Western Reserve University (1979-present).

He is currently Vice-Chairman of the Department of Orthopaedic Surgery, the Co-Chair of the Salter Society; Co-Editor of the *Journal of Pediatric Orthopaedics;* President/CEO of the SICOT Foundation; and member of the Medical Advisory Board, Shriner's Hospital for Children. He is the Past-President of the Ohio Orthopaedic Society (1997-1999), Pediatric Orthopaedic Society of North America [POSNA] (2002-2003), and Scoliosis Research Society [SRS] (2006-2007; 2007-2008). He is the immediate Past-Deputy Editor of Pediatric Orthopaedics for the *Journal of Bone and Joint Surgery American* (2003-2005).

He has received numerous honors and awards, most notably the American Orthopaedic Association (AOA) North American Traveling Fellowship (1979), an endowed chair from his institution (2006), the POSNA Arthur H. Huene Award (2008) and the 2013 SRS Lifetime Achievement Award.

Major interests include spinal deformities, trauma, hip abnormalities, and foot deformities. He has published 153 peer-reviewed articles, 86 chapters in textbooks and edited four textbooks. He has presented more than 700 regional, national and international lectures.

Social Events

Opening Ceremonies & Welcome Reception
Wednesday, September 18, 2013
6:00 – 9:00pm

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

The Annual Meeting will officially begin with Opening Ceremonies and this year's Howard Steel Lecture, presented by Guillaume d'Angerville, owner of the Domaine Marquis d'Angerville winery. The evening will include an introduction of the SRS officers and honored presidents from other spine societies. All 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 conversation and reunions with colleagues and friends.

The Welcome Reception is supported, in part, by a grant from Medtronic.

Farewell Reception
Friday, September 20, 2013
7:45 – 11:00pm

Open to all registered delegates and registered guests. Tickets are $25 each and must be purchased in advance. A limited number of tickets may be available onsite, but SRS strongly urges delegates and guests to purchase tickets at the time of registration. Name badges are required.

The 48th Annual Meeting & Course will culminate with a cultural experience at Les Halles De Lyon- Paul Bocuse. Buses will depart the Cité Centre de Congrèss beginning at 7:45pm, and will continue to run between Les Halles and the convention center until 11:00pm. Join us in the gastronomy capital of the world to experience the best of Lyon all in one place. This covered market opened in 1971 and is home to over 55 different vendors including wine, chocolate, cheese and traditional dishes. All guests will be invited to sample offerings from each vendor at no additional cost, guaranteeing no one leaves hungry! Casual attire is appropriate.

Opening Ceremonies Agenda • Wednesday, September 18, 2013

6:00 – 6:05 pm	**Welcome to Lyon** *Pierre Roussouly, MD, Local Host*
6:05 – 6:10 pm	**Presidential Welcome** *Kamal N. Ibrahim, MD, FRCS(C), MA, President*
6:10 – 6:20 pm	**Introduction of Visiting Presidents** **Introduction of SRS Traveling Fellows** **Introduction of Fellowship and Award Recipients** *Kamal N. Ibrahim, MD, FRCS(C), MA, President*
6:20 – 6:35 pm	**The American French Spine Connection: 1913-2013** *Christian Morin, MD* *Rémi Kohler, MD*
6:35 – 6:40 pm	**Presentation of Blount Humanitarian Award** *Introduction by Lawrence Haber, MD, Awards & Scholarships Committee Chair* *Presentation by Kamal N. Ibrahim, MD, FRCS(C), MA, President & Lawrence Haber, MD*
6:40 – 6:50 pm	**Acknowledgement of Corporate Supporters** *B. Stephens Richards, III, MD, Past President & Corporate Relations Committee Chair*
6:50 – 6:52 pm	**Introduction of Howard Steel Lecturer** *Daniel H. Chopin, MD, Local Host*
6:52 – 7:22pm	**Howard Steel Lecture** "The Vineyards of Burgundy and Their Famous Climates: A Brief Encounter" *Mr. Guillaume d'Angerville, Owner of Domaine Marquis d'Angerville*
7:22 – 7:25pm	**Closing Remarks** *Kamal N. Ibrahim, MD, FRCS(C), MA, President*

Tours

The following tours are available to registered delegates and guests through Dekon Congress & Tourism, our partners in Lyon. All tour reservations must be made directly through Dekon, who will be available at the Tours & Accomodation Desk in the Bellecour Level Lobby of the Cité Centre de Congrès. Any questions regarding registration or tour details should be directed to Dekon.

Monday, September 16, 2013 - Sunday, September 22, 2013		
10:00am-4:00pm	Lyon Le Grand Tour: One-Day Pass	18 €
Tuesday, September 17, 2013		
1:30-6:30pm	Half Day in Beaujolais	75 €
10:00am-6:30pm	One Day in Lyon and Beaujolais	95 €
Wednesday, September 18, 2013		
9:30am-1:30pm	Lyon Authentic	56 €
Thursday, September 19, 2013		
9:30am-1:30pm	Cooking Class at L'atelier des Chefs *Sold Out	Included in Guest Base Registration
Friday, September 20, 2013		
9:30am-1:30pm	Lyon Authentic	56 €
9:30am-1:30pm	Cooking Class at L'atelier des Chefs	Included in Guest Base Registration
Saturday, September 21, 2013		
1:30-6:30pm	Half Day in Beaujolais	75 €
10:00am-6:30pm	One Day in Lyon and Beaujolais	95 €

Half Day in Beaujolais

Tuesday, September 17, 2013
Saturday, September 21, 2013
1:30-6:30pm
75 €

This tour meets at 1:30pm at the hop-on, hop-off stop of Place Bellecour to take the "Beaujolais" guided excursion. Enjoy a nice drive in the heart of the Beaujolais vineyards and discover charming villages such as Saint Amour, Juliénas, Fleurie, Chiroubles, Morgon, and Moulin à Vent. Several stops during the wine road drive in Fleurie, Moulin à Vent and Morgon (these three stops are subject to change). Wine tasting in a Morgon (or similar) cellar at 4:30pm. At 5:30pm return to Lyon through the Beaujolais wine road (Route des Crus). Tour will arrive back at Place Bellecour around 6:30pm.

Information:
* French or English guided tour of the Beaujolais wine road (Route des Crus)
* Three wines, artisanal cheeses, and deli tasting
* Does NOT include lunch

One Day in Lyon and Beaujolais

Tuesday, September 17, 2013
Saturday, September 21, 2013
10:00am-6:30pm
95 €

This audio-guided tour of Lyon, in a hop-on hop-off bus, departs the Place Bellecour stop at 10:00am. The city has more than 2,000 years of history and is included on the UNESCO's World Heritage list. Visit on your own with "Lyon le Grand Tour" Commentary in French, English, Spanish, Italian, German, Japanese and Chinese. After lunch on your own, the tour will depart Place Bellecour at 1:30pm to take the Beaujolais guided tour. Enjoy a nice drive in the heart of the Beaujolais vineyards and discover charming villages like Saint Amour, Juliénas, Fleurie, Chiroubles, Morgon, and Moulin à Vent. Three stops during the wine road drive in Fleurie, Moulin à Vent, and Morgon (these three stops are subject to change). Wine tasting in a Morgon (or similar) cellar at 4:30pm. At 5:30 return to Lyon through the Beaujolais wine road (Route des Crus). Tour will arrive back at Place Bellecour around 6:30pm.

Information :
* 1 ticket for Hop-on Hop-off bus : "Lyon Le Grand Tour"
* French or English guided tour of the Beaujolais wine road (Route des Crus)
* Three wines, artisanal cheeses, and deli tasting
* Approximate duration of the tour with Lyon Grand Tour : 1hr 15min
* Does NOT include lunch

Lyon Authentic

Wednesday, September 18, 2013
Friday, September 20, 2013
9:30am-1:30pm
56€

Visit old Lyon beginning at 9:30am at Place Bellecour, under Louis XIV statue on horseback, for the start of the visit. You are accompanied throughout the morning by your professional guide, in the heart of Old Lyon historic district, which boasts 2,000 years of history, classified as World Heritage by UNESCO. The second site in Renaissance Europe after Venice, the old city is revealed through the mysteries of its alleyways. Your guide will lead you into its most secret recesses. Next, cross the Saone to a stop in front of the famous fresco of Lyon. This huge mural was painted in 1995 and it represents 30 of the most famous people from Lyon, men and women from every era. Among them is Chef Paul Bocuse, the king of lyonnaise gastronomic cuisine. Leaning over the balcony or smiling at the doorstep, these great citizens from Lyon seem to be greeting you. This impressive 800 m^2 trompe l'oeil is one of the many outstanding works from the artists of La Cité de la Création, a creative company now renowned all over the world. Lyon, a city with over 150 murals, is now exporting its expertise. After lunch, you are driven to the restaurant by your guide who will explain the secrets of gastronomy of Lyon. In this authentic restaurant orchestrated by Josiane, you will be welcomed for a lunch break in a warm atmosphere.

Lyon Le Grand Tour- One-Day Pass

Monday, September 16, 2013 - Sunday, September 22, 2013
Departures: 10:00am / 11:00am / 11:45am / 12:45am / 2:00pm / 3:00pm / 4:00pm / 5:00pm Place Bellecour
18 €

Discover the city of Lyon and enjoy its fantastic and unique views from our open top deck buses! Your pass, valid for one or two consecutive days on the tour route, allows you to hop on and off as often as you please, at any of our nine stops using tour route. * Amusing and practical type of transportation for a comfortable visit within Lyon. This tour gives you the possibility to visit the main monuments in your own time and to be seated comfortably each time you take the bus.

Lyon le Grand Tour : 1 Pass* / 1 Tour Route / 12 Stops :
1. Place Bellecour
2. Terreaux
3. Mur peint/Saint Vincent
4. Marché Saint-Antoine
5. Saint Jean/Vieux Lyon
6. Confluence
7. Notre Dame de Fourvière
8. Parc des Hauteurs
9. Beaux Arts
10. Cordeliers/République
11. Berges du Rhône
12. Rhône Cruise

Commentaries in seven languages : French, English, Italian, German, Spanish, Japanese, and Chinese.
With your printed voucher, issued from a booking made online, you can show up at any Lyon Le Grand Tour bus stop and exchange it to the driver himself. Two-day pass has to be used on consecutive days.

Includes:
* Transportation in open top-decker coach
* Recorded commentary and personal earphone sets (digital sound)
* Duration: 1hr 30min

Conflict of Interest Disclosures

The Scoliosis Research Society gratefully acknowledges NuVasive for their support of the Wireless Internet and Pre-Meeting Course.

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Brian A. O'Shaughnessy, MD	USA	Medtronic (b); DePuy Synthes Spine (b); Globus Medical (b); Stryker Spine (b)
Peter O. Newton, MD	USA	DePuy Synthes Spine (a,b,g); EOS Imaging (a); NuVasive (c)
Eric C. Parent, PT, MSc, PhD	Canada	No Relationships
Delphine Perie-Wenier, PhD	Canada	No Relationships
Yann Pereon, MD, PhD	France	No Relationships
Joseph H. Perra, MD	USA	Medtronic (a,b,g); Stryker Spine (e); DePuy Synthes Spine (a)
Peter O. Newton, MD	USA	DePuy Synthes Spine (a,b,g); EOS Imaging (a); NuVasive (c)

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Alberto Ponte, MD	Italy	No Relationships
Yong Qiu, MD	China	No Relationships
K. Daniel Riew, MD	USA	JBJS Spine (e); Spine (e); Global Spine Journal (e); Medtronic (a,g); Biomet (a); Spinal Kinetics (c); Paradigm (c); Amedica (c); PSD (c); Nexgen Spine (c); Spineology (c); Vertiflex (c); Expanding Orthopedics (c); Benvenue Medical, Inc (c); Osprey (c)
Manuel Rigo, MD	Spain	No Relationships
Michele Romano, PT	Italy	No Relationships
Amer F. Samdani, MD	USA	DePuy Synthes Spine (b); SpineGuard (b); Zimmer (b); Stryker Spine (b)
Justin S. Smith, MD, PhD	USA	Biomet (b); DePuy Synthes Spine (b,g); Medtronic (b,e); Globus Medical (g)
Luke Stikeleather, CO	USA	Scoliosis Journal (e)
Ferran Pellise Urquiza, MD	Spain	DePuy Synthes Spine (a,b,g); K2M (a); Biomet (b)
Monica Villagrasa-Escudero, PT, MSc, DO	Spain	No Relationships
Michael G. Vitale, MD, MPH	USA	Stryker Spine (b); Biomet Spine (b,g); Synthes Spine (a); OMeGA (a);
Jeffrey C. Wang, MD	USA	Biomet (g); DePuy Synthes Spine (g); Medtronics (g); Seaspine (g); Osprey (g); Aesculap (g); Stryker Spine (g); Amedica (c,g); Bone Biologics (c); Axiomed (c); Corespine (c); Expanding Ortho (c); Pioneer (c); Axis (c); Syndicom (c); VG Innovations (c); Pearldiver (c); Flexuspine (c); Fziomed (c); Benvenue (c); Promethean (c); Nexgen (c); Electrocore (c); Surgitech (c)
Stuart L. Weinstein, MD	USA	No Relationships
James H. Wynne, CPO	USA	Boston Brace (f)
Fabio Zaina, MD	Italy	No Relationships
Reinhard D. Zeller, MD, FRCSC	Canada	Spinevision (g); Paradigm Spine (b)
Guang-Qian Zhou, MD, PhD	China	No Relationships
Paper Authors (if not listed above)		
Emily Abbott, BS	USA	No Relationships
Mark F. Abel, MD	USA	No Relationships
Emre Acaroglu, MD	Turkey	Medtronic (b); DePuy Synthes Spine (a); Biomet Spine (d); IncredX (c)
Paul D. Ackerman, MD	USA	No Relationships
Frank L. Acosta, MD	USA	Stryker Spine (a)
Samer Adeeb, PhD, PEng	Canada	No Relationships
Azeem Ahmad, BA, BS	USA	No Relationships
Kasra Ahmadinia, MD	USA	No Relationships
Tsutomu Akazawa, MD	Japan	No Relationships
Behrooz A. Akbarnia, MD	USA	K2M (a,b); NuVasive (a,b,c); Ellipse Technology (b); DePuy Synthes Spine (a,b); K-Spine (b)
Zaid T. Al-Aubaidi, MD	Denmark	No Relationships
Abigail Allen, MD	USA	No Relationships
Jesse Allert, MD	USA	No Relationships
Benjamin Alman, MD	Canada	No Relationships
Robert J. Ames, BA	USA	No Relationships

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Beejal Y. Amin, MD	USA	No Relationships
Kei Ando, PhD	Japan	No Relationships
Lindsay Andras, MD	USA	No Relationships
Miroslaw Andusiewicz, PhD	Poland	No Relationships
Prokopis Annis, MD	USA	No Relationships
David F. Antezana, MD	USA	No Relationshipss
Luis Miguel Antón-Rodrigálvarez, PhD	Spain	No Relationships
Georgios Arealis, PhD	United Kingdom	No Relationships
Hideyuki Arima	Japan	No Relationships
Vincent Arlet, MD	USA	Synthes (a); DePuy Synthes Spine (b); Medtronic (g)
Sheyan Armaghani, PhD	USA	No Relationships
Paul Arnold, PhD	USA	Stryker Spine (b); Theken Spine (b); Fziomed (b); K2M (b); Medtronic (b); Apatech (b); Z-Plasty (c); Cerapedics (b); Life Spine (b); Integra Life (b); SpineWave (b)
Satoshi Asano, MD, PhD	Japan	No Relationships
Takashi Asazuma, MD, PhD	Japan	No Relationships
Benjamin Aubert, MSc	France	No Relationships
Carl-Éric Aubin, PhD, PEng	Canada	Natural Sciences and Engineering Research Council of Canada (e); Medtronic (a,b); BostonBrace (a); Lagarrigue/Rodin4D (a)
Michael Auriemma	USA	No Relationships
Yaser M. Baghdadi, MD	USA	No Relationships
Andrea Baioni	Italy	No Relationships
Wajeeh R. Bakhsh, BA	USA	No Relationships
Hooman Bakhshi	USA	No Relationships
Christine Baldus, RN, MHS	USA	No Relationships
Keith D. Baldwin, MD, MSPT, MPH	USA	Pfizer (c); JBJS (g)
Massimo Balsano, MD	Italy	Lanx (e); NuVasive (e); Medtronic (b)
Bibek Banskota, MBBS, MRCS, MS	USA	No Relationships
Tanvir Bari	Denmark	No Relationships
Kaku Barkoh, MD	USA	No Relationships
Michal Barna, MD	Czech Republic	No Relationships
Matthew Barrett Dobbs, MD	USA	D-Bar Enterprises (b,g); Pfizer (b)
Carlos Barrios, MD, PhD	Spain	No Relationships
James Barsi, MD	USA	No Relationships
Carrie E. Bartley, MA	USA	No Relationships
Yair Barzilay, MD	Israel	No Relationships
Batuhan Baserdem	USA	No Relationships
Tracey Bastrom, MA	USA	No Relationships

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David Baulesh	USA	No Relationships
Marie Beausejour, MscA	Canada	No Relationships
James T. Bennett, MD	USA	No Relationships
Shay Bess, MD	USA	Allosource (e); DePuy Synthes Spine (a,b,d); Pioneer Spine (g); Medtronic (b); Alphatec (b)
Randal R. Betz, MD	USA	DePuy Synthes Spine (a,d,g); Medtronic (g); Osteotech (d,g)
Ni Bi	China	No Relationships
Kristina Bianco, BA	USA	No Relationships
Jesse E. Bible, MD	USA	No Relationships
Ashley W. Blom	United Kingdom	No Relationships
Gideon Blumstein, MS	USA	No Relationships
Jerald D. Borgella	USA	No Relationships
Patrick Bosch, MD	USA	Haemontics (a)
Anouar Bourghli, MD	France	No Relationships
Benjamin Bouyer	France	No Relationships
Austin Bowles, MS	USA	No Relationships
Marco Brayda-Bruno, MD	Italy	No Relationships
Keith H. Bridwell, MD	USA	No Relationships
Kristin Bright, PhD	USA	No Relationships
Paul A. Broadstone, MD	USA	No Relationships
Paul A. Broadstone, MD	USA	No Relationships
Darrel S. Brodke, MD	USA	Amedica (c,g); DePuy Synthes Spine (g); Medtronic (g); Pioneer (c); Vertiflex (c)
Nicolas Bronsard, MD, PhD	France	No Relationships
Jacob M. Buchowski, MD, MS	USA	CoreLink (b); Globus Medical (b,d); Stryker Spine (b,d); DePuy Synthes Spine (d).; K2M (a,d)
Brandon Bucklen, PhD	USA	Globus Medical (f)
Philippe Buechler, PhD	Switzerland	No Relationships
Lori Buegeler, RN, BC	USA	No Relationships
Shane Burch, MD	USA	Medtronic (b,e)
Amélie Burckhardt	Switzerland	No Relationships
Jesús J F. Burgos, PhD	Spain	No Relationships
Douglas C. Burton, MD	USA	DePuy Synthes Spine (a,b,g); Axial BioTech (g)
Donita Bylski-Austrow, PhD	USA	SpineForm (a,g); DePuy Synthes Spine (g)
Lidia Cabanes	Spain	No Relationships
Michelle S. Caird, MD	USA	No Relationships
Blair Calancie, PhD	USA	No Relationships
Frank P. Cammisa, MD	USA	No Relationships
Robert M. Campbell, MD	USA	No Relationships
Brendan Caprio, BS	USA	No Relationships
John Caridi, MD	USA	No Relationships

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Antonio Caronni, MD, PhD	Italy	No Relationships
Patrick M. Carry, BA	USA	No Relationships
Jeffrey Cassidy, MD	USA	No Relationships
Rene M. Castelein, MD, PhD	Netherlands	Medtronic (a,d)
Angela Caudill, MPT	USA	No Relationships
Paul C. Celestre, MD	USA	No Relationships
Javier Cervera	Spain	No Relationships
Charles M. Chan, MD	USA	No Relationships
Chris Yin Wei Chan, MS (Orth)	Malaysia	No Relationships
Ka Yan Chan	Hong Kong	No Relationships
Yu-Hui Chang, PhD	USA	No Relationships
Masaaki Chazono, MD, PhD	Japan	No Relationships
Ching-Jen Chen, BA	USA	No Relationships
Jack C. Cheng, MD	Hong Kong	No Relationships
Thomas Cheriyan, MD	USA	No Relationships
Franco Tsz Fung Cheung, MPhil	Hong Kong	No Relationships
Alexander C. Ching, MD	USA	DePuy Synthes Spine (b); Atlas Spine (b)
Samuel K. Cho, MD	USA	No Relationships
Woojin Cho, MD, PhD	USA	No Relationships
Dean Chou, MD	USA	Globus Medical (b); Medtronic (b); DePuy Synthes Spine (b)
Winnie C. Chu, FRCR, FHKAM, MD	China	No Relationships
Soo Yong Chua	Singapore	No Relationships
Tapanut Chuntarapas, MD	USA	No Relationships
Aaron J. Clark, MD, PhD	USA	No Relationships
Emma M. Clark	United Kingdom	No Relationships
Julien Clin, PhD	Canada	No Relationships
Nikita Cobetto	Canada	No Relationships
Jeffrey D. Coe, MD	USA	NuVasive (a,b); Medtronic (a,b); SI Bone (b); NuTech (a); Benvenue Medical (a); Synthes (b); Phygen (c); Implantium (c)
Mindy Cohen, MD	USA	No Relationships
Cristi R. Cook, DVM	USA	No Relationships
Matthew T. Coombs, MSc	USA	No Relationships
Carlos Correa Gorospe	Spain	No Relationships
Terrence Crowder, MD	USA	No Relationships
Matthew E. Cunningham, MD, PhD	USA	No Relationships
Kirk W. Dabney, MD	USA	DePuy Synthes Spine (b)
Benny Dahl, MD, PhD, DMSci	Denmark	Globus Medical (b); Medtronic (b)
Elias Dakwar, MD	USA	No Relationships
Alan H. Daniels, MD	USA	No Relationships

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Aina J. Danielsson, MD, PhD	Sweden	No Relationships
Jason Datta, MD	USA	No Relationships
Michael D. Daubs, MD	USA	DePuy Synthes Spine (b,g); Stryker Spine (a)
Rick A. Davis, MD	USA	DePuy Synthes Spine (b); Zimmer (b)
Gema De Blas, MD, PhD	Spain	No Relationships
Jacques A. de Guise, PhD	Canada	EOS Imaging (a,g)
Pierre A. D'hemecourt	USA	No Relationships
Adriana De La Rocha, MS	USA	No Relationships
Marcelo De Oliveira, PhD (candidate)	Switzerland	No Relationships
Maria R. DeAngelis	USA	No Relationships
Ozgur Dede, MD	USA	No Relationships
Vincent F. Deeney, MD	USA	No Relationships
Nicholas deGiorgio-Miller, MBChB	New Zealand	No Relationships
Rick B. Delamarter, MD	USA	No Relationships
Gokhan H. Demirkiran	Turkey	No Relationships
Kedar Deogaonkar, MD, FRCS	USA	No Relationships
J. M. DePasse, MD	USA	No Relationships
Frederique Desbiens-Blais, Masters	Canada	No Relationships
Clinton J. Devin, MD	USA	Stryker Spine (a); DePuy Synthes Spine (a)
Vedat Deviren, MD	USA	NuVasive (b,g); Stryker Spine (b); Guidepoint (b); Medtronic (b)
Pierre Devos, MS	USA	No Relationships
Christopher DeWald, MD	USA	No Relationships
Arjun A. Dhawale, MD	USA	No Relationships
Mario Di Silvestre, MD	Italy	No Relationships
John Dodam	USA	No Relationships
Michael Dombek	USA	No Relationships
Montse Domingo-Sàbat	Spain	DePuy Synthes Spine (a)
Miriam Donohue, PhD	USA	No Relationships
Ian G. Dorward, MD	USA	No Relationships
John J. Doski, MD	USA	No Relationships
Susan Dubowy, BS	USA	No Relationships
Jacek Durmala, PhD	Poland	No Relationships
Aviva G. Dworkin, BS	USA	No Relationships
Pierre A. D'Hemecourt, MD	USA	No Relationships

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Robert K. Eastlack, MD	USA	Aesculap (b,e); Trinity Orthopaedics (a,e); Top Doctors Labs (e); Phygen (e); DiFusion (b,e); Biomet (b); Amedica (b); Synthes (a,b,d); Pioneer Surgical (b); NuVasive (b); Globus Medical (a,b,g); Stryker Spine (b,d); Trinity Orthopaedics (b); Baxano Surgical (a,b); NuTech (b,g); Invuity (b); Smith and Nephew (a); Integra (a); NuVasive (a,c,g); Pioneer Surgical (a,d,g); Alphatec (a); Eli Lilly (d)
Mark R. Edelstein, BA	USA	No Relationships
Charles C. Edwards, MD	USA	No Relationships
Natalia N. Egorova, PhD, MPH	USA	No Relationships
Frank J. Eismont, MD	USA	No Relationships
Ron El-Hawary, MD, MSc, FRCSC	Canada	DePuy Synthes Spine (a,b); Medtronic (a); Synthes (a); Halifax Biomedical (b)
Sherief Elsayed, FRCS (Tr & Orth)	United Kingdom	No Relationships
Arash Emami, MD	USA	No Relationships
Osa Emohare, MBBS, PhD	USA	No Relationships
Meric Enercan, MD	Turkey	No Relationships
Eva Enns, PhD	USA	No Relationships
Mark A. Erickson, MD	USA	Medtronic (a)
Thomas J. Errico, MD	USA	No Relationships
David Essig, MD	USA	No Relationships
European Spine Study Group	Spain	DePuy Synthes Spine (a)
Mandy Falk, PA-C	USA	No Relationships
Michael Faloon, MD	USA	No Relationships
Michael G. Fehlings, MD, PhD	Canada	Synthes (a); New World Laboratories (b); Alopex (b); DePuy Synthes Spine (b,g); Medtronic (a)
Kevin M. Felton, BS, MLA	USA	No Relationships
Richard G. Fessler, MD, PhD	USA	Medtronic (a,b,g); DePuy Synthes Spine (g); Stryker Spine (g); Lanx (b,e)
Anthony Fine	USA	No Relationships
Joel Finkelstein, MSc, MD, FRCSC	Canada	No Relationships
Staci A. Fischer, MD	USA	No Relationships
Charles G. Fisher, MD, MHSc	Canada	Medtronic (a,b,g); NuVasive (b); DePuy Synthes Spine (a)
John M. Flynn, MD	USA	Biomet (g); Wolters-Kluwer Health - Lippincott Williams & Wilkins (g); Orthopedics Today (e)
Didier Fort	France	No Relationships
Sidsel S. Fruergaard	Denmark	No Relationships
Kai-Ming Fu, MD, PhD	USA	Medtronic (b); Synthes (d)
Jonathan E. Fuller, MD	USA	No Relationships
Haruki Funao, MD	USA	No Relationships
Stephen P. Gadomski, BA	USA	No Relationships
Robert W. Gaines, MD	USA	No Relationships

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Jeffrey Galinkin, MD	USA	No Relationships
Itai Gans, BS	USA	No Relationships
Sumeet Garg, MD	USA	No Relationships
Marilyn L. Gates, MD	USA	No Relationships
Melissa Gebhardt, PA-C	USA	No Relationships
Matthew J. Geck, MD	USA	Globus Medical (b,e); Medtronic (d); Zimmer (g); Difusion(c); DePuy Synthes Spine (d)
Martin Gehrchen, MD, PhD	Denmark	Medtronic (a,b); Globus Medical (a,b)
Victor F. German, MD, PhD	USA	No Relationships
Ges Ges	France	No Relationships
Olivier Gille, MD, PhD	France	No Relationships
Federico P. Girardi, MD	USA	Centinel Spine (b); DePuy Synthes Spine (b,g); Ethicon (b); Lanx (b); LDR Spine USA (b); LifeSpine (b,g); NuVasive (b,g); Ortho Development (b,g); Orthogem (b); Spineart USA (b,e); Spineview (b); Wenzel Spine (b); Centinel Spine (e); HealthPoint Capital (e); Paradigm Spine (e); Scient'x USA (e); Spinal Kinetics (e)
Joseph P. Gjolaj, MD	USA	No Relationships
David Glos, BSE	USA	No Relationships
Michael Glotzbecker, MD	USA	No Relationships
Jakub Godzik	USA	No Relationships
Tae Sik Goh	Republic of Korea	No Relationships
Ziya L. Gokaslan, MD	USA	US Spine (c,e); Spinal Kinetics (c); K2M (a); Medtronic (a); DePuy Synthes Spine (a); JNS Spine (e); Spine Journal (e); Journal of Spinal Disorders (e); European Spine Journal (e); Nature Review World Neurosurgery (e); Journal of Surgical Oncology (e)
Meryl Gold, BA	USA	No Relationships
Michael J. Goytan, MD	Canada	No Relationships
Vadim Goz, BA	USA	No Relationships
Suellen C. Greco, DVM	USA	No Relationships
Tiziana Greggi, MD	Italy	No Relationships
Michael Grevitt, FRCS(Orth)	United Kingdom	No Relationships
Brian E. Grottkau, MD	USA	No Relationships
Gurkan Gumussuyu, MD	Turkey	No Relationships
Yazeed M. Gussous, MBBS	USA	No Relationships
Gabriel Gutman	Israel	No Relationships
Yoon Ha, MD, PhD	Republic of Korea	No Relationships
Nancy Hadley-Miller	USA	No Relationships
Matthew A. Halanski, MD	USA	No Relationships
D. Kojo Hamilton, MD	USA	No Relationships
Kim Hammerberg, MD	USA	No Relationships

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Azmi Hamzaoglu, MD	Turkey	Medtronic (b)
Christina Hardesty, MD	USA	No Relationships
Ian J. Harding, BA, BM, BCh, FRCS(Orth)	United Kingdom	No Relationships
Nanjundappa S. Harshavardhana, MD, MS(Orth), Dip SICOT	USA	No Relationships
Robert A. Hart, MD	USA	SeaSpine (g); DePuy Synthes Spine (a,b,d,g); Medtronic (a,b); Eli Lilly (b); Synthes (a); SpineConnect (c)
Nathan L. Hartin, MD	USA	No Relationships
Kazuhiro Hasegawa, MD, PhD	Japan	No Relationships
Tomohiko Hasegawa	Japan	No Relationships
Carol C. Hasler, MD	Switzerland	No Relationships
Nabil Hassan, MD	USA	No Relationships
Hamid Hassanzadeh, MD	USA	No Relationships
Bryan Haughom, MD	USA	No Relationships
Robert F. Heary, MD	USA	DePuy Synthes Spine (a,g); Zimmer Spine (g); Thieme Medical Publishers (g)
Mark J. Heidenreich, BS	USA	No Relationships
Michael Hellman, MD	USA	No Relationships
Jose A. Herrera-Soto, MD	USA	Biomet (b,d,g); Spine Form (e)
W. F. Hess, MD	USA	K2M (a); DePuy Synthes Spine (b)
Eduardo Hevia, MD	Spain	No Relationships
Brian W. Hill, MD	USA	No Relationships
Toru Hirano	Japan	No Relationships
Jayme R. Hiratzka, MD	USA	No Relationships
Wolfgang Hitzl, PhD, MSc	Austria	No Relationships
Bruce F. Hodgson, FRACS	New Zealand	No Relationships
Christian Hoelscher, BS	USA	No Relationships
Daniel G. Hoernschemeyer, MD	USA	OrthoPediatrics (b,c,e); Corelink (b); Stryker Spine (a)
Terrence F. Holekamp, MD, PhD	USA	No Relationships
Courtney A. Holland, MD	USA	No Relationships
Laurens Holmes, PhD, DrPH	USA	No Relationships
Jae Taek Hong, MD, PhD	Republic of Korea	No Relationships
Pooya Hosseinzadeh, MD	USA	No Relationships
Richard Hostin, MD	USA	DePuy Synthes Spine (a,b)
Andrew Howard, MD, MSc, FRCSC	Canada	No Relationships
Michael T. Hresko, MD	USA	Medtronics (a); NuVasive (a)
Tessa Huncke, MD	USA	No Relationships
Mir Hussain	USA	Globus Medical (f)

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John Hutchinson	United Kingdom	DePuy Synthes Spine (a)
Ki S. Hwang, MD	USA	No Relationships
Steven W. Hwang, MD	USA	No Relationships
Joshua E. Hyman, MD	USA	OMeGA (a)
David M. Ibrahimi, MD	USA	No Relationships
Takahiro Iida	Japan	No Relationships
Brice Ilharreborde, MD	France	No Relationships
Shiro Imagama, MD	Japan	No Relationships
Satoshi Inami	Japan	No Relationships
Masatoshi Inoue	Japan	No Relationships
Yoshihiro Inui	Japan	No Relationships
Naoki Ishiguro	Japan	No Relationships
Kimona Issa, MD	USA	No Relationships
Manabu Ito, MD, PhD	Japan	No Relationships
Masaaki Ito	Japan	No Relationships
Zenya Ito	Japan	No Relationships
Eyal Itshayek, MD	Israel	No Relationships
Chizuo Iwai	Japan	No Relationships
Henry J. Iwinski, MD	USA	No Relationships
Amit Jain, MD	USA	No Relationships
Surbhi Jain, MBBS	USA	No Relationships
Tuomas Jalanko	Finland	Medtronic (a)
Piotr Janusz, MD	Poland	No Relationships
Tyler Jenkins, BS	USA	No Relationships
Seth Jerabek, MD	USA	No Relationships
Zhang Jianguo, MD	China	No Relationships
Siddharth B. Joglekar	USA	No Relationships
Elizabeth Joiner, BS	USA	No Relationships
Julie Joncas, BSc	Canada	No Relationships
John Jones, MD	USA	No Relationships
Ajeya P. Joshi, MD	USA	Spinesmith (c); Phygen (c)
Cristina M. Justice, PhD	USA	No Relationships
Muayad Kadhim, MD	USA	No Relationships
Sinan Kahraman	Turkey	No Relationships
Kenichiro Kakutani, MD, PhD	Japan	No Relationships
Antony Kallur, MD	USA	No Relationships
Nobuhiro Kamiya	USA	No Relationships
Shinjiro Kaneko, MD, PhD	Japan	No Relationships
Daniel G. Kang, MD	USA	No Relationships
Matthew Kang, MD	USA	No Relationships

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Linda E. Kanim, MA	USA	No Relationships
Wajdi W. Kanj, MD	USA	No Relationships
Adam S. Kanter, MD	USA	Lanx (b); NuVasive (a)
Leon Kaplan, MD	Israel	Mazor (e); Medtronic (e)
Raj Karia, MPH	USA	No Relationships
Sven Karstensen	Denmark	No Relationships
Kazuki Kawakami	Japan	Medtronic (b); DePuy Synthes Spine (b)
Derek M. Kelly, MD	USA	No Relationships
Michael P. Kelly, MD	USA	No Relationships
John W. Kemppainen, MD	USA	No Relationships
Farbod Khaki	USA	No Relationships
Saif Khalil, PhD	USA	Globus Medical (f)
Safdar N. Khan, MD	USA	No Relationships
Hak-Sun Kim, MD	Republic of Korea	No Relationships
Han Jo Kim, MD	USA	Spine Innovation (e); Medtronic (e); EOS Imaging (a); World Scientific Publishers (g)
Harry Kim	USA	No Relationships
Il Sup Kim	Republic of Korea	No Relationships
Jin-Hyok Kim	Republic of Korea	No Relationships
Sang D. Kim, MD, MS	USA	No Relationships
Sung-Soo Kim, MD	Republic of Korea	No Relationships
Yongjung J. Kim, MD	USA	MSD (d); Stryker Spine (b)
Akilah B. King, BA	USA	No Relationships
Joseph King, MD	USA	No Relationships
Emily A. Kipper	USA	No Relationships
Eric Klineberg, MD	USA	DePuy Synthes Spine (a,d); Alphatec (b); Stryker Spine (d)
Noelle Klocke, MS	USA	Globus Medical (f)
Sho Kobayashi, PhD	Japan	No Relationships
Linda Koester, BS	USA	No Relationships
Heiko Koller, MD	Germany	No Relationships
Branko Kopjar	USA	Cerapedics (b); Smith and Nephew (b); MFG Spine (b)
Toshiaki Kotani, MD, PhD	Japan	No Relationships
Malgorzata Kotwicka	Poland	No Relationships
Jan Kryl	Czech Republic	No Relationships
Craig A. Kuhns, MD	USA	Doctors Research Group (c); Stryker Spine (b); Core Link (e); Spineology (b)
Preethi M. Kulkarni, MD	USA	No Relationships
Abhishek Kumar	Canada	No Relationships

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Takuto Kurakawa, MD	Japan	No Relationships
Mark F. Kurd, MD	USA	No Relationships
Keiichi Kuroki, DVM, PhD	USA	No Relationships
Mun Keong Kwan, MS (Orth)	Malaysia	No Relationships
Frank La Marca, MD	USA	Biomet (b); Lanx (b); Globus Medical (b,g); Stryker Spine (a,g); DePuy Synthes Spine (a); TRS (c)
Ginette Lacroix, RN	Canada	No Relationships
Virginie Lafage, PhD	USA	Nemaris (c); DePuy Synthes Spine (a); Medtronic (b)
Jaren LaGreca	USA	No Relationships
Tero Laine, MD, PhD	Sweden	No Relationships
Tsz Ping Lam, MB, BS	Hong Kong	No Relationships
Ginette Larouche	Canada	No Relationships
Brandon Lawrence, MD	USA	No Relationships
Sylvie Le May, RN, PhD	Canada	No Relationships
Stacey B. Leach, DVM	USA	No Relationships
Darren R. Lebl, MD	USA	No Relationships
Charles Gerald T. Ledonio, MD	USA	Medtronic (a)
Byung Ho Lee, MD, PhD	Republic of Korea	No Relationships
Chee Kean Lee, MS (Orth)	Malaysia	No Relationships
Christopher Lee, MD	USA	No Relationships
Dong-Ho Lee, MD, PhD	Republic of Korea	No Relationships
Ho Jin Lee	Republic of Korea	No Relationships
Hwan-Mo Lee, MD	Republic of Korea	No Relationships
Jung Sub Lee, MD, PhD	Republic of Korea	No Relationships
Jung-Hee Lee, MD	Republic of Korea	No Relationships
Kwong Man Lee, PhD	Hong Kong	No Relationships
Alan D. Legatt, MD, PhD	USA	No Relationships
Lawrence G. Lenke, MD	USA	Axial Biotech (a); DePuy Synthes Spine (a); Medtronic (g); Quality Medical Publishing(g)
Vincent Leone, MD	USA	No Relationships
Julian J. Leong, FRCS PhD	United Kingdom	No Relationships
Jean-Christophe Leveque, MD	USA	No Relationships
Tao Li	China	No Relationships
Ying Li, MD	USA	No Relationships
Zheng Li	China	No Relationships
Jin Qian	China	No Relationships

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Dong-Ju Lim	Republic of Korea	No Relationships
David Limbrick, MD, PhD	USA	No Relationships
Breton Line, BSME	USA	No Relationships
Francesco Lolli	Italy	No Relationships
Denise Lopez, MSN, ARNP	USA	No Relationships
Scott J. Luhmann, MD	USA	Medtronic (b,d); Stryker Spine (d,e); Lippincott (g); Globus Medical (g)
Kristopher Lundine, MD, MSc, FRCSC	Canada	No Relationships
Alessandro Luzzati	Italy	No Relationships
Marios G. Lykissas, MD, PhD	USA	No Relationships
Kerstin Löfdahl-Hällerman, MD, PhD	Sweden	No Relationships
Jean-Marc Mac-Thiong, MD, PhD	Canada	DePuy Synthes Spine (a); Medtronic (a); Spinologics (c,e,f,g); MMDS Medical (g)
Masafumi Machida, MD	Japan	No Relationships
William G. Mackenzie, MD	USA	No Relationships
Stephen T. Magill, PhD	USA	No Relationships
Stephen P. Maier, BA	USA	No Relationships
Queenie Wah Yan Mak, PGd(Health Education), BSc (FNS)	Hong Kong	No Relationships
Elena Maredi, MD	Italy	No Relationships
Konstantinos Martikos, MD	Italy	No Relationships
William H. Martin, PhD	USA	No Relationships
Keishi Maruo, MD	Japan	No Relationships
Toru Maruyama, MD, PhD	Japan	No Relationships
Hiroki Matsui	Japan	No Relationships
Hiroko Matsumoto, MA	USA	No Relationships
Morio Matsumoto, MD	Japan	No Relationships
Tomohiro Matsumoto, MD, PhD	Japan	No Relationships
Yukihiro Matsuyama, MD	Japan	No Relationships
Mikko Mattila, MD	Finland	No Relationships
Edyta A. Matusik, Senior Assistant	Poland	No Relationships
Pawel Matusik	Poland	No Relationships
Michael Mayer, MD	Germany	No Relationships
Keyvan Mazda, MD, MS	France	Zimmer (b)
Ali M. Maziad, MD, MSc	USA	No Relationships
Daren J. McCalla, BS	USA	No Relationships
Ian McCarthy, PhD	USA	NuVasive (a)
Keegan McClary, BS	USA	No Relationships

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Jamal McClendon, MD	USA	No Relationships
Anna M. McClung, BSN, RN	USA	No Relationships
Kathleen E. McCoy, MD	USA	No Relationships
Frances L. McCullough, MNSc	USA	No Relationships
Amy L. McIntosh, MD	USA	No Relationships
Bryan McNair, MS	USA	No Relationships
Amir A. Mehbod, MD	USA	Zimmer (b); Stryker Spine (b,g)
Hossein Mehdian, MD, MS(Orth), FRCS(Ed)	United Kingdom	No Relationships
Oliver Meier, MD	Germany	No Relationships
Gregory Mencio, MD	USA	No Relationships
Emmanuel N. Menga, MD	USA	No Relationships
Addisu Mesfin, MD	USA	No Relationships
Melodie F. Metzger, PhD	USA	Medtronic (a); Stryker Spine (a)
Todd A. Milbrandt, MD, MS	USA	No Relationships
Freeman Miller, MD	USA	No Relationships
Patricia E. Miller, MS	USA	No Relationships
Woo-Kie Min, MD, PhD	Republic of Korea	No Relationships
Shohei Minami, MD	Japan	No Relationships
Firoz Miyanji, MD, FRCSC	Canada	DePuy Synthes Spine (a,b)
Marina Moguilevitch, MD	USA	No Relationships
Saeed Mohammad, MBChB(Glas), FRCS(Glas), FRCS(Tr&Orth)	United Kingdom	No Relationships
Alice A. Moisan, BSN	USA	No Relationships
Mark Moldavsky, MS	USA	Globus Medical (f)
Elena Montes	Spain	No Relationships
Seong-Hwan Moon, MD, PhD	Republic of Korea	No Relationships
Ross R. Moquin, MD	USA	K2M (e); Medtronic (e)
Alain Moreau, PhD	Canada	Fourth Dimension Spine(a); Paradigm Spine (e)
Robert A. Morgan, MD	USA	No Relationships
Etsuro K. Motoyama, MD	USA	No Relationships
Ryan D. Muchow, MD	USA	No Relationships
Gregory M. Mundis, MD	USA	NuVasive (a,b,d,g); K2M (b,d); DePuy Synthes Spine (a)
Francesco Muntoni, MD, FRCPCH, FMed, Sci	United Kingdom	No Relationships
Hideki Murakami, MD, PhD	Japan	No Relationships
Akio Muramoto, MD	Japan	No Relationships
Robert F. Murphy, MD	USA	No Relationships

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Rebecca Mutich, BSRT	USA	No Relationships
Karen S. Myung, MD, PhD	USA	No Relationships
Sean Nabar	USA	No Relationships
Floreana Naef, MD	USA	No Relationships
Toshiro Nagai	Japan	No Relationships
Yutaka Nakamura, MD, PhD	Japan	No Relationships
Yusuke Nakao	Japan	No Relationships
Yoshinori Nakata, MD	Japan	No Relationships
Takashi Namikawa, MD, PhD	Japan	No Relationships
Sreeharsha V. Nandyala, BA	USA	No Relationships
Cassie Nash	USA	No Relationships
Marie-Lyne Nault, MD, PhD	Canada	No Relationships
Francesco Negrini	Italy	No Relationships
Geraldine I. Neiss, PhD	USA	No Relationships
Ian W. Nelson, MBBS, MCh, Orth, FRCS	United Kingdom	DePuy Synthes Spine (a)
Petr Nesnidal, MD	Czech Republic	No Relationships
Brian J. Neuman, MD	USA	No Relationships
Bobby K. Ng, MD	Hong Kong	No Relationships
Ayato Nohara	Japan	No Relationships
Yutaka Nohara, MD	Japan	No Relationships
Crystal Norgren	USA	No Relationships
Natasha O'Malley	USA	No Relationships
Kevin R. O'Neill, MD, MS	USA	No Relationships
Ibrahim Obeid, MD	France	No Relationships
Michael F. Obrien, MD	USA	DePuy Synthes Spine (a,b,g); Osteotech (b)
Russell M. Odono, MD	USA	No Relationships
Alexa J. Offen, BSc Hons	United Kingdom	No Relationships
Tetsuya Ohara	Japan	No Relationships
David O. Okonkwo, MD, PhD	USA	Lanx (b); Medtronic (a); NuVasive (b)
Margaret A. Olsen, PhD, MPH	USA	No Relationships
Kyotaro Ota	Japan	No Relationships
Jean A. Ouellet, MD	Canada	DePuy Synthes Spine (b)
Satoru Ozeki	Japan	Wright Medical (b); Smith & Nephew (e)
Cagatay Ozturk, MD	Turkey	Medtronic (b)
Anne M. Padberg, MS	USA	No Relationships
Joshua M. Pahys, MD	USA	DePuy Synthes Spine (b)
Stefan Parent, MD, PhD	Canada	DePuy Synthes Spine (a,b); Medtronic (b); Spinologics (c); EOS-Imaging (a)
Howard Y. Park, BA	USA	No Relationships

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Moon Soo Park, PhD	Republic of Korea	No Relationships
Justin C. Paul, MD, PhD	USA	No Relationships
Abhijit Pawar, MD	USA	No Relationships
Jeff Pawelek	USA	No Relationships
Andrew C. Pedtke, MD	USA	No Relationships
Huang Peng, MD, PhD	China	No Relationships
Phedra Penn, MS	USA	No Relationships
Mar Perez Martin-Buitrago	Spain	DePuy Synthes Spine (a)
Maty Petcharaporn, BS	USA	No Relationships
Austin Peters	USA	No Relationships
Josh Philbrick, MD	USA	No Relationships
Travis Philipp, BA	USA	No Relationships
Jonathan H. Phillips, MD	USA	Biomet (a,g); OrthoPediatrics (e); Synthes (b)
Melissa Pielech, MA	USA	No Relationships
Chaiwat Piyaskulkaew, MD	Thailand	No Relationships
Gabriel Piza Vallespir, MD, PhD	Spain	No Relationships
Christian Pizarro, MD	USA	No Relationships
Howard M. Place, MD	USA	No Relationships
Avraam Ploumis, MD, PhD	Greece	No Relationships
David Podeszwa, MD	USA	No Relationships
Connie Poe-Kochert, BSN	USA	No Relationships
Vincent Pointillart, MD, PhD	France	No Relationships
Sina Pourtaheri, MD	USA	No Relationships
Themistocles S. Protopsaltis, MD	USA	K2M (d); Surgimap Spine (d)
Paolo Punsalan, MD	USA	No Relationships
Erion Qamirani, MD, PhD	USA	No Relationships
Ling Qin, MD	China	No Relationships
Ling Qin, PhD	Hong Kong	No Relationships
Linda Racine	USA	No Relationships
Kristen E. Radcliff, MD	USA	Globus Medical (a,g)
Mark D. Rahm, MD	USA	Globus Medical (g); K2M (a); SpineSmith (g); Medtronic (b)
Laura Rainoldi	Italy	No Relationships
Patricia L. Rampy, MS, REPT, CNIM	USA	No Relationships
Karl E. Rathjen, MD	USA	No Relationships
Bernard A. Rawlins, MD	USA	Medtronic (g)
Wilson Ray, MD	USA	DePuy Synthes Spine (b)
Barry L. Raynor, BA	USA	No Relationships
FOCOS Research Associates	Ghana	No Relationships
Samantha J. Reichard	USA	No Relationships

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Jan Revella, RN	USA	No Relationships
Laurence D. Rhines, MD	USA	Stryker Spine (b)
Leslie Rhodes, MSN	USA	No Relationships
Mary Riordan, BA	USA	No Relationships
Guillaume Riouallon, MD	France	No Relationships
Todd F. Ritzman, MD	USA	No Relationships
James W. Roach, MD	USA	No Relationships
Samuel T. Robinson, BS	USA	Stryker Spine (a); Medtronic (a)
Kenneth J. Rogers, PhD	USA	No Relationships
Marie Roguski, MD	USA	No Relationships
Samuel Romero-Vargas, MD	Mexico	No Relationships
Patrick Ross, MD	USA	No Relationships
Thomas Ross, MS, RN	USA	No Relationships
Megan K. Roth, PhD	USA	No Relationships
Marjolaine Roy-Beaudry, MSc	Canada	No Relationships
Benjamin D. Roye, MD, MPH	USA	OMeGA (a)
David P. Roye, MD	USA	Stryker Spine (b); Biomet (a); OMeGA (a)
Mark J. Ruoff, MD	USA	Baxano Surgical (d); Neostem (c)
Francisco J. S. Pérez-Grueso, MD	Spain	DePuy Synthes Spine (a,b); K2M (a)
Cristina Sacramento-Dominguez, MD, PhD	Spain	No Relationships
Rajiv Saigal, MD, PhD	USA	No Relationships
Toshiki Saito	Japan	No Relationships
Tsuyoshi Sakuma, MD, PhD	Japan	No Relationships
Andrew A. Sama, MD	USA	DePuy Synthes Spine (b,g); Orthodevelopment Corporation (b,g); Osteotech (b,g); Lifespine (b); Spine View (b); Paradigm Spine, Small Bone Innovations (c); Mesoblast Clinical Trial (a); Sentio (e); RTI (b)
Richard Samade, PhD	USA	No Relationships
Wudbhav Sankar, MD	USA	No Relationships
Ignacio Sanpera, MD, PhD	Spain	No Relationships
Neil Saran, MD, MHSc, FRCSC	Canada	DePuy Synthes Spine (a)
Zeeshan Sardar, MD, CM	Canada	No Relationships
Vishal Sarwahi, MD	USA	DePuy Synthes Spine (a); K2M (a); Stryker Spine (a)
Lim Beng Saw, MS Orth	Malaysia	No Relationships
Jeffrey R. Sawyer, MD	USA	No Relationships
Brian Scannell, MD	USA	No Relationships
William Schairer	USA	No Relationships
Carrie Scharf Stern, MD	USA	No Relationships
Justin K. Scheer, BS	USA	No Relationships
Tom P. Schlösser, MD	Netherlands	No Relationships
Joshua E. Schroeder, MD	USA	No Relationships

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James Schuster, MD, PhD	USA	No Relationships
Richard M. Schwend, MD	USA	K2M (a,b)
Donna C. Scott, MSN	USA	No Relationships
Fady s. Sedra, MB BcH, MSc, MRCS	United Kingdom	No Relationships
Derek A. Seehausen, BA	USA	No Relationships
Lee S. Segal, MD	USA	No Relationships
Dilip K. Sengupta, MD	USA	Globus Medical (a,c,e,g)
Rajiv K. Sethi, MD	USA	No Relationships
Rajiv K. Sethi, MD	USA	No Relationships
Navil F. Sethna, MD	USA	No Relationships
Eiman Shafa, MD	USA	No Relationships
Ellen C. Shaffrey	USA	No Relationships
David Shau	USA	No Relationships
William J. Shaughnessy, MD	USA	No Relationships
M. Shaw, FRCS	United Kingdom	No Relationships
Jianxiong Shen, MD	China	No Relationships
John M. Shepherd, MD	USA	No Relationships
Nitin Shetty, FRCS	United Kingdom	No Relationships
Lin Shi, PhD	Hong Kong	No Relationships
Yo Shiba, MD	Japan	No Relationships
Adam L. Shimer, MD	USA	No Relationships
Haruka Shimoda, MD	Japan	No Relationships
Dong Eun Shin, MD, PhD	Republic of Korea	No Relationships
Jae-Hyuk Shin	USA	No Relationships
Jong Ki Shin	Republic of Korea	No Relationships
M. W. Shrader, MD	USA	No Relationships
Harry L. Shufflebarger, MD	USA	DePuy Synthes Spine (a,b,e,g); Axial Biotech (a)
Irfan Siddique, MBChB, FRCSOrth	United Kingdom	No Relationships
Brenda A. Sides, MA	USA	No Relationships
Christine Sieberg, PhD	USA	No Relationships
Kris Siemionow, MD	USA	Alphatec (b); Mazor ST (g); Teraphysics (b); DePuy Synthes Spine (d); Medtronic (b)
Clément Silvestre	France	No Relationships
James W. Simmons, DO, PhD	USA	DePuy Synthes Spine (f); Synthes Spine (f)
Laura Simons, PhD	USA	No Relationships
Manish Singh, MD	USA	No Relationships
Anuj Singla, MD	USA	No Relationships

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Kumar Sinha, MD	USA	No Relationships
Prakash Sitoula, MD	USA	No Relationships
David L. Skaggs, MD, MMM	USA	Medtronic (b,d,g); BeachBody LLC (b); Biomet (b,d,g); Stryker Spine (d)
Wafa Skalli, PhD	France	No Relationships
Wafa Skalli, PhD	France	No Relationships
Kseniya Slobodyanyuk	USA	No Relationships
John T. Smith, MD	USA	Synthes Spine (b,g); Ellipse Technologies (f)
Timothy R. Smith, MD, PhD, MPH	USA	No Relationships
Gbolabo Sokunbi, MD	USA	No Relationships
Jochen P. Son-Hing, MD, FRCSC	USA	No Relationships
Bowei Song	USA	No Relationships
Kwang-Sup Song, MD	Republic of Korea	No Relationships
Steven Sparagana, MD	USA	No Relationships
David A. Spiegel, MD	USA	No Relationships
Ellen Spurrier	USA	No Relationships
Jeremy J. Stallbaumer, MD	USA	No Relationships
Anthony A. Stans, MD	USA	No Relationships
Douglas Stewart	USA	No Relationships
Tyler Stewart, BS	USA	No Relationships
Sophia Strike	USA	No Relationships
Complex Spine Study Group	USA	K2M (a)
Growing Spine Study Group	USA	Growing Spine Foundation (a)
Harms Study Group	USA	DePuy Synthes Spine (a)
International Spine Study Group	USA	DePuy Synthes Spine (a)
Jan Stulik, MD, PhD	Czech Republic	No Relationships
Peter Sturm, MD	USA	DePuy Synthes Spine (a,b); Pioneer Surgical (c); OrthoPediatrics (b)
Etan P. Sugarman, MD	USA	No Relationships
Ryo Sugawara	Japan	No Relationships
Patrick A. Sugrue, MD	USA	No Relationships
Heejong Sung, PhD	USA	No Relationships
Sanjeev Suratwala, MD	USA	No Relationships
Teppei Suzuki	Japan	No Relationships
Yoshitaka Suzuki	Japan	No Relationships
Kandice Swindle	USA	No Relationships
José Miguel Sánchez Márquez, MD	Spain	No Relationships
Katsushi Takeshita, MD	Japan	Medtronic (b); DePuy Synthes Spine (b)
Daisaku Takeuchi	Japan	No Relationships
Michael Talcott, DVM	USA	No Relationships

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Anne M. Tallmage, BS	USA	OrthoPediatrics (b,c,e,g); Corelink (b); Stryker Spine (a)
Vishwas R. Talwalkar, MD	USA	No Relationships
Hiroshi Taneichi, MD	Japan	No Relationships
Hiroshi Taneichi, MD	Japan	No Relationships
Xiangyu Tang	China	No Relationships
Ryoji Tauchi, MD	Japan	No Relationships
Bobby Tay, MD	USA	Omega (a); Biomet (b); Stryker Spine (b); Synthes (b); NuVasive (a); Globus Medical (a)
Hilary J. Taylor	United Kingdom	No Relationships
H Thomas Temple, MD	USA	No Relationships
Jamie S. Terran, BS	USA	No Relationships
Deepika Thacker	USA	No Relationships
Alexander A. Theologis, MD	USA	No Relationships
Senthilnathan Thirugnanasambandam, MD	USA	No Relationships
Robert Thomas, MD	USA	No Relationships
George H. Thompson, MD	USA	Journal of Pediatric Orthopaedics (b,f); SpineForm (b); OrthoPediatrics (b)
Sara E. Thompson, BA	USA	No Relationships
Beverly Thornhill, MD	USA	No Relationships
Jon H. Tobias	United Kingdom	No Relationships
Daisuke Togawa	Japan	No Relationships
Courtney Toombs, BS	USA	No Relationships
Hidehisa Torikai	Japan	No Relationships
Terry R. Trammell, MD	USA	Medtronic (a,b); K2M (a); Biomet (a,b)
Ensor E. Transfeldt, MD	USA	Medtronic (g); Stryker Spine (g)
Hope Trevino, AA	USA	No Relationships
Vikas Trivedi, MBBS, MS/DNB	India	No Relationships
Per D. Trobisch, MD	Germany	No Relationships
Taichi Tsuji, MD	Japan	No Relationships
Isabelle Turgeon, BSc	Canada	No Relationships
Koki Uno, MD, PhD	Japan	K2M (d); DePuy Synthes Spine (d)
Bekir Y. Uçar, MD	Turkey	No Relationships

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Alexander R. Vaccaro, MD, PhD	USA	Replication Medica (c); Globus Medical(c,g); K2M (c); Paradigm Spine (c); Stout Medical (c);Spine Medica (c); Computational Biodynamics (c); Progressive Spinal Technologies (c); Spinology; Small Bone Innovations (c); NeuCore (c); Cross Current (c); Syndicom (c); In Vivo (c); Flagship Surgical (c); Advanced Spinal Intellectual Properties (c); Cytonics (c); Bonovo Orthopaedics (c); Electrocore (c); Gamma Spine (c); Location Based Intelligence (c); FlowPharma (c); R.S.I. (c); Rothman Institute and Related (c);Innovative Surgical Design (c); Spinicity (c); DePuy Synthes Spine (g); Medtronics (g); Stryker Spine (a,g); Biomet Spine (g); Aesculap (g); NuVasive (a,g); Cerapedics (a); Stout Medical (b); Gerson Lehrman Group (b); Guidepoint Global (b); Medacorp (b); Innovative Surgical Design (b,e)
Elizabeth M. Van Allen, MS	USA	No Relationships
Claudio Vergari, PhD	France	No Relationships
Kushagra Verma, MD, MS	USA	No Relationships
Rajat Verma, MSc, FRCS, FRCS(Orth)	United Kingdom	No Relationships
Koen L. Vincken, PhD	Netherlands	No Relationships
Donald Virostek, BS	USA	No Relationships
Jean M. Vital	France	No Relationships
Francesco Vommaro	Italy	No Relationships
Tomas Vyskocil	Czech Republic	No Relationships
Karol Wadolowski, Master of Physiotherapy	Poland	No Relationships
Janet L. Walker, MD	USA	No Relationships
Eric Wall, MD	USA	Spine Form (g); OrthoPediatrics (b); Stryker Spine Trauma (b)
Colin Wallis, Mb, ChB, FRCPCH, MRCP, MD, DCH, FCP (SA)	United Kingdom	No Relationships
Kristine L. Walter, MA	USA	No Relationships
Defeng Wang, PhD	Hong Kong	No Relationships
Michael Y. Wang, MD	USA	Aesculap Spine (b); DePuy Synthes Spine (b,g); Innovative Surgical Designs (c); Spinicity (c)
Yan Wang, MD	China	No Relationships
Yingsong Wang, MD	China	No Relationships
Yiongsong Wang, MD	China	No Relationships
W. Timothy Ward, MD	USA	No Relationships
William c. Warner, MD	USA	No Relationships
John M. Wattenbarger, MD	USA	No Relationships
Jeffrey H. Weinreb, BS	USA	No Relationships
Nathan Wetters	USA	No Relationships
Lesley Wheeler, BS	USA	No Relationships
Gregory R. White, MD	USA	Medtronic (d); DePuy Synthes Spine (d); Transgenomic (d)
Nicholas J. White, MPH	USA	No Relationships

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Jared M. Wohlgemut, BSc	United Kingdom	No Relationships
Stephane Wolff	France	No Relationships
Kai Ann Wong, MBBS	Malaysia	No Relationships
Kirkham B. Wood, MD	USA	No Relationships
James G. Wright, MD	Canada	Journal of Bone and Joint Surgery- American (e,g); Saunders/Mosby Elsevier (g)
Margaret L. Wright, BS	USA	No Relationships
Jingming Xie	China	No Relationships
Yang Xu, MD, PhD	China	No Relationships
Mitsuru Yagi, MD, PhD	Japan	No Relationships
Kent T. Yamaguchi, BA	USA	No Relationships
Takuya Yamamoto	Japan	No Relationships
Yu Yamato	Japan	No Relationships
Ken Yamazaki, MD	Japan	No Relationships
Haruhisa Yanagida, MD	Japan	No Relationships
Charles I. Yang, MD	USA	No Relationships
Tejas K. Yarashi, MBChB	United Kingdom	No Relationships
Mohammed N. Yasin, FRCSEd (Tr & Orth)	United Kingdom	No Relationships
Tatsuya Yasuda	Japan	No Relationships
Ilker Yaylali, MD, PhD	USA	No Relationships
Jung U. Yoo, MD	USA	Osiris Therapeutics (g)
Wai Weng Yoon, BSc (Hons), MBBS, MRCS, FRCS (Tr & Orth)	United Kingdom	No Relationships
Petya Yorgova, MS	USA	No Relationships
Miao Yu, MD	China	No Relationships
Wai Ping Fiona Yu, MPH, BSc(Advanced)	Hong Kong	No Relationships
Wing Sze Yu, MPhil	Hong Kong	No Relationships
Juliane Zenner, MD	Germany	No Relationships
Hong Zhang, MD	USA	No Relationships
Ying Zhang	China	No Relationships
Yonggang Zhang, PhD	China	No Relationships
Li Zhao	USA	No Relationships
WenKui Zhao, MD	China	No Relationships
Zhi Zhao	China	No Relationships
Guoquan Zheng, MD	China	No Relationships
Xuhui Zhou, MD	USA	No Relationships
John Ziewacz, MD, MPH	USA	No Relationships
Jeannie Zuk, PhD	USA	No Relationships
Natalie L. Zusman, BS	USA	No Relationships

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Conflict of Interest Disclosures

Pre-Meeting Course

A Global Perspective of the Management of Spinal Disease and Deformity

Course Chair: John R. Dimar, II, MD

Wednesday, September 18, 2013
Cité Centre de Congrès
Lyon, France

Sponsored by the Scoliosis Research Society

The Scoliosis Research Society gratefully acknowledges DePuy Synthes Spine, Medtronic and NuVasive for their support of the Pre-Meeting Course.

Pre-Meeting Course Program

A Global Perspective of the Management of Spinal Disease & Deformity

Scoliosis Research Society • Pre-Meeting Course
Wednesday, September 18, 2013
7:45am – 4:30pm
Cité Centre de Congrès
Lyon, France

Course Chair:
John R. Dimar, II, MD

2012-2013 Education Committee

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Course Overview

This interactive course, presented by internationally renowned faculty through symposia and case examples, will address principles of improvement and techniques for optimizing outcomes and safety for deformity patients.

Course Objectives and Outcomes

As a result of participating in this activity, participants should be able to:

- . Describe the effect of abnormalities of the Central Nervous System (CNS) on the alignment of the spine during growth in the pediatric and adult spine.
- Differentiate between the current surgical options available for the treatment of complex cervical spinal deformities and identify which techniques deliver the best outcomes.
- Describe the currently available classification systems for congenital scoliosis and how they may help clarify the treatment options for various types of congenital malformations.
- Recognize the importance of the pelvic parameter's effect on spinal sagittal balance and determine which surgical treatment paradigms effectively treat sagittal imbalance.
- Analyze the causes of pediatric sagittal imbalance and appraise the various treatment techniques available to correct isolated and sagittal imbalance associated with multi-planar deformity.

Target Audience

Presentations at the 48th Annual Meeting & Course will have value for physicians and allied health personnel who treat spinal deformities at all levels and in all ages of patients. Medical students, residents, fellows, and researchers with an interest in spinal deformities will also benefit from the materials presented.

Continuing Medical Education (CME) Accreditation

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.

SRS designates this live activity for a maximum of 8.25 *AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

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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 are included in front section of this book.

Pre-Meeting Course Program

CME Certificates

CME Certificates will be available immediately upon the close of the meeting at www.srs.org/professionals/meetings/am13.

Delegates should log on to the website listed above and enter their last name and the ID number listed at the top of their Annual Meeting registration confirmation form. The system will then ask delegates to indicate which sessions they attended, to complete evaluation forms for each of those sessions, and then generate a PDF certificate which may be printed or saved. Session attendance and evaluation information are saved in the database, and certificates may be accessed again, in the event the certificate is lost or another copy is required.

Please note that certificates will not be mailed or emailed after the meeting. The online certificate program is the only source for this documentation. If you have any questions, please visit the Registration Desk or email the SRS office at meetings@srs.org.

FDA Statement

All drugs and medical devices used in the United States are administered in accordance with Food and Drug Administration (FDA) regulations. These regulations vary depending on the risks associated with the drug or medical device, the similarity of the drug or medical device to products already on the market, and the quality and scope of clinical data available. Some drugs and medical devices demonstrated in Scoliosis Research Society meetings or described in Scoliosis Research Society print publications have FDA clearance for use for specific purposes or for use only in restricted research settings. The FDA has stated that it is the responsibility of the physician to determine the FDA status of each drug or device he or she wishes to use in clinical practice, and to use the products with appropriate patient consent and in compliance with applicable law.

Disclaimer

The material presented at the 48th Annual Meeting & Course has been made available by the Scoliosis Research Society for educational purposes only. This material is not intended to represent the only, nor necessarily best, method or procedure appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement opinion of the presenter which may be helpful to others who face similar situations.

SRS disclaims any and all liability for injury or other damages resulting to any individuals attending a session for all claims which may arise out of the use of the techniques demonstrated there in by such individuals, whether these claims shall be asserted by a physician or other party

Audience Response System (ARS)

This course will include an audience response system component. Audience response questions can be found in this course book and can be answered using the "Polls or Feedback" module of the SRS Annual Meeting & Course Online and Mobile App. Click on the appropriate session to access the questions for that particular session. A live feed of audience response will be shown at the conclusion of each session.

Pre-Meeting Course Program

SRS Annual Meeting & Course Online and Mobile App

A mobile and online app will be available to all delegates during the 48th Annual Meeting & Course. The app is designed to provide all the information about the Annual Meeting & Course and Lyon in one convenient location and can be accessed from any smart phone or computer with an internet connection. To download the app visit, http://eventmobi.com/srsam13 or scan the QR code below with your smart phone

How to Use a QR Code/ Download the App

Smart phone cameras are able to scan QR Codes, or Quick Response Codes, to instantly link you to a specific image or URL. To use a QR Code all you need is an app that allows you to scan using the camera built into your phone. To access the SRS Annual Meeting App ARS directly using the QR code, follow these directions.

1. Your smart phone needs to have a QR scanner application installed.
   - For Blackberry download: The QR Code Scanner Pro from the Blackberry App Store OR there is a QR Code Scanner built in to the Blackberry Messenger.
   - For iPhone download: Scan. This app can be found in the app store by searching the word scan. The app is the property of QR Code City, LLC.
2. Once the app is downloaded you are ready to scan the QR code. Place the QR code in the middle of the brackets so that it is centered and as large as the brackets.
3. On the iPhone: Once the QR code is centered it will automatically scan and load the webpage linked to the QR code
4. On the Blackberry:
   - Blackberry Messenger: Click into Blackberry Messenger and scroll down to find the option that says "scan a group barcode." The app will then give you a short tutorial how to scan your code.
   - QR Code Scanner Pro: Open the app and click the scan option. Once you have your code centered and as large as the brackets select "click to scan." The app will then pull up the URL.
5. On the iPhone: You can click on the arrow in the bottom right-hand corner to open the webpage in safari. You can also navigate the app while you are still in the Scan App.
6. On the Blackberry: Once you scan the code you will be able to navigate the entire app. To permanently save the app click on your blackberry button and select save page. A message will prompt you to save to message list-click ok. The app will save to your email. Anytime you want to revisit the app, click on the message in your email and you will automatically be linked back to the app

Pre-Meeting Course Program

Lunchtime Sessions
The following symposia will take place during the lunch hour from 12:35 – 1:35pm

Wednesday, September 18, 3013

Lifelong Radiology Exposure for Spine Surgery
Location: Forum 4, Forum Level
Chair: Mark Weidenbaum, MD

The Lunchtime Symposium entitled "Lifelong Radiation Exposure in Spinal Deformity- Can We Do Better?" will briefly explore the overall radiation experienced by patients with spinal deformity and by surgeons caring for these conditions. General definitions and concepts of radiation will be reviewed and some specifics of radiographs and imaging modalities (CT, Myelo-CT, bone scan, etc) will be discussed. The course will also briefly look at technical aspects (shielding, technique, equipment) as well as differences between pediatric and adult populations, in addition to intraoperative radiation exposure for the surgeon and the patient. The purpose of this effort is to try to develop ways to reduce radiation while maintaining optimum care.

A Global Perspective on Neuromonitoring
Location: Forum 5/6, Forum Level
Chairs: Norbert Passuti, MD & Ensor E. Transfeldt, MD

Neuromonitoring remains an essential technique in preventing potential neurologic injury during spine surgery. Most spine surgeons serve as the final interpreter of these modalities during their intraoperative cases and therefore should have a thorough understanding of the basic science of how monitoring works and how to tailor the neuromonitoring techniques available to a specific surgery. The surgeon should be familiar with the correct type of anesthetic techniques necessary during surgery and have a basic knowledge of how to analyze and respond to abnormal neuromonitoring signals. Appreciating these key fundamentals of neuromonitoring will enable the surgeon to respond quickly to abnormal signals and take appropriate corrective measures.

Research Grant Outcomes
Location: Forum 1, Forum Level
Chair: Charles E. Johnston, MD

The SRS Research Grant Committee presents a lunchtime symposium giving recent grant recipients an opportunity to present and discuss the fruits of their labors. After presenting their preliminary or final results, each project will be discussed in detail. There will also be an opportunity to discuss the grant funding application process with the members of the SRS Research Grants Committee.

Pre-Meeting Course Program

The Pre-Meeting Course is supported, in part, by grants from DePuy Synthes Spine, Medtronic and NuVasive.

A Global Perspective of the Management of Spinal Disease & Deformity
Course Chair: John R. Dimar, II, MD

Combined Morning Session

Neuromuscular Scoliosis and Neurodegenerative Adult Spinal Deformity: Pediatric to Adulthood Treatment Techniques
Moderators: John R. Dimar, II, MD & Lori A. Karol, MD
Room: Forum 5/6, Forum Level

7:45 – 7:48am	**Introduction** *Kamal N. Ibrahim, MD, FRCS(C), MA*
7:48 – 7:55am	**The History of the International Contribution to the Modern Treatment of Spinal Surgery** *Nathan Lebwohl, MD*
7:55 – 8:10am	**Introduction to ARS and Cases** *John R. Dimar, II, MD*
8:10 – 8:15am	**The Treatment of Deformity Associated with Degenerative Neurologic Conditions: Are There Differences in the Global Treatment of Children with SMA-2 and Older Patients with SMA -3: Young SMA Patient** *Hilali H. Noordeen, FRCS (p. 56)*
8:15 – 8:20am	**The Treatment of Deformity Associated with Degenerative Neurologic Conditions: Are There Differences in the Global Treatment of Children with SMA-2 and Older Patients with SMA -3: Older SMA Patient** *James O. Sanders, MD (p. 59)*
8:20 – 8:25am	**Current Worldwide Treatment Techniques for the Treatment of Spinal Deformity Associated with Cerebral Palsy: Global Perspective & Treatment Techniques** *Muharrem Yazici, MD (p. 61)*
8:25 – 8:30am	**Current Worldwide Treatment Techniques for the Treatment of Spinal Deformity Associated with Cerebral Palsy: The US Perspective** *Paul D. Sponseller, MD (p. 63)*
8:30 – 8:40am	**Discussion**
8:40 – 8:47am	**Indications for the Treatment of Pediatric Neuromuscular Deformities Following Traumatic Paralysis** *John R. Dimar, II, MD (p. 66)*
8:47 – 8:54am	**Neuromuscular Scoliosis Secondary to Chiari, Synrinx or a Tethered Cord Syndrome Due to a Tight Filum Terminale: Worldwide Management and Treatment** *Andrew H. Jea, MD(p. 69)*
8:54 – 9:01am	**A Global Perspective of the Management of Severe Spinal Deformities with Paralysis in Spinal Tuberculosis** *S. Rajasekaran, MD, FRCS, MCh, PhD (p. 71)*
9:01 – 9:09am	**Discussion**
9:09 – 9:29am	**Case Presentations: The Treatment of Pediatric Neurogenic Deformity: How Do Techniques Differ Around the World?** *Moderator: Steven M. Mardjetko, MD (p. 75)* *Panel: Alain Dimeglio, MD; Lawrence L. Haber, MD; Suken A. Shah, MD*
9:29 – 9:36am	**Dangers and Pitfalls in the Treatment in Adult Neuromuscular Deformity** *Steven D. Glassman, MD (p. 76)*
9:36 – 9:43am	**Spinal Disease Associated with Parkinson Disease: How to Identify and Treat Concurrent Spinal Pathology** *Joseph H. Perra, MD (p. 77)*
9:43 – 9:50am	**Diagnosis and Treatment of Adult Deformity Associated with Hereditary Sensory Neuropathies** *Mark B. Dekutoski, MD (p. 80)*
9:50 – 10:00am	**Discussion**
10:00 – 10:20am	**Debate: The Treatment of Spinal Disease in the Adult Stroke Patient: Indications for Surgery** *Moderator: Sigurd H. Berven, MD (p. 80)* *Debaters: Stephen J. Lewis, MD, MSc, FRCSC; Mark Weidenbaum, MD*
10:20 – 10:35am	**Break**

Pre-Meeting Course Program

Concurrent Morning Session 1 *(Runs Concurrently with Concurrent Morning Session 2)*

Techniques for the Treatment of Complex Cervical Deformity: An International Perspective
Moderators: Michael Ruf, MD & Christopher I. Shaffrey, MD
Room: Forum 5/6, Forum Level

10:35 – 10:42am	**Advanced Imaging Techniques Required for Complex Cervical Reconstructions** *Christopher P. Ames, MD (p. 82)*
10:42 – 10:49am	**Advanced DISH with Dysphagia: Treatment Options** *Justin S. Smith, MD, PhD (p. 86)*
10:49 – 10:56am	**Options for the Correction of Cervical Kyphosis in the Ankylosed Spine** *K. Daniel Riew, MD (p. 89)*
10:56 – 11:03am	**How to Avoid and Treat Post-Traumatic Kyphosis** *Jeffrey C. Wang, MD (p. 92)*
11:03 – 11:13am	**Discussion**
11:13 – 11:23am	**Case Presentations: Examples of Complex Cervical Reconstructions** *Moderator: Christopher I. Shaffrey, MD (p. 93)* *Panel: Charles H. Crawford, III, MD; Serena S. Hu, MD; Tyler Koski, MD; Brian A. O'Shaughnessy, MD*
11:23 – 11:30am	**Treatment Options for Occipital/ C1/C2 Instability in the Inflammatory Arthritis Patient** *Todd J. Albert, MD (p. 94)*
11:30 – 11:37am	**Treatment of Global Cervical Stenosis: When is a Laminoplasty vs. a Posterior Laminectomy and Fusion Indicated** *Manubu Ito, MD (p. 98)*
11:37 – 11:44am	**Reconstruction of the Kyphotic Spine With Pyogenic Osteomyelitis** *Michael Ruf, MD (p. 101)*
11:44 – 11:51am	**Stabilization of Cervical Spine Following Tumorous Destruction** *Praveen V. Mummaneni, MD (p. 103)*
11:51am – 12:01pm	**Discussion**
12:01 – 12:21pm	**Debate: How is Cervical Stenosis Treated Globally: Anterior vs. Posterior Treatment of Cervical Myelopathy** *Moderator: Sean Molloy, MBBS, MSc, FRCS* *Debaters: Todd J. Albert, MD; Christopher I. Shaffrey, MD (p. 104,106)*

12:35 – 1:35pm Lunchtime Symposia

Lifelong Radiology Exposure for Spine Surgery
Room: Forum 4, Forum Level

A Global Perspective on Neuromonitoring
Room: Forum 5/6, Forum Level

Research Grant Outcomes
Room: Forum 1, Forum Level

Pre-Meeting Course Program

Concurrent Morning Session 2 *(Runs Concurrently with Concurrent Morning Session 1)*

A Worldwide Viewpoint on the Treatment of Congenital Scoliosis
Moderators: Noriaki Kawakami, MD, DMSc & Michael J. McMaster, MD, DSc, FRCS
Room: Forum 1, Forum Level

10:35 – 10:42am	**Identification of Abnormalities Associated with Congenital Deformity of the Spine: Intra-Spinal, Renal and Cardiac** *Lori A. Karol, MD (p. 110)*
10:42– 10:49am	**International Classification Systems of Congenital Scoliosis: Which Ones are Effective** *Michael J. McMaster, MD, DSc, FRCS (p. 111)*
10:49 – 10:56am	**Classification and Treatment of Dorsal Hemi-Vertebrae Presenting with Neurologic Symptoms** *Daniel J. Sucato, MD, MS (p. 113)*
10:56 – 11:03am	**Congenital Abnormalities of the Cervical Spine: Treatment of Basilar Impression, Occipital Synostosis and Odontoid Dysplasia: A Global Treatment Perspective** *Jean Dubousset, MD (p. 116)*
11:03 – 11:13am	**Discussion**
11:13 – 11:23am	**Case Presentations: Congenital Cervical Deformity** *Moderator: John B. Emans, MD (p. 117)* *Panel: John P. Dormans, MD; B. Stephens Richards, III, MD; Reinhard D. Zeller, MD, FRCSC*
11:23 – 11:30am	**The Treatment of Syndromic Cervical Deformities Associated: How do Techniques Differ Worldwide?** *John P. Dormans, MD (p. 118)*
11:30 – 11:37am	**Klippel Feil Syndrome: Diagnosis, Treatment Options & Sports Participation** *Steven M. Mardjetko, MD, FAAP (p. 120)*
11:37 – 11:44am	**Surgical Options for the Treatment of Congenital Scoliosis** *Noriaki Kawakami, MD, DMSc (p. 126)*
11:44 – 11:51am	**Sacral & Lumbosacral Agenesis: Diagnosis and Global Treatment Options** *Frances A. Farley, MD (p. 128)*
11:51am – 12:01pm	**Discussion**
12:01 – 12:21pm	**Debate: Hemi-Vertebrae Excision vs. Growth Arrest Procedures (Posterior, Arrest, Anterior/Posterior Fusion)** *Moderator: Richard E. McCarthy, MD* *Debaters: Daniel J. Hedequist, MD; Ilkka J. Helenius, MD, PhD (p. 131, 132)*

12:35 – 1:35pm Lunchtime Symposia

Lifelong Radiology Exposure for Spine Surgery
Room: Forum 4, Forum Level

A Global Perspective on Neuromonitoring
Room: Forum 5/6, Forum Level

Research Grant Outcomes
Room: Forum 1, Forum Level

Pre-Meeting Course Program

Combined Afternoon Session 1

Techniques for the Preservation of Sagittal Balance: An International Perspective
Moderators: John R. Dimar, II, MD & Pierre Roussouly, MD
Room: Forum 5/6, Forum Level

1:45 – 1:52pm **The Evolution of the Concept of Pelvic Parameters and Their Relationship to Sagittal Spinal Alignment**
Hubert Labelle, MD (p. 134)

1:52 – 1:59pm **Lumbosacral Segmental Kyphosis: Selection Criteria for the Reduction of a Balanced and Unbalanced High Grade Spondylolisthesis**
Pierre Roussouly, MD (p. 136)

1:59 – 2:06pm **Abnormal Sagittal Alignment in Neuromuscular Scoliosis: When is Treatment Required?**
Ahmet Alanay, MD (p. 138)

2:06 – 2:13pm **Scheuermann's Kyphosis and Roundback: Current Treatment Guidelines**
B. Stephens Richards, III, MD (p. 140)

2:13 – 2:20pm **Sagittal Imbalance Due to a Congenital Dorsal Hemi-Vertebrae: When is Treatment Indicated?**
Lawrence G. Lenke, MD (p. 143)

2:20 – 2:32pm **Discussion**

2:32 – 2:52pm **Debate: Best Treatment Recommendations: Three Cases of Pediatric Patients with Post Traumatic Sagittal Imbalance, Post-Infectious, PJK in Neuromuscular Kyphoscoliosis**
Moderator: Laurel C. Blakemore, MD (p. 145)
Debaters: Kenneth M.C. Cheung, MD; Suken A. Shah, MD

Combined Afternoon Session 2

Adult Sagittal Deformity: Etiology, Identification, Classification & Outcomes
Moderators: Sigurd H. Berven, MD & Khaled Kebaish, MD
Room: Forum 5/6, Forum Level

2:53 – 3:00pm **The Etiology of Positive Sagittal Balance Within the Aging Population**
Khaled Kebaish, MD (p. 148)

3:00 – 3:07pm **What are the Available Preoperative Measurement and Classification Techniques: Are they Effective and Useful?**
Frank J. Schwab, MD (p. 151)

3:07– 3:14pm **Can Prospective Operative Planning Prevent a Flatback Deformity in the Multiply Operated Low Back?**
Sigurd H. Berven, MD (p. 155)

3:14 – 3:21pm **Post-Surgical Proximal Junctional Kyphosis: Etiology and Avoidance Techniques**
David W. Polly, Jr., MD (p. 156)

3:21 – 3:31pm **Discussion**

3:31 – 3:38pm **Are Sagittal Plane Re-Alignment Procedures Cost Effective?**
Charles H. Crawford, III, MD (p. 158)

3:38 – 3:45pm **What Patient Outcome Data is Available to Justify the Use of Major PSO Procedures for the Restoration of Sagittal Alignment vs. Conservative Treatment?**
Mark Weidenbaum, MD (p. 160)

3:45 – 3:50pm **Discussion**

3:50 – 4:10pm **Case Presentations: Anterior/Posterior Surgery vs. Posterior Based Surgery for Adult Sagittal Imbalance: Are Treatment Techniques Similar Globally?**
Moderator: Munish Chandra Gupta, MD (p. 163)
Panel: Youssry M.K. El –Hawary, MD; Kamal N. Ibrahim, MD, FRCS(c), MA; Marinus De Kleuver, MD, PhD; Ronald A. Lehman, Jr., MD

4:10 – 4:25pm **ARS and Cases**
John R. Dimar, II, MD

4:25 – 4:30pm **Closing Remarks**
John R. Dimar, II, MD

Combined Morning Session:
Neuromuscular Scoliosis and Neurodegenerative Adult Spinal Deformity: Pediatric to Adulthood Treatment Techniques

Moderators:

John R. Dimar, II, MD & Lori A. Karol, MD

Faculty:

Sigurd H. Berven, MD; Mark Dekutoski, MD; Alain Dimeglio, MD; John R. Dimar II, MD; Steven D. Glassman, MD; Lawrence L. Haber, MD; Kamal N. Ibrahim, MD, FRCS(C), MA; Andrew H. Jea, MD; Nathan Lebwohl, MD; Stephen J. Lewis, MD, MSc, FRCSC; Steven M. Mardjetko, MD; Joseph H. Perra, MD; S. Rajasekaran, MD, FRCS, MCh, PhD; James O. Sanders, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Mark Weidenbaum, MD; Muharrem Yazici, MD

The Treatment of Deformity Associated with Degenerative Neurologic Conditions: Are There Differences in the Global Treatment of Children with SMA-II & Older Patients with SMA-III: Young SMA Patient

Mr. N S Harshavardhana, Mr. MHH Noordeen
Royal National Orthopaedic Hospital NHS Trust, Stanmore – United Kingdom

Spinal Muscular Atrophy (SMA) is acquired by autosomal recessive mode of inheritance

- Form of a defect in survival motor neuron on chromosome No. 5
- Primarily affects anterior horn cells causing
- Progressive degeneration of motor neurons
  * Progressive muscle weakness
- Incidence: 10 – 16 / 100,000 live births
- Clinical spectrum: Early infant death to normal adult life expectancy
- Clinical manifestations: Mainly orthopaedic & rehabilitation and pulmonary
- Other issues: Gastrointestinal & nutritional, and palliative care
- Severity depends on age at diagnosis of SMA
- Pulmonary manifestations are
  * Progressive decline in pulmonary function / vital capacity
  * Progressive muscle weakness: Diaphragmatic breathing
  * Bell shaped thorax – Collapsing *'Parasol'* deformity of chest cage
- Death usually due to chronic respiratory failure
- Orthopaedic manifestations include
  * Scoliosis
  * Hip dysplasia
  * Contractures
  * Muscle weakness

Natural History: Three distinct phases noted

  * Initial onset of muscle weakness
  * Plateau phase
  * Deterioration phase with progressive decline in function and activity
- Though strength may be maintained, function declines with time

Diagnosis:

- Previously by denervation potentials on EMG, reduced amplitudes on NCV, muscle biopsy, LMN type paresis (flaccidity & hypotonia) and by exclusion.
- Now by SMA gene deletion and genetic testing
  * Sensitivity – 95% and
  * Specificity – 100%

Classification: Based on age of onset / age at diagnosis of underlying neuro-degenerative disorder

- Clinical: 3 types
- Functional (Evans): 4 types
- Modified classification system: By international standards of care committee for SMA (2005)
- My talk will cover clinical types - SMA II & III regarding approach and surgical management

Key to treating any neuro-muscular spinal deformity: Know the *natural history*

SMA clinical type I: Age at diagnosis is usually <6 mo

- 95% of them die by the age of 2 yrs.
- Definitive spinal fusion – acceptable
- Short-life span: Severe form of rapidly progressive disease (Werdig-Hoffmann type)

SMA Clinical Type II: Age of diagnosis between 6 mo – 2yrs.

- Most common form of SMA presenting in early-onset scoliosis clinics
- 90% of them survive for at least 10yrs
- Up to 70% of them survive for at least 25yrs
- Maybe ambulators initially to begin with and are wheel-chair bound by age 6yrs
- Progressive decline in function, activity and muscle strength with disease progression
- Synonymous with SMA functional type III

SMA Clinical type III: Age at diagnosis between 2 - 3 yrs.

- Retain ambulatory potential up to adolescence / adulthood
- Milder form of disease (Kuegelberg-Welander type)
- Synonymous with SMA functional type IV

Scoliosis in SMA: Mean age of diagnosis 6-8 yrs.

- Evaluate hips: R/o hip dysplasia / dislocation
- Rx Spine always first before addressing hips
- Most common curve pattern: Thoraco-lumbar deformity (90% of cases)
- Other curve types that can be seen include

  * Single thoracic
  * Single lumbar
  * Double thoracic
- Joint / shared care with neuro-muscular / pulmonary / Gastro-intestinal & rehabilitative team to optimze outcomes

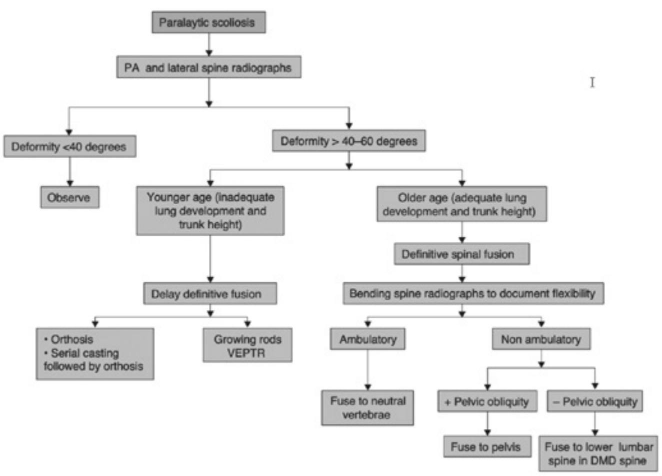
Pre-operative evaluation: Baseline pulmonary function test

  * Challenging in very young children: CT lung volumes
  * More recently: Dynamic lung MRI
- Anaesthetic evaluation
- Pre-operative nutritional / GI optimization regarding weight gain – Gastrostomy tube feeds
- Xrays: Sitting entire spine – AP & Lateral views Supine traction AP xrays to assess flexibility of curve

Scoliosis Surgery for SMA: First and foremost do NO harm

- Approach – Most commonly used: Posterior
- Role of Anterior surgery – Decreasing with use of pedicle screws
  Dictated by pulmonary function / reserve
- Surgical options in posterior surgery: Growth sparing Sx Vs. Definitive spinal fusion
- Growth sparing Sx:
- Growing rods & Luque-trolley system
  VEPTR (Vertebral expandable prosthetic titanium rib)

Generic surgical algorithm for Mx of NMS: Bridwell KH et al: The textbook of spinal surgery, 2011



SMA Type II: Includes children who are able to sit but cannot walk and those who can stand / walk (Modified SMA classification types II & III)

- Usual age of diagnosis: Between 6mo- 2yrs
- Multiple studies / evidence exist: Definitive spinal fusion is detrimental to lung growth and pulmonary maturation
- Has historically been treated with: Growing rods – Dual submuscular
  Luque-Galveston system
  VEPTR: Rib – Spine
  Rib – pelvis anchors
  VEPTR lateral gantry: Eiffel tower constructs
- More recently: Advent of magnetic growth rods (MGRs) – Boon to these kids
  * One off surgery
  * Eliminates the need for repeated anaesthesia and risks associated with it – Impact on cognitive development, memory and function
  * Early results are promising
  * Rate of pulmonary function decline is reduced / delayed
  * Personal series: Spectacular improvement in lung function at 2 yrs. f/u
  * No side-effects / risks from magnetic coil
  * Encouraged by preliminary results: Am converting conventional growing rod patients to MGRs
  * Index example of SMA-II in 6yr/F treated with MGR is shown in Fig. 1
  * Lower rate of complications: In-comparison to growing rods & VEPTRs
  * Potentially can also be combined with VEPTR (anchors are compatible)
  * Long-term results with minimum follow-up of at least 5 years needed
  * Not approved by FDA and licensed for use in USA
  * Paper 32 (Friday 0826): Discusses the effect on PFT by use of MGR for EOS-NM

SMA Type III: Include Modified SMA classification Type IV patients

- Age of onset in 2nd – 3rd decade
- Retain ambulant potential to adulthood
- Life expectancy – almost normal to general population
- Mx of scoliosis
  * Observation and bracing in skeletally immature patients
  * Definitive spinal fusion after skeletal maturation
  * Fusion levels: To neutral vertebra
  * Avoid fusion to pelvis which may compromise ambulatory capacity

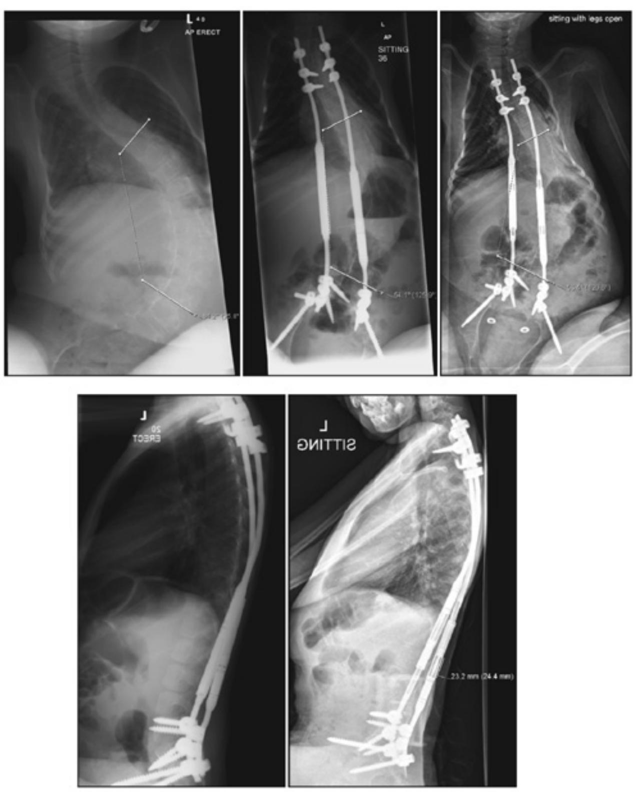
* Anterior surgery: To save one or two levels in lumbar spine feasible

Key points / Summary:

SMA types II and III have differing severity of affection which has a bearing on surgical management of scoliosis. Bracing does not alter the natural history of SMA and may be detrimental in causing constrictive respiratory disease esp. when rigid orthosis is used. While growth sparing modality is primary method of preventing progression of deformity in type II, definitive spinal fusion can safely be performed in older children with type III who are nearing 2nd decade of life. The main aim of surgery in type II is to optimize spinal growth (trunk height) with pulmonary maturation. Many published studies in literature have reported benefits of surgery with better seating ability, higher caregiver satisfaction and overall quality of life. Surgical risks include risk of infection (higher infection rate than AIS), excessive intra-operative bleeding, loss of correction, instrumentation failure and pseudoarthrosis. The beneficial effect of surgery on pulmonary function is yet to be established. Early results with use of magnetic growth rods for SMA II have been encouraging with dramatic decrease in rate of pulmonary decline. However long-term studies with larger patient cohort are desired.

Fig 1: SMA – II child with parasol chest deformity: Magnetic growth rod (MGR) insertion

Arrest in progression of scoliosis with 23mm T1-S1 length gain at 18mo post-op



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Notes

The Treatment of Deformity Associated with Degenerative Neurologic Conditions: Are There Differences in the Global Treatment of Children with SMA-2 & Older Patients with SMA -3: Older SMA Patient

James O. Sanders, MD
University of Rochester
Dept. of Orthopedics and Rehabilitation
James_sanders@urmc.rochester.edu
Rochester, NY, USA

Basics: SMA is caused by a defect of the survival motor neuron gene from homozygous or compound heterozygous mutation in the SMN1 gene (OMIM - 600354) on chromosome 5q12. This gene is also involved in the more severe SMA type I (OMIM - 253300) and the less severe SMA type III (OMIM - 253400) and SMA type IV (OMIM - 271150). Disease severity is partially modified by the SMN2 copy number with more SMN2 causing less severe disease (substitutes for SMN1 deficiency). Motor and pulmonary function typically deteriorate over time.

Type II or SMA II or chronic Werdrnig-Hoffmann is characterized by onset usually between 3 and 15 months and survival beyond 4 years and usually until adolescence or later.

Type III is also known as SMA III or Kugelberg-Welander Syndrome (KWS) and has later onset and retains more functional abilities than the more severe type II.

Current Clinical Trials: Because of the devastating nature of SMA, there are a number of clinical trials. Those active as of June 2013 and registered through Clinicaltrials.gov are listed below:

1. Spinal Muscular Atrophy (SMA) Biomarkers Study in the Immediate Postnatal Period of Development
2. Infants With Spinal Muscular Atrophy Type I
3. Clinical Trial of Exercise in Patients With Spinal Muscular Atrophy (SMA)
4. Clinical Assessment of Spinal Muscular Atrophy Type II and III (SMA Europe)
5. Valproate and Levocarnitine in Children With Spinal Muscular Atrophy
6. A Study to Assess the Safety and Pharmacokinetics of ISIS SMNRx in Infants With Spinal Muscular Atrophy
7. An Open-label Safety, Tolerability and Dose-range Finding Study of Multiple Doses of ISIS SMNRx in Patient With Spinal Muscular Atrophy
8. An Open-label Safety and Tolerability Study of ISIS SMNRx in Patients With Spinal Muscular Atrophy Who Previously Participated in ISIS 396443-CS1
9. International SMA Patient Registry
10. SMN Copy Number Distribution in Mali, West Africa

11. Short and Long Term Treatment With 4-AP in Ambulatory SMA Patients

Non-Scoliosis Issues:

GI – Delayed emptying, constipation, dysmotility

Pulmonary – weak musculature, ineffective cough, aspiration

Scoliosis: In SMA II, progressive scoliosis is frequent. Scoliosis surgery can preclude clinical trials of ISIS-SMNRx by inhibiting a lumbar puncture - a dilemma for many families.

Issues with SMA II:

1. Current clinical trials and scoliosis fusion are important in family decisions
2. Improvements in pulmonary care apart from scoliosis surgery have improved longevity.
3. Bracing's role is undefined
   a. Chest constriction can occur from the brace
   b. Bracing may delay in curve progression
   c. Bracing may assist with sitting balance
4. Curves are typically early onset –results in frequent surgeries in younger, frail children, and kyphosis is common in the younger patients.
5. Parasol shaped chest from poor intercostal strength
6. Bone quality may be poor.
   a. Possible role for bisphosphonates
   b. Difficulties with fixation
7. In children with intermediate function, fusion can limit torso and hip motion with subsequent limitations to ADL's and manual wheelchair propulsion.
8. Pelvic obliquity is typical of the curves
9. Constructs include:
   a. Growing rods
   b. VEPTR
   c. Standard to pelvis
10. Curves can progress after fusion in the young.

Issues with SMA III:

1. Curves are typically of later onset but may still become large preadolescent.
2. Bone quality can still be an issue.
3. Less likely to have pelvic obliquity
4. Does bracing limit ambulation?
5. Does fusion to the sacrum limit ambulation?
6. Constructs:
   a. Less often to pelvis
   b. Less often need growing rods or VEPTRs

Selected References:

1 Mesfin A, Sponseller PD, Leet AI. Spinal muscular atrophy: manifestations and management. J Am Acad Orthop Surg. 2012 Jun;20(6):393-401. *A very good recent review covering both scoliosis and non-scoliosis issues*

2 Zebala LP, Bridwell KH, Baldus C, et al. Minimum 5-year radiographic results of long scoliosis fusion in juvenile spinal muscular atrophy patients: major curve progression after instrumented fusion. J Pediatr Orthop. 2011 Jul-Aug;31(5):480-8. *Once you have finished correcting the curve, you may not be done as the curves will often progress as the patients go through their growth spurt.*

3 McElroy MJ, Shaner AC, Crawford TO, et al. Growing rods for scoliosis in spinal muscular atrophy: structural effects, complications, and hospital stays. Spine (Phila Pa 1976). 2011 Jul 15;36(16):1305-11. *Growing rods and VEPTR's have a role. None of the treatments are benign*

4 Khirani S, Colella M, Caldarelli V, et al. Longitudinal course of lung function and respiratory muscle strength in spinal muscular atrophy type 2 and 3. European journal of paediatric neurology : EJPN : official journal of the European Paediatric Neurology Society. 2013 May 11. *Lung fuction does worsen over time but not as significatly for type 3 as type 2.*

5 Mills B, Bach JR, Zhao C, Saporito L, Sabharwal S. Posterior spinal fusion in children with flaccid neuromuscular scoliosis: the role of noninvasive positive pressure ventilatory support. J Pediatr Orthop. 2013 Jul-Aug;33(5):488-93. *Something very helpful to keep in you back pocket for pulmonary support.*

6 Barsdorf AI, Sproule DM, Kaufmann P. Scoliosis surgery in children with neuromuscular disease: findings from the US National Inpatient Sample, 1997 to 2003. Archives of neurology. 2010 Feb;67(2):231-5. *As you might expect, patients with SMA have longer lengths of stay and more sigificant morbidy than non-neurmucular kn*

Notes

Current Worldwide Treatment Techniques for the Treatment of Spinal Deformity Associated with Cerebral Palsy: Global Perspective and Treatment Techniques

Muharrem Yazici, MD
Hacettepe University
Ankara,Turkey
mimyazici@gmail.com

Cerebral palsy
Static lesion in immature brain that leaves children with permanent motor impairment

Global perspective
- Identical etiology
- Identical pathology
- Identical process
- Identical result

So what is the difference?
Better yet, is there one?

Incidence
- Epidemiologic studies
  - Overall incidence
  - Developed countries
  - Developing countries
  - Underdeveloped countries

Etiology
- Increasing maternal age
- Multiple births
- Genetic factors
- Factors related to delivery
  - Childbirth without professional help
  - Insufficiency of the medical team and/or institution regarding technique, knowledge and management

Severity of disease
- Developed countries
  Generally a higher rate of GMFSC 4-5
  Though general prevalence stayed stable in the last years, there is a shift toward more severe cases
  Better neonatal and pediatric care
- Developing countries
  CP population comprises of milder cases
  Severe cases expire early

Though causes change over the years, overall prevalence does not!

While better prenatal care and delivery decrease incidence, higher survival of very-low birth weight babies and pushing the limits of pregnancy further every day increase it

Incidence of CP patients requiring orthopedic care
- Severity of disease
- Duration of survival
- Social perception
  - Perceiving these children as ordinary members of the community and accepting that they have the same rights as any other individual
  - Removing the remnants of the medieval perception of 'cursed individuals'
  - Families being unembarrassed of their child
  - Family that has confidently accepted providing treatment that will be lengthy, difficult, sometimes disappointing, and exhausting for the parent
  - Financial and emotional resources to support this treatment
    - Sufficient insurance coverage
    - Supporting establishments for the family
      - Extended family in traditional societies
      - Government-funded institutions or NGOs
- The requirement for orthopedic care is on the rise!

Development level of a country
- Income per capita
- Indicators of health and education (rate of schools, number of physicians per capita)
- Poverty
- Unemployment rate
- Regional disparity
- Distribution of income
- Criteria added recently
  - Longevity and health
  - Access to information
  - Sufficient income for a satisfactory lifestyle
  - Political freedom
  - Secure human rights
- New criteria
  - Number of CP patients requiring orthopedic care and having easy access to it
    - Improved neonatal care
    - Improved mental, social and economic status

Why should treatment be different if the condition is the same?

Spinal deformity

- Time of presentation
- Co-morbidities
  - Confirmed and potential preventative measures regarding these co-morbidities
    - ◊ Seizure management
      - » Medical, surgical
    - ◊ Nutritional support
      - » GI tube feeding, etc
    - ◊ Spasticity management by ITB
    - ◊ Osteoporosis management
- Patient's state of rehabilitation at the time and rehabilitation resources they can access post-treatment
- Social environment of patient
  - Can they use a wheelchair?
  - Is their living situation suitable for crutches or a walker?
- Severity of deformity at presentation
  - Extent of surgical intervention required by deformity
    - ◊ Anterior surgery or VCR
  - State of skin and paravertebral muscles
    - ◊ Extra procedures required for closure?
- Surgery
  - Technical infrastructure
    - ◊ Great pediatrics team
    - ◊ Anesthesiology
    - ◊ Pediatric ICU
    - ◊ Nutrition team
- Implant inventory
  - Availability of modern spinal instrumentation
    - ◊ in country
    - ◊ in hospital
    - ◊ for this particular patient
- Cost
  - Implant
  - Surgery
  - Preop workup postop care

Is spine deformity surgery in patients with CP truly beneficial?

- Many controversial results
  - Conviction and assent that benefits trump drawbacks in the modern world
  - However postop complications and insufficient correction decrease satisfaction
  - If we cannot prevent/decrease complications, the decision to treat is open for discussion

Last words

- Spinal deformity is not a sole problem of the spine
  - This situation is more true for CP deformities than any other condition
- Not all patients have be perfectly corrected using state-of-the-art implants
  - Sublaminar wiring and classical Galveston still good alternatives
  - However, implant choice is the least important factor for successfully surgery in CP deformities
- If there is a lack in infrastructure, resources, knowledge and experience…
  - Managing the patient with non-op methods may be the most prudent course of action for all involved (patient, family, and surgeon)
- Regardless of the severity of their disease or their contribution to society, CP patients deserve the same rights and opportunities provided to the rest of the community
- A perfect x-ray can never be exchanged for a heart that beats, or a brain that communicates, regardless of the limits
- Attempting a surgery with limited resources that is demanding and risky in the best of circumstances is not gracious or helpful, but merely foolhardiness!

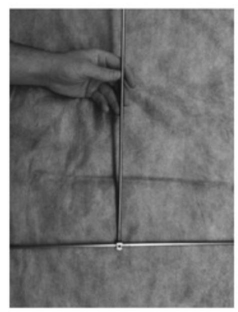
Notes

Concurrent Worldwide Treatment Techniques for the Treatment of Spinal Deformity Associated with Cerebral Palsy: The US Perspective

Paul Sponseller MD
Baltimore, Maryland, USA

1. I. Preop Considerations
    a. Evaluate hips- affect sitting if windswept or stiff
        i. Adjust sagittal plane
    b. Preop visit 2-3 weeks prior
    c. Infection prevention:
        i. -Check U/A
        ii. -Chlorhexidine scrub
        iii. -Gm Negative prophylaxis
    d. Anesthes
2. II. Approach: Posterior vs. AP
    a. A&P for NM deformity routine in '80's & 90's

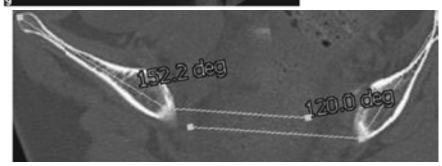
        i. Lonstein, Bradford, Winter
    b. New osteotomies, fixation changes everything!
    c. Current Harms prospective CP study
        i. 15% A&P
        ii. Mostly among larger curves (mean 105^{o} vs. 76^{o})
    d. AP Approach still preferred for:
        i. Severe lordosis or lordoscoliosis
        ii. Especially in lumbar spine
        iii. Some Curves >90^{o}
    e. A&P issues
        i. *Same day?*
            1. Depends on Blood loss, coagulation & ventilation
            2. Discuss with anesthetist in preop plan
    f. Anterior Instrumentation?
        i. *Only*:
            1. If severe (Grade 4) rotation exists
            2. If bone density is adequate
            3. If flexible after discectomy (Otherwise may limit posterior correction)



3. III. Pelvic Fixation:
    a. T2-pelvis = best deformity control
        i. But may affect transfers, ability to cath
        ii. Sparing levels = adding on later!!
    b. Main Goal
        i. To correct pelvic obliquity
            1. Unit Rod - Best published overall
            2. T-Square to check
        ii. SAI screws
            1. -Compress and distract pelvis
    c. Technique
        i. Check "teardrop" if?
            1. (obturator oblique)
    d. ↓Start more laterally if "vertical" hemipelvis

i. Seat screw heads at same depth as & in-line with S1 screws

ii. Drive partly into bone

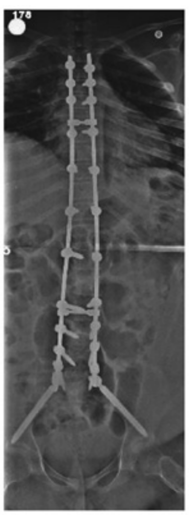


e. Transverse-plane pelvic asymmetry

i. Complicates iliac fixation

ii. Likely in windswept pelvis

4. IV. Implant Density & placement



a. 2 consecutive levels caudally (S1&2)

i. Usually skip L5

ii. 2-3 consecutive levels cranially

iii. Every level at curve apex

iv. Every other level in between

v. Saves time, EBL, cost

b. Crosslinks

5. V. Correction Sequence

a. Distal -to-proximal=usual

i. Cantilever

ii. Compress/distract

iii. Differential rod contour

b. Proximal to distal

i. For proximal kyphosis or scoliosis

ii. Pelvic screws facilitate this - Not unit rod!

c. Standard Correction

i. Lock rods in SAI screws distally

ii. Leave long ~2-3 cm against sacrum

iii. For compression/distraction

iv. Platform for derotation

d. S1 and L4/5

i. Minimizes stress on Screws and caps

e. Correction Sequence

i. Concave rod in first

1. Reduction screws in concavity

2. Wires /tapes if needed

ii. Distract concavity

1. Then derotate

f. Convex rod second

i. Compress and differentially contour

g. Staged Temporary internal distraction

h. Final

i. Bone Graft-Local autograft

ii. Allograft is my preference in long NM cases

iii. Soak in Gentamicin

6. VI. VCR in CP Scoliosis

a. 23 patients
   i. Most = thoracolumbar
   ii. 65% curve correction
   iii. 1800 cc EBL (76% Blood Volume)
b. 2 transient neurologic complications
   i. 1 cord, 1 radicular
c. Message:
   i. Last option for rigid, focal, kyphoscoliotic curves
   ii. Use other methods for non-focal curves

7. VII. When To Abort/Stage
   a. Combination of adverse factors:
      i. Decreased clotting
         1. Objective or subjective
   b. Increased Airway Resistance
      i. Need for pressors
      ii. Unreliable Monitoring
      iii. Convert to temporary distraction!
         1. Or halo traction
      iv. Usually > 1-2 wks to return
8. VIII. Growing Rods
   a. Good for SMA
   b. High infection rate in CP, MM
9. IX. Complications: Prox Junctional Kyphosis (PJK)
   a. Can PJK be avoided?
      i. Avoid dramatic kyphosis correction
      ii. Transition rod
      iii. T1 vs T2, etc
   b. Will it cause problems?
      i. Need to look down
   c. Preoperative Evaluation: PJK
   d. Examine head & trunk control
      i. Risk of PJK, fixation failure
      ii. Increased preop kyphosis-greater risk
   e. Especially with kyphosis correction
   f. Evaluate pelvis, hips, and contractures
      i. Extension contracture= compensatory kyphosis
   g. Complications-Infection
      i. 5-15% across Neuromuscular spectrum
      ii. Infections often polymicrobial / gram negative
      iii. 52%
   h. SPINE 2000
   i. UTI
      i. Urinary and fecal colonization
      ii. Broad-spectrum coverage best
      iii. Add antibiotics to bone graft
   j. Infection: Prevention
      i. Minimize skin tension
      ii. Broad Spectrum antibiotics
         1. Local Abx in graft
         2. Liquid Gent 10 mg/kg
      iii. Drain
         1. Borkhuu, Shah 2008
         2. Aspirate deep wound if any question
         3. A&P fusion optimizes end result
   k. Infection: Rx
         1. I&D
         2. VAC
         3. Flaps
            a. Plastic surgeon
      i. Leave implant until fused
      ii. Increased risk of pseudarthrosis
10. X. What have we learned about CP deformity?
   a. Work-up important for management
   b. Prevent infection, bleeding
   c. Surgery:
      i. Image entire spine
      ii. Greater EBL, infection rate
      iii. Do not fuse short

Notes

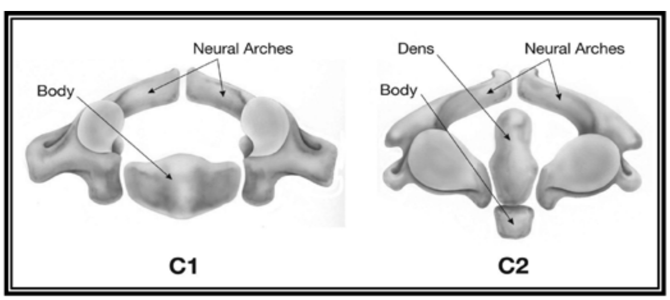
Indications for the Treatment of Pediatric Neuromuscular Deformities Following Traumatic Paralysis

Paul C. Celestre, MD, Clinical Instructor of Orthopedics
University of Louisville & The Leatherman Spine Center
Louisville, Kentucky, USA

John R. Dimar II, MD, Clinical Professor of Orthopedics
University of Louisville & The Leatherman Spine Center
Louisville, Kentucky, USA

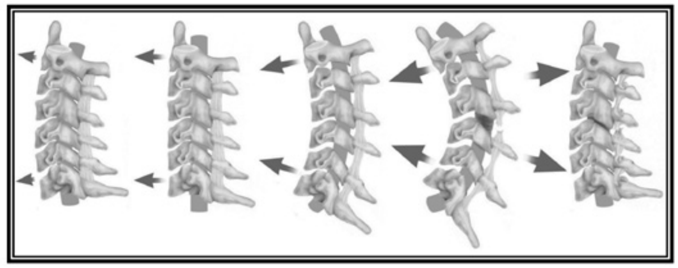
SRS Annual Meeting – Lyon, France 2013

1. Epidemiology:
    a. Spinal cord injuries in children younger than 15 years represent less than 4% of all spinal cord injuries in the united states.
    b. 60-80% of spine trauma in this age group occurs in the cervical spine.
    c. Children younger than 11 years of age with a neurological injury secondary to cervical spine trauma have a 5.1 fold greater mortality than patients older than 11.
    d. Recreational aquatics, especially diving, account for 66% of all sport associated spine trauma in the pediatric population. Rarely, child abuse can cause spinal cord injury.
    e. *Our Assumption is That Children Heal Faster & Better Than Adults Following Spinal Trauma Thus They Are Treated with Adult Treatment Paradigms: A Finding That is Not Supported by The Literature*
2. Anatomical Considerations
    a. Because of a larger head to body mass ratio, as well as shallow C1 superior facet joints and increased ligamentous laxity, injuries to the Occipital-cervical complex (Occiput-C1-C2) are more common in young children.



Growth Plates Make Radiographs Difficult to Interpret In Children

    b. Spinal Cord Injury Without Radiographic Abnormality (SCIWORA) may represent up to 30% of spinal cord injuries in the pediatric population, especially in children younger than 4 years.
        i. MRI is not 100% sensitive for ligamentous injuries in this population.
        ii. Prognosis for SCIWORA is poor.



Spinal Cord Injury Without Radiographic Abnormality (SCIWORA)- Nowdays an MRI Will Generally Show Some Degree of Ligamentous Injury or a Spinal Cord Injury

    c. Discs in the pediatric spine are stronger than vertebral bodies leading to an increased incidence of traumatic intraosseous disc herniations and multilevel compression fractures
    d. There is little evidence to support the notion that children with incomplete SCI recover neurological function better than adults.
    e. Scoliosis develops commonly after pediatric spinal cord injury, with estimates ranging from 23-97%, compared to 5% in adults.
3. Patterns of injury:
    a. Atlanto-Occipital Dissociation: AOD is common, particularly in children younger than 4 who are involved in a motor-vehicle accident.
        i. Although commonly fatal secondary to lack of respiratory drive in the field, some patients do survive.
        ii. This injury is commonly missed.
        iii. Treatment of AOD
            1. Halo-Thoracic immobilization with posterior only bone grafting from Occiput-C2 for children younger than 12 months.
            2. C1-2 Transarticular screw with occipital plating in patients older than 1 year.
    b. Atlanto-Axial Instability: AAI is also common, particularly in patients younger than 11 years. Up to 4mm of motion on flexion-extension radiographs may be normal.

i. AAI may be associated with os odontoideum and in the setting of SCI, definitive fusion is recommended.
   1. C1-2 posterior wiring with postoperative halo-thoracic immobilization or C1-2 Transarticular screws are recommended.

c. Flexion-Distraction Injuries
   i. Seen commonly in children wearing lap-belts involved in high-speed motor vehicle accidents.
   ii. Rapid deceleration causes a hyper-flexion moment which distracts across all columns of the spine
   iii. Chance fractures are a specific subset of these injuries with only bony injury and no ligamentous disruption.
      1. Chance fractures may be treated with a hyperextension cast or orthosis fitted under general anesthesia.
   iv. Other flexion distraction injuries are better treated with short segment posterior fusion using either hooks or pedicle screws.
   v. Progressive kyphosis >30 degrees indicates a failure of brace treatment.

4. Post-Traumatic Spinal Deformity: Mandatory Follow-up
   a. Children with a SCI prior to their pubertal growth spurt (approximately 12 years for females and 14 for males) have an incidence of scoliosis approaching 100%.
   b. Curve patterns are similar to those seen in neuromuscular scoliosis.
   c. Children with a spinal cord injury should be monitored very closely for the development of deformity and maintain a *high index of suspension*
   d. Bracing begins when a scoliosis of any magnitude is detected in prepubescent patients.
      i. Some patients who are started in a brace with curves less than 10 degrees may avoid the need for surgery
   e. Curves presenting with a Cobb angle of greater than 20 degrees are treated surgically.
   f. Fusion is almost always carried to the pelvis.
   g. Most complete SCI are fused at the time of initial presentation if enough spinal growth is present (>10 years old)

5. Literature Review: Incidence of Deformity Following a SCI
   a. Parent et. al. did a systematic review of the literature came to the following conclusions:
      i. Scoliosis Develops in 97% of children before their growth spurt & 52% after the growth spurt
      ii. Very Slight Evidence that neurologic recovery is better in children
      iii. Traumatic SCI should be suspected despite normal radiographs (SCIWORA)
   b. Mulcahey et. al. reviewed 217 children following a SCI for the development of a neuromuscular scoliosis and determined the following:
      i. Neuromuscular scoliosis in highly prevalent in children injured at an early age
      ii. SCI level, motor score, & severity are not predictor of the development of scoliosis
      iii. Age at injury is the only predictor of the worst curve & spinal fusion
      iv. TLSOs have no proof of effectiveness despite widespread use
   c. Yalcin et. al. Reported on 4 thoracolumbar (T5,T5,T10, L2) SCIWORA injuries that developed deformity that required surgery and found:
      i. At injury the average age was 3.9 years old
      ii. Scoliosis developed 17 months later
      iii. Surgical stabilization 6.5 years after the SCI
      iv. 54 → 9.5° correction with pedicle screws
   d. Cheirn et. al. reviewed a National Data base over 11 years & identified 4949 SCI patients.
      i. Pediatric patients have a 5.99 per 100,000 Rate of SCI
      ii. Cervical injuries most common: Incidence Rate = 4.06
      iii. Males & the poor have higher rates of injury
      iv. Incidence increase 10.5 X for cervical & 7.5 X for other SCI among teenagers
      v. Incidence further increases 28.6 X for cervical & 18.8 X for other SCIs

Pre-Meeting Course Handouts

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Notes

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Neuromuscular Scoliosis Secondary to Chiari, Syrinx or a Tethered Cord Syndrome Due to a Tight Filum Terminale: Worldwide Management and Treatment

Andrew Jea, MD, FAANS, FACS, FAAP
Associate Professor
Department of Neurosurgery
Baylor College of Medicine
Director of Neuro-Spine Program
Division of Pediatric Neurosurgery
Texas Children's Hospital
6621 Fannin Street
CCC 1230.01
Houston, Texas 77030 USA
Phone: 832-822-3950
Fax: 713-796-9636

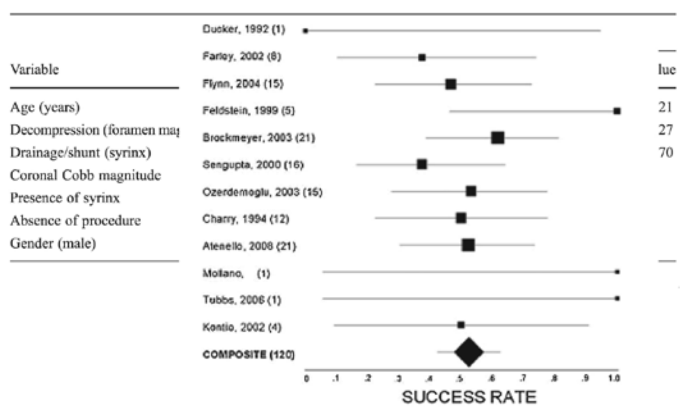
- Scoliosis associated with Chiari I malformation [1]
  * Introduction
  * Scoliosis often associated with Chiari malformation
    ◊ Important to distinguish Chiari I malformation from other subtypes of Chiari malformation such as Chiari II malformation
      » Chiari II malformation associated with myelomeningocele, congenital intracranial abnormalities, and different pathophysiology for scoliosis
      » Chiari I malformation diagnosed by MRI with > 5 mm of cerebellar tonsillar ectopia below foramen magnum
      » Classic presentation for Chiari I malformation includes tussive headaches
    ◊ **Key Fact** Incidence of scoliosis with Chiari I malformation 13-36%
      » Atypical features
        - Left apical
        - Kyphotic
        - Rapid progression
    ◊ Chiari malformation often associated with syringomyelia
    ◊ Syringomyelia typically an indication for surgical decompression
      » Chiari decompression results in improvement of syringomyelia in 65-93% patients
        - **Key Fact** Syrinx improvement preceded curve reduction on
        - average by 7 months [2]
        - Failure of syrinx improvement was associated with scoliosis progression
  * Methods
    ◊ Meta-analysis of 12 articles evaluating outcomes of pediatric scoliosis in patients with diagnosis of Chiari I malformation

Table 1 Summary of pediatric Chiari I patients with scoliosis and surgical intervention

Author	Year	Journal	N	Gender (M)	Age (years)	No. of patients with syrinx	No. of syrinx drainage	Coronal Cobb (°)	Follow-up (months)	Improved	Stable	Worse	N/A
Ducker [9]	1992	JSD	1	0	9	1	1	49	4.8			1	
Farley et al. [13]	2002	JSDT	9	2	8.7±3.1	2	0	46.3±17.1	34.7±20.7		3	5	1
Flynn et al. [15]	2004	Spine	15	6	9.0±4.2	13	5	36.3±13.8	76.2±44.4	4	3	8	
Feldstein [14]	1999	PN	7	3	10.6±5.3	7	0	35.4±8.6	32.4±10.3	3	2		2
Brockmeyer et al. [5]	2003	Spine	22	7	8.5±4.8	20	0	33.2±11.4	28.8	4	9	8	1
Sengupta et al. [26]	2000	ESJ	16	10	11±3	16	0	41±10.8	30±17.5	5	1	10	
Ozerdemoglu et al. [24]	2003	Spine	15	7	11.2±4.8	15	4	33.5±9.4	93±82.4	7	1	7	
Charry et al. [6]	1994	JPO	14	8	7.5±3.5	0	0	24.6±13.6	33.7±30.2	4	2	6	2
Attenello et al. [3]	2008	JNP	21	4	9±2.6	21	0	28±8.3	39±36	8	3	10	
Mollano [21]	2005	IOJ	1	1	5.5	1	0	54	84	1			
Tubbs et al. [28]	2006	CNS	1	1	16	0	0	13	36		1		
Kontio et al. [19]	2002	JPO	4	2	11.7±2.2	4	4	33.8±9.0	48.8±17.4	1	1	2	
Total			126	51 (40 %)	9.7±4.1	100 (79 %)	14	34.4±13.0	48.3±48.2	37 (29 %)	26 (21 %)	57 (45 %)	6 (5 %)

CNS child's nervous system, ESJ European Spine Journal, IOJ Iowa Orthopaedic Journal, JNP Journal of Neurosurgery: Pediatrics, JPO Journal of Pediatric Orthopaedics, JSD Journal of Spinal Disorders, JSDT Journal of Spinal Disorders and Techniques, PN Pediatric Neurosurgery

    ◊ Results and Conclusions
      » Multivariate analysis revealed three statistically significant variables: age (p=0.052); foramen magnum decompression (p=0.023); syrinx drainage/shunting (p=0.052)
        - Most significant factor: surgical decompression of foramen magnum (OR16.0, 95% CI 1.5-171.8)
      » **Key Fact** Forest plot of articles shows approximately 50% of patients appear to have stable or improved curve magnitude after surgical treatment of Chiari malformation



- Scoliosis associated with tethered cord syndrome from tight filum terminale [3]
  * Introduction
    ◊ The spinal cord may be tethered by a thickened filum with a low conus medullaris but without other forms of dysraphism (tight filum terminale)

- ◊ **Key Fact** Yamada et al. [4] demonstrated that longitudinal stretching of spinal cord may alter tissue metabolism manifested by motor and sensory changes in lower extremities, incontinence, and neuromuscular scoliosis in approximately 30% of patients
- ◊ It has been suggested that release of tethered spinal cord may stabilize or reverse progression of scoliosis
  - » Development of scoliosis may be body's attempt to minimize abnormal tension placed on spinal cord
  - » Rotation of spine towards concave side shortens distance traveled by spinal cord

* Methods

TABLE 1. Spinal Curvature Before and After Untethering Surgery

Patient Cohort n = 45				
Normal Spinal Curvature at Presentation n = 31		Presented with Scoliosis n = 14		
Spinal curvature remained normal n = 29	Developed new scoliosis n = 2	Curve worsened n = 7	Curve stabilized n = 5	Curve improved n = 2

TABLE 2. Clinical Features in 45 Pediatric Patients with Tethered Cord Syndrome

Clinical Feature	No. Patients (%)
Bowel/bladder dysfunction/abnormal urodynamics	15/45 (33%)
Caudal regression/VATER	14/45 (31%)
Syndromic/MR	11/45 (24%)
Presence of vertebral anomalies	10/45 (22%)
Thoracic/terminal syrinx	10/45 (22%)
LE problems: tight heel cord, flat feet	4/45 (9%)
Chiari/cervical syrinx	3/45 (7%)
Back/LE pain	3/45 (7%)
Sacral dimple/skin appendage	3/45 (7%)
Hip dislocation/dysplasia	2/45 (4%)
Ambulatory (>2-yr-old)	19/24 (79%)

MR indicates mental retardation; LE, lower extremity.

- ◊ Results
  - » **Key Fact** Multivariate analysis showed that Cobb angle > 35 degrees on presentation was the only variable that correlated with curve progression despite untethering
- ◊ Conclusions
  - » In patients with preoperative Cobb angle less than 35 degrees and a tight filum terminale, spinal cord untethering may prevent, or even reverse, scoliosis curve progression
  - » In patients with preoperative Cobb angle greater than 35 degrees, concurrent or early scoliosis surgery at the time of untethering maybe considered

- Is untethering necessary prior to scoliosis correction? [5]

* Introduction

- ◊ Scoliosis often develops in patients with myelomeningocele
- ◊ Risk factors for development of scoliosis in these patients include motor level, ambulatory status, and last intact laminar arch
  - » Scoliosis develops in almost 100% of patients with thoracic motor level
- ◊ Nearly all patients with myelomeningocele demonstrate a radiographically tethered spinal cord
  - » However, only 10-30% develop symptoms
- ◊ A tethered spinal cord may predispose patient to neurological injury when undergoing surgical correction of scoliosis
- ◊ On other hand, untethering spinal cord in patients with myelomeningocele also carries risk of worsening neurological function and wound problems

* Methods

- ◊ Describe 17 patients with myelomeningocele who did NOT undergo untethering prior to scoliosis surgery

TABLE 1: Summary of patient characteristics

total no. patients	17
M	7
F	10
mean age at surgery in yrs (range)	12.4 (10–17)
mean length of follow-up in yrs (range)	3.3 (2–8)
patients w/ shunt (%)	14 (82)

TABLE 2: Deformity correction*

Deformity	Cobb Angle (°) Preop	Most Recent Follow-Up
major coronal curve	82 (56–120)	35 (20–55)
kyphosis	50 (20–110)	33 (12–66)

* Values are presented as means with ranges in parentheses.

* Results

- ◊ No patient experienced a shunt-related issue postoperatively
- ◊ No new cranial nerve dysfunction, changes in urological function, or upper extremity neurological deterioration
- ◊ One patient had moderate right quadriceps muscle weakness postoperatively which improved to baseline one month after surgery
- ◊ 4 patients (23%) with wound problems

* Conclusions

- ◊ Nearly all patients with myelomeningocele have a tethered spinal cord
- ◊ **Key Fact** A patient with myelomeningocele who is asymptomatic may not need prophylactic untethering of the spinal cord prior to scoliosis surgery

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Notes

A Global Perspective of the Management of Severe Spinal Deformities with Paralysis in Spinal Tuberculosis

S. Rajasekaran, MS, FRCS, FACS, MCh, PhD
Chairman – Dept of Orthopaedics & Spine Surgery
Ganga Hospital, Coimbatore 641 043, India
sr@gangahospital.com

Introduction

There are more than 2 million patients with active spinal tuberculosis in the world today and tuberculosis still remains a major cause of paraplegia in many parts of the world. Highly effective antituberculous chemotherapy has now converted uncomplicated spinal tuberculosis into a ‘*medical disease*’ but neurological deficit and progressive deformity remain as major management challenges.

Tuberculous Paraplegia

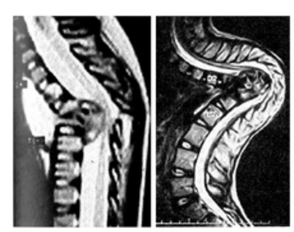
Neurological deficit of some form has been reported in 5-20% of patients with spinal tuberculosis. Neurological involvement is most frequent in the thoracic and thoracolumbar region as the spinal canal is narrower here and thoracic lesions are more prone to severe kyphosis which leads to retropulsion of sequestrated fragment of bone and disc into the canal. Lower limb weakness with bladder and bowel involvement is the usual neurological presentation.

Tuberculous Paraplegia – Pathology

Neurological deficits can occur both in active phase of the disease (*paraplegia of active disease*) and even many years later after complete cure of the disease (*paraplegia of healed disease* or *late onset paraplegia*). In the active phase, compression of the spinal cord due to abscess, granulation tissue, sequestrated bone or disc material is the usual cause of paraplegia. In lesions involving the facet joints or in patients with complete loss of one or more vertebrae, a pathological subluxation or dislocation can result in sudden onset of neurological involvement. In contrast, in healed disease, the cord gets stretched gradually over the sharp ridge of bone at the apex of the kyphosis (internal gibbus) leading to gradually progressive deficits. The etiology of paraplegia in the two groups and the prognosis is given in Table 1. (Fig 1)

TABLE 1: CAUSES OF NEUROLOGICAL COMPLICATIONS IN SPINAL TUBERCULOSIS

CAUSE	PROGNOSIS
ACTIVE DISEASE	
• Compressive pathology • Inflammatory edema • Granulation and caseous tissue with sequestrated material • Infective vasculitis • Spinal tumor syndrome • Pathological dislocation of spine • Direct infiltration of tuberculous bacilli into the cord	Usually responds well to conservative chemotherapy and a "Middle path regimen" can safely be followed if facility for surgery is not available
HEALED DISEASE	
• Stretching of cord over the bony ridge at the apex of the deformity (internal gibbus) • Progressive constriction of cord due to extradural fibrosis	Surgery is essential to relieve mechanical compression. The prognosis is guarded.



(a) (b)

Fig 1. MRI scans of two patients with paraplegia of active and healed disease respectively. (a) In paraplegia of active disease, there is a large collection of abscess and granulation tissue material inside the canal which causes severe cord compression. The natural kyphosis of the thoracic region allows easy retropulsion of the inflammatory material into the canal. (b). In paraplegia of healed disease, the cord is stretched and compressed over a long distance, not only at the apex but also over the adjacent segments. Myelomalacia is also frequently found and indicates poor prognosis.

Prognosis for the recovery of cord function

The presence of active disease which points to an inflammatory cause of compression, an incomplete involvement, a short duration of deficit, minimal kyphotic deformity, younger age, and good nutritional status are associated with good prognosis for recovery. Substantial neurologic improvement with some residual spasticity can occur even if the decompression is performed within one year of onset of symptoms, but surgery performed 2 years or more after onset is rarely of any benefit (Hsu et al, 1988). (Table 2.)

FACTORS LEADING TO POOR RECOVERY OF CORD
• Inactive disease with poor mechanical compression • Complete paralysis • Paralysis for more than 1 year • Presence of severe kyphosis • Older age and poor nutrition • Presence of myelomalacia and syringomyelia on MRI

The Management Dilemma

The appropriate treatment for tuberculosis paraplegia is still a dilemma due to the following factors:

1. There are conflicting reports of good results by both the proponents of chemotherapy and also radical surgery.
2. There is complete absence of any randomized trials to prove the superiority of either chemotherapy or radical surgery.
3. Surgical treatment requires good surgical expertise and advanced operating facilities. Tuberculosis is rare in places where such facilities are available and good facilities are not present where tuberculosis is rampant.

Antituberculous therapy have proved to be effective in >70% of patients with neurological deficit due to active disease. In a series of 89 consecutive patients treated conservatively, 81 returned to normal life and full activity *(Pattisson PR 1986), Konstam and Blesovsky (1962)* reported a series of 56 patients with paraplegia of whom 50% improved completely with conservative therapy. Of the remaining 28 patients, simple drainage of the abscess was adequate to achieve complete recovery in 26. A conservative regimen can be used confidently, especially in less privileged countries where adequate facilities for hospital treatment may not be available (*Rajeswari et al. 1997*) but however it has a disadvantage of protracted and prolonged treatment. Patients may develop secondary complications of prolonged recumbency and the treatment may not be successful in the presence of frank instability.

Much argument has also been made for surgical decompression, on the basis that it provides earlier and higher rates of recovery (*Hodgson et al 1967*). The opportunity can also be utilized to reduce the deformity and fuse the spine anteriorly. The general condition of the patient improves rapidly, and it has been argued that it is unfair to allow a patient to lie paralysed for weeks or months with the conservative regimen when surgical decompression may produce complete recovery earlier (*Hodgson et al, 1967*)

The surgical procedure most commonly performed is that described by Hodgson & Stock (1956) where the diseased bone is removed by an anterior approach up to bleeding healthy bones and the bone gap reconstructed by either rib, iliac crest or fibular graft. However, this surgery is a radical procedure and carries a high risk of mortality and morbidity.

This necessitates the need for two different approaches depending upon the level of facilities for major surgery available.

Treatment in areas where surgical facility is not available

In areas where surgical facility is rare, it is important to conserve the resources and perform surgery only in patients who are not responding to chemotherapy. This philosophy is encouraged by the good results reported by many surgeons (*Konstam and Blesobsky, 1962; Kumar,1988; Tuli, 1975)*. Here the principle of 'middle path regime' is followed, where all patients are started initially on chemotherapy and surgery is performed only under the following indications.

Indications for Surgery under 'Middle path regime' (*Tuli, 1975*)

1. Failure of Clinical improvement even after 4 weeks of chemotherapy
2. Progression of neurological deficit while under chemotherapy
3. Progression of bone destruction while under chemotherapy
4. Children who present with radiological 'Spine at Risk' signs (*Rajasekaran, JBJS 2001)*
5. Primary drug resistance
6. To obtain tissue for histopathology when diagnosis is inconclusive even by CT-guided biopsy

Treatment in regions where advanced spine surgery is possible

Surgery, as mentioned before, has got the advantages of complete debridement of the disease focus, reconstruction of the spinal column, stabilization of the spine and early mobilization.

The surgical procedure followed differs in tuberculous paraplegia in active disease and the late onset paraplegia of healed disease.

Surgery in Active Disease.
The aim of surgery here to achieve a good debridement to remove cold abscess, cacious tissue, sequestrated bone and all disease material that are encroaching the spinal canal and causing cord compression. There has been a slow change in concepts and evolution of techniques in this group in the last two decades.

Modified Hong Kong Surgery
Modified Hong Kong Surgery, as described by Hodson & Stock(1956), where by an anterior approach a thorough debridement is performed till bleeding healthy bone is reached and a defect reconstructed by bone grafts was the gold standard. (Fig 2)

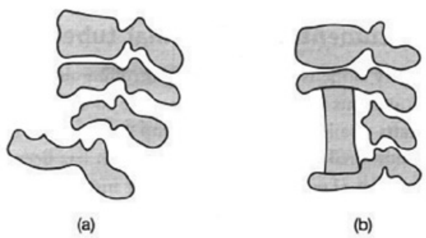


Fig 2: Modified Hong Kong procedure. (a) Debridement is performed until healthy bleeding bone is reached above and below the lesion. In active lesions, it is usually possible to open up the kyphosis by applying external pressure over the kyphosis. (b) Grafts can then be snugly fitted into notches made in the endplates of the vertebra above and below

The originators of surgery claimed faster healing and bony fusion but it's superiority in curing a neurological deficit has not been established. Although this surgery was very effective in patients with minimal disease, there was an unacceptable increase in complications with failure of bone grafts whenever the graft length has to be more than two disc spaces (Rajasekaran JBJS, 1989) . The initial phobia of using implants in the presence of active tuberculous infection has been found to be unfounded and the work of Oga et al clearly (1993), proved that titanium implants can be safely used in active disease.

This led to the principle of posterior stabilization by pedicle screws and anterior reconstruction by bone grafts. Addition of titanium screws allowed better correction of deformity and reduced the rate of graft failure. The high success with this procedure also allowed surgeons to be bold enough to reconstruct the anterior deficit by the use of titanium cages. This not only was found to be safe but also allowed stable reconstruction of even large defects.

The major change in surgical philosophy in the last decade has been the trend to perform debridement, stabilization and anterior reconstruction – all by *'posterior only'* approach. This approach has been found to be safe, especially in the thoracic and thoracolumbar region where the nerve roots at the apex of the disease after the level of T11 can be safely sacrificed to provide a easy access to the anterior column through the postero-lateral route. Here stabilization of the spine by pedicle screws with temporary rods on one side after an adequate laminectomy is achieved. Decompression of the anterior column is then performed through a postero-lateral route. Complete excision of the facet and pedicle and sacrificing the thoracic nerve root can greatly aid in access. After a thorough debridement, the anterior defect is made good either by an appropriate bone graft or preferably a titanium cage. Needless to say, good debridement and uninterrupted chemotherapy are crucial for success in preventing recurrence.

Surgery for late onset paraplegia in healed disease
Late onset paraplegia is due to progressive kyphosis beyond 100 degrees where the spinal cord gets slowly stretched over the sharp ridge of bone which is termed as 'internal gibbus'. Here the prognosis is poor as the cord has been stretched over a long time and surgery is also associated with lot of complications. Late onset paraplegia is a sequeale of childhood spinal tuberculosis and it is important to prevent it. where the progress of deformity occurs even after cure of the disease. Rajasekaran (2001) has described the natural history of childhood spinal tuberculosis and 'Spine-at-risk' signs which will allow children who are prone for progressive collapse even very early in the course of the disease (Fig 3).

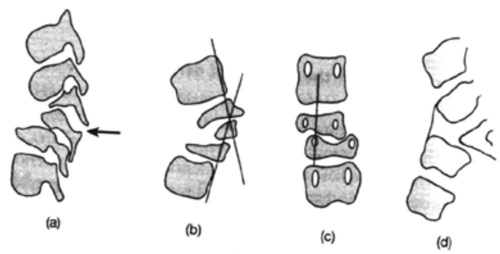


Fig 3: Spine at Risk radiologic signs. (a) Facet dislocation: the facet joint dislocates at the level of the apex of the curve, causing instability and loss of alignment. In severe cases, the separation can occur at two levels. (b) Retropulsion sign: the posterior retropulsion of the diseased vertebral segment is identified by drawing two lines along the posterior surfaces of the first upper and lower normal vertebrae. The diseased segments are found to be retropulsed posterior to the intersection of lines. (c) Lateral translation sign; lateral translation is confirmed when the line drawn through the middle of the pedicle of the lower vertebra does not touch the pedicle of the superior vertebra. (d) Topple sign: In the intial stages of collapse, the line drawn along the anterior surface of the lower normal vertebra intersects the inferior surface of the upper normal vertebra. "Tilt" or 'toppling' occurs when the line intersects above the middle of the anterior surface of the first normal superior vertebra

Spinal stabilization must be selectively done in this group to prevent late onset paraplegia In established disease with severe deformity, a Closing-Opening Wedge Osteotomy (*Kawahara,2001 Rajasekaran, 2010)* which is performed by an all posterior approach is the procedure of choice

(Fig 4.)

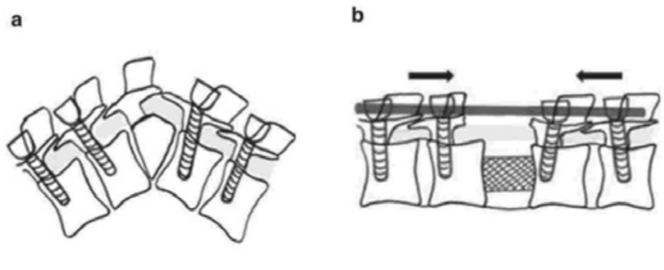


Fig 4. a In the surgical procedure, a temporary stabilisation of the spinal column with a pedicle screw construct is first performed before decompression. (b) After thorough decompression, the posterior rim of the fusion mass is removed. An appropriate sized cage or bone graft isused to open the anterior column so that kinking of the cord is avoided. Posterior compression of the pedicle screws is performed to achieve further correction

Here, a wedge osteotomy is performed at the kyphosis and the spinal deformity gradually corrected by closing on the posterior side and opening on the anterior side. Anterior gap is reconstructed by a cage which also acts as a fulcrum on which the spine can be closed posteriorly to achieve a reasonably correction of deformity. However, needless to say, a surgical team very experienced in this form of surgery is important to achieve success.

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Notes

Neurogenic Spinal Deformity: A Global Perspective

Steven Mardjetko MD, FAAP
Illinois Bone and Joint Institute
Morton Grove, IL, USA

Case Presentation: Congenital Myopathy with progressive Neuromuscular spinal deformity

1. Historical Perspective in the treatment of Neuromuscular Spinal Deformity
2. The Evolution of Neuromuscular Spinal Deformity Classification Systems
3. Regional variations in the etiologies of spinal deformity
4. Differences in social norms related to providing care for individuals and children with Neuromuscular disease.
5. scope of health care coverage and the role of government safety net.
6. Philanthropic support: internal and external
7. Patient Selection: who should get treatment and who shouldn't
8. Minimum Institutional requirements to perform Neuromuscular spinal deformity surgery
9. Non-operative care for NM spinal deformity- access to orthotics
10. Drawing up a Surgical Plan: cost/benefit analysis of neurodiagnostics, in-patient care, Instrumentation systems
11. Preparing for Surgical Treatment
    a. Nutritional evaluation and nutritional support
    b. Anesthetic evaluation
12. Access to and selection of specific surgical instrumentation systems
13. Intra-operative Neural Monitoring in Neuromuscular spinal deformity: when is this mandatory?
14. Blood salvage/conservation/transfusion for NM spinal deformity surgery
15. Halo-Gravity traction as an adjunct to deformity correction in NM patients
16. Technical aspects of NM deformity correction: Surgical Goal Setting
    a. Spinal release procedures: anterior vs. posterior, staged vs. same day
    b. FJOs, SPOs, PSO's, VCRs
    c. Fixation options: Screws, hooks, SLW. Implant density
    d. Corrective Maneuvers:
    e. Pelvic fixation: when and how
    f. Bone Graft options
    g. Techniques to minimize adjacent segment failure
17. Postoperative Management for NM spinal deformity patients
    a. Post-op PICU care
    b. Recognition and management of post-op complications
    c. Discharge Planning: WC modifications
    d. Follow-up schedule:

Notes

The Dangers and Pitfalls in the Treatment of Adult Neurovascular Deformity

Steven D. Glassman, MD
Professor of Orthopedic Surgery, University of Louisville
Attending Surgeon, Leatherman Spine Center
President-Elect, Scoliosis Research Society
Louisville, KY, USA

Introduction:

Surgical treatment of adult spinal deformity is difficult. The deformities can be rigid, the bone may be weak, the patients are often unhealthy, and complications are frequent. If this is not enough of a challenge, it is possible to select a subgroup that is even more problematic: Adult Neuromuscular Deformity.

Neuromuscular diseases add a level of complexity to the management of adult deformity which requires careful decision making and a significantly increased risk tolerance. The goal of this talk is to review some of the critical issues and common pitfalls in the treatment of adult neuromuscular deformity.

1. Neuromuscular Deformity in Children
   a. Most of the experience and literature involves surgery for neuromuscular scoliosis in children.
      i. Children with neuromuscular deformity are often severely involved: poor cognition, non-ambulatory, medically ill
      ii. Very high rates of surgical complications
         1. Perioperative complications of anterior procedures on the spine, McDonnell,M., Glassman,S. JBJS 1996
         2. New strategies and decision making in the management of neuromuscular scoliosis, Sarwark,J., Sarwahi, V. Orthop Clinics North Am 2007
         3. Risk factors for major complcations after surgery for neuromuscular scoliosis, Master,D., Son-Hing, J., Thompson, G.. SPINE 2011
2. Neuromuscular Deformity in Adolescents
   a. Importance of differentiating “idiopathic type” curves from primary neurogenic deformity.
      i. Beware of unfused “compensatory” curves
      ii. Don’t cheat short. Rules for selecting level in AIS do not apply
      iii. Fusion to the pelvic may impair ambulation
         1. The natural history of the neuromuscular disease will drive the behavior of the deformity.
3. Neuromuscular Deformity in Young Adults
   a. How does the neuromuscular disease impact normal degenerative aging changes
      i. Is the neuromuscular dysfunction fixed or progressive?
      ii. Don’t expect normal compensatory responses.
      iii. Does controlling the disease control the deformity?
   b. Condition specific considerations
      i. Cerebral Palsy
      ii. Muscular Dystrophies
   c. Deformities may be large and rigid – neglected cases
      i. Need for complex procedures
      ii. Limitations based on pulmonary and other medical risks
      iii. Benefit of newer surgical techniques?
         1. Posterior multilevel vertebral osteotomy for correction of severe and rigid neuromuscular scoliosis. Suh, S., Jang, K. SPINE 2009
4. Neuromuscular Deformity in Older Adults
   a. All sagittal imbalances are not equal.
      i. Beware of (+) sagittal imbalance without structural etiology
      ii. Assess MRI – R/O imbalance secondary to spinal stenosis
      iii. Camptocormia
   b. Condition specific considerations
      i. Post-polio syndrome
      ii. Parkinson’s Disease
         1. Spinal surgery in patients with Parkinson’s Disease: Construct failure and progressive deformity. Babat, B., McClain, R. SPINE 2004.
         2. Spinal surgery in patients with Parkinson’s Disease: Experience with the challenges posed by sagittal imbalance and the Parkinson”s spine. Koller, H, Koski, T. Eur Spine J. 2010.

Conclusion:

Adult neuromuscular spinal deformity is a really difficult problem without a simple answer. Patients need firstly to understand the elevated risk of typical medical and surgical complications. Further, they need to understand the unique risks of recurrent deformity related to the underlying neuromuscular disease or to disease progression their disease. Surgeons treating these patients need to be willing to manage the inevitable complications and to accept pretty dramatic failure in some cases. On the other hand, successful surgical treatment in this patient population can be very rewarding.

Notes

Spinal Disease Associated with Parkinson Disease: How to Identify & Treat Concurrent Spinal Pathology

Joseph H. Perra, MD
Twin Cities Spine Center
Minneapolis, MN, USA

Parkinson's Disease - Parkinson's disease is a progressive disorder of the nervous system that affects your movement. Lifetime risk of developing PD is 1.5%

1. Characteristics:
   a. Develops gradually
   b. Tremor - most well-known sign
   c. Commonly causes stiffness or slowing of movement.
2. Early stages "variable"
   a. May be tremor in one hand or decreased facial expressiveness
   b. Gait disturbances, speech softens or slurs
   c. Symptoms progress over time
3. Diagnosis;
   a. Clinical – no current "test"
   b. cardinal motor signs of PD are 4–6-Hz resting tremor, rigidity, bradykinesia, and gait disorder/postural instability. Other symptoms include stooped posture, hypophonia, and paucity of facial expression, dementia a late sign
   c. can be difficult to diagnose PD correctly, and the early signs of PD can often be subtle
4. No cure at present but treatments that improve symptoms
   a. Medications
      i. Carbidopa-levodopa
      ii. Dopamine agonists
      iii. MAO B inhibitors
      iv. Catechol O-methyltransferase (COMT) inhibitors
      v. Anticholinergics
      vi. Amantadine
   b. Deep brain stimulation
      i. advanced Parkinson's disease who have unstable medication (levodopa) responses
      ii. very effective in controlling erratic and fluctuating responses to levodopa or for controlling dyskinesias that can't be controlled with medication adjustments
5. Additional issues:

a. Thinking difficulties. (dementia) and thinking difficulties, which usually occur in the later stages of Parkinson's disease. Such cognitive problems aren't very responsive to medications.

b. Depression and emotional changes. Many people with Parkinson's disease may experience depression and other emotional changes, such as fear, anxiety or loss of motivation.

c. Sleep problems and sleep disorders. waking up frequently throughout the night, waking up early or suddenly falling asleep during the day,

d. Bladder problems. unable to control urine or having difficulty urinating.

e. Constipation. Many people with Parkinson's disease develop constipation primarily due to a slower digestive tract.

f. Sexual dysfunction. Some people with Parkinson's disease may notice a decrease in sexual desire or performance

g. Akinesia or bradykinesia - slowness of movement and thought process

h. Associated spinal issues associated with aging and poorer muscle control.

    1. Degenerative changes of the spine
    2. Pain
    3. Spinal stenosis
    4. Postural instability including sagital and coronal imbalance, prevalence of deformities (involuntary trunk flexion/camptocormia, anterocollis, scoliosis) in PD was 33.5%

6. Spinal conditions in PD - Symptoms and functional deficits of spinal disease were often masked by PD, posing diagnostic difficulty

    a. Spinal stenosis

    b. Cervical myelopathy

    c. Spinal deformities

        i. A number of spinal deformities have been described in association with PD. The stooped posture classically associated with PD is the most common abnormality. Other disorders include camptocormia, myopathy-induced postural deformity, Pisa syndrome, and degenerative scoliosis

7. Camptocormia

    a. Camptocormia, or "bent spine syndrome," is an extreme forward flexion of the thoracolumbar spine, which often worsens during standing or walking, but completely resolves when supine

    b. prevalence of camptocormia in patients with PD vary from 3–12.9%.

    c. Medical management of camptocormia in PD remains suboptimal.

    d. Subthalamic nucleus DBS has been reported to improve camptocormia associated with PD

    e. Spinal deformity surgery reported as possible, but with high complication and revision rates, Babat 11/14 pts with 22 revisions.

    f. consider surgical intervention only after subthalamic nucleus DBS has been performed and then only in patients who were highly motivated to walk

    g. anterocollis or "dropped head" may suffer from a form of atypical parkinsonism that does not respond to DBS.

8. Myopathy Associated Postural Deformity in PD

    a. Inflammatory myopathy of the paraspinal muscles can mimic the appearance of camptocormia in PD.

    b. treated with steroids and they noted marked improvemen in forward flexion

9. Pisa Syndrome

    a. lateral flexion of the trunk when sitting or standing an associated backward axial rotation of the spine

    b. generally associated with the use of neuroleptics, antiemetics, and/or cholinesterase inhibitors

10. Surgery in Patients With Parkinson's Disease

    a. Surgeons considering treatment of patients with PD should anticipate increased medical and surgical risks and need experience with adult deformity surgery and the demands of revision surgeries. Accordingly, nonsurgical therapy should be maxed out.

    b. the symptoms of postural instability, depression, and cognitive impairment, which are common features of later-stage PD, can make postoperative rehabilitation a challenge

    c. The role of DBS in the management of severe spinal deformity associated with PD is not yet known and the presence of spinal deformity should not be considered a contraindication for DBS as long as other standard criteria for DBS surgery exist.

    d. Short-segment spinal decompression and fusion may be considered in patients with coexistent camptocormia and spinal stenosis with myelopathy or radiculopathy. Long-segment spinal fixation procedures should be performed sparingly due to the very high complication rates reported in the literature.

e. A primary goal in surgical treatment of adult spinal deformity is to achieve proper alignment for ergonomic standing. To succeed, the surgeon must take into account not only the global spinal balance but also the pelvic position
   i. incomplete correction of spino-pelvic alignment in PD patients caused recalcitrant sagittal imbalance due to the disease-related forward 'pull' of the trunk and gravity line while the degree of postural instability correlated with increasing severity of the neuromuscular disease.
   ii. Osteoarthritis of the hip can aggravate the lack of existing spinal and spino-pelvic compensatory mechanisms. If surgery is indicated, osteoarthritis of the hip should be ruled out and if symptomatic, addressed prior to spinal surgery.
   iii. PD patients the muscular tension band is weak, prone to fatigue and spinal adjustment with compensation adjacent to a surgical fusion that did not achieve physiological contour is unlikely
   iv. reconstruction of physiological lordosis and lumbo-pelvic parameters is crucial when considering multi-level fusions even though this may indicate fusion into the thoracic spine.

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Bone Joint Surg Br 2005 vol. 87-B no. SUPP III 29

Heiko Koller,1 Frank Acosta,4 Juliane Zenner,1 Luis Ferraris,1 Wolfgang Hitzl,3 Oliver Meier,1 Steven Ondra,2 Tyler Koski,2 and Rene Schmidt1

Spinal surgery in patients with Parkinson's disease: experiences with the challenges posed by sagittal imbalance and the Parkinson's spine Eur Spine J. 2010 October; 19(10): 1785–1794.

Notes

Diagnosis and Treatment of Adult Deformity Associated with Hereditary Sensory Neuropathies

Mark B. Dekutoski, MD
The CORE Institute
Sun City West, Arizona, USA

PRESENTATION OUTLINE

- Character of Presentation
- Evaluation, Diagnosis and Differential
- Pathophysiology of HSN
- Natural History of Curve progression in HSN
- Limited Case based knowledge
- Case management and Pearls

Notes

Debate: The Treatment of Spinal Disease in the Adult Stroke Patient: Indications for Surgery

Sigurd Berven, MD
San Francisco, CA, USA

Case Presentation:

- 64yo female with a history of hypertension and progressive degenerative scoliosis
- Patient disabled from work as a teacher
- Walking tolerance limited to 2 blocks due to back pain and neurogenic claudication
- 3 years after initial surgery, patient sustained an episode with severe headache and onset of neck pain. She had a right sided hemiparesis
- She fell to floor at home and presented as an outpatient 3 mos later with severe neck and back pain
- Moderate ataxia to her gait with partial loss of proprioception. No fixed motor or sensory deficit

Debate Key Points:

- Preoperative Evaluation
    * Imaging
    * Neurology Evaluation
    * Discussion of risks and benefits
    * Indications for surgery vs non-operative care
- Intraoperative Considerations
    * Blood Pressure Goals
    * Choice of Levels
- Post-operative Treatment
    * Restarting ASA
    * BP management- ICU

Notes

Concurrent Morning Session 1:
Techniques for the Treatment of Complex Cervical Deformity: An International Perspective

Moderators:

Michael Ruf, MD & Christopher I. Shaffrey, MD

Faculty:

Todd J. Albert, MD; Christopher P. Ames, MD; Marco Brayda-Bruno, MD; Charles H. Crawford, III, MD; Serena S. Hu, MD; Manubu Ito, MD; Tyler Koski, MD; Praveen V. Mummaneni, MD; Brian A. O'Shaughnessy, MD; K. Daniel Riew, MD; Michael Ruf, MD; Justin S. Smith, MD, PhD; Jeffrey C. Wang, MD

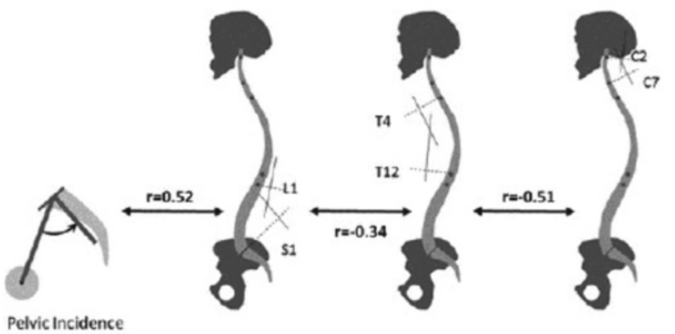
Pre-Meeting Course Handouts

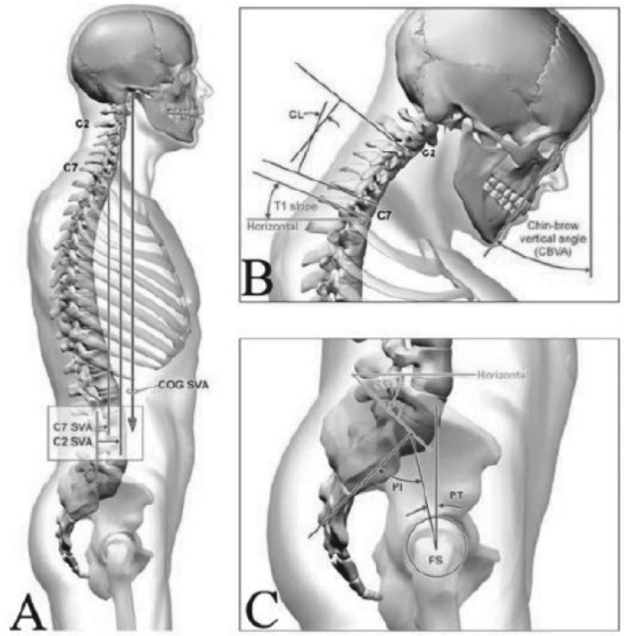
Advanced Imaging Analysis and Techniques Required for Complex Cervical Reconstructions in Deformity and Tumor

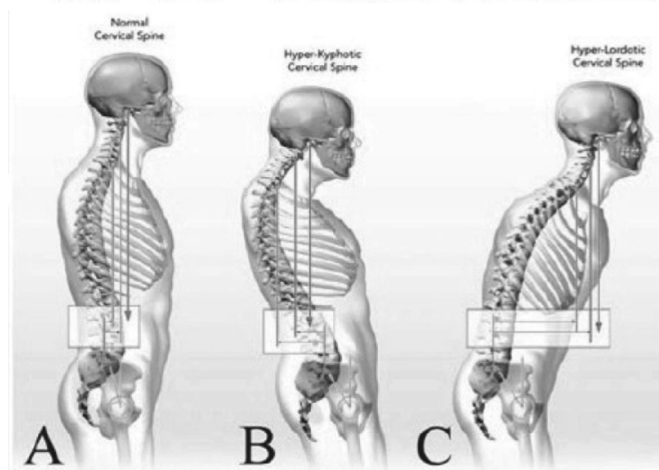
Christopher P. Ames, MD
Professor of Neurosurgery
Director of Spine Tumor Surgery
Director of Spinal Deformity
University of California San Francisco
400 Parnassus Ave
San Francisco, CA 94143 USA

Radiographic Assessment in Cervical Deformity

1. Radiographic Assessment of Cervical Alignment
    a. What is normal alignment of the cervical spine?

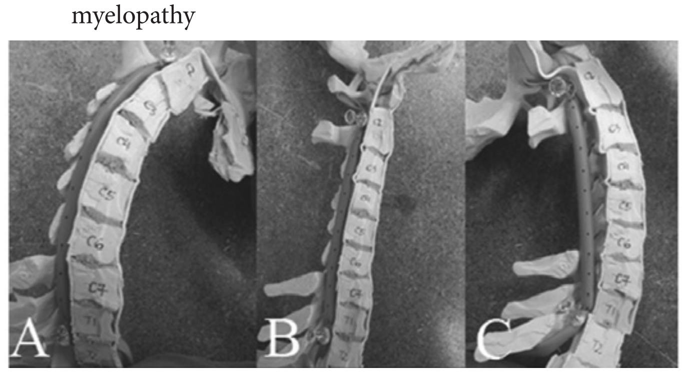






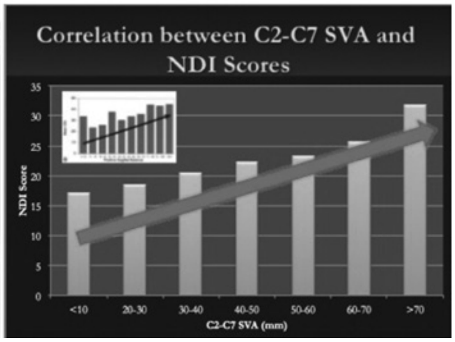
    b. Cervical alignment in the setting of subjacent spinal pelvic alignment
    c. Importance of assessing cervical alignment on standing 3 foot scoliosis films
        i. AP and lateral
        ii. UT scoliosis
        iii. Shoulder balance for coronal deformities

2. Why does cervical sagittal mal-alignment cause pain?
    a. Cantilever forces at cervical thoracic junction
    b. Why would cervical sagittal mal-alignment contribute to myelopathy

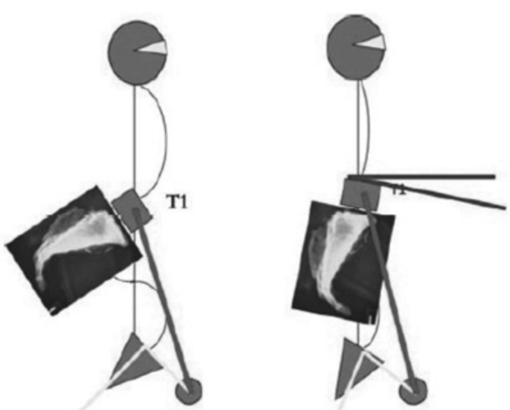


MJOA Correlations to Cervical SVA

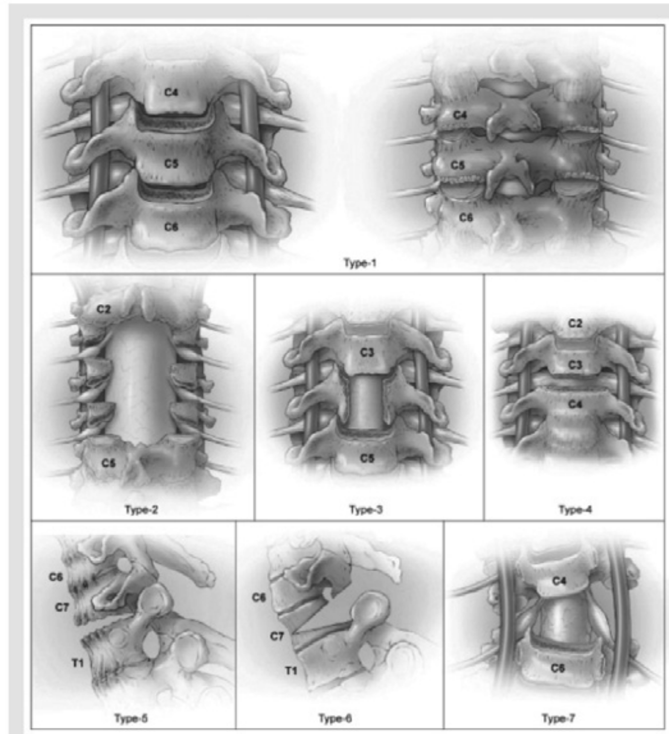
3. Plain radiographic parameters important in the assessment of cervical alignment
   a. C2-C7 cSVA



   b. C1-2 lordosis (PT of cervical spine)
   c. T1 slope (a moving target PI for the c spine)



   d. Cervical Lordosis
   e. CL-T1 slope
   f. Upper thoracic kyphosis T1-T4
   g. PI-LL, SVA, PT
   h. ROM on flexion and extension films
   i. Traction Films
4. Role of cervical CT scan
   a. Assessment of fusion status of discs and joints regarding mobility and osteotomy type required
   b. ISSG Cervical Osteotomy classification



   c. Assessment of C1-2 joints regarding vertical and rotational reducibility
   d. Fixation points-pedicles, lateral mass –especially important in revision surgery, pediatrics and NF
5. Role of MRI in deformity
   a. Cord shape in tension
   b. Cord tethering
   c. Diffusion MRI in myelopathy
      i. the density of the tracked nerve bundle through whole myelopathic cords was in an association with the modified JOA score in CSM cases (r=0.949, p=.015)
      ii. the density of the tracked nerve bundle through whole myelopathic cords was in an association with the modified JOA score in CSM cases (r=0.949, p=.015)
   d. Vertebral artery size, patency and location
6. Assessment of vertebral artery in deformity 3D CTA
   a. C1-2 Hong
      i. the authors analyzed the records of 1013 Korean patients who underwent computed tomography (CT) angiography to evaluate the incidence of anomalous variations in the third segment of the VA and to determine the incidence and morphometric characteristics of any detected posterior ponticuli

ii. The mean age of the patients was approximately 55.7 years and the prevalence of a posterior ponticulus was 15.6%. The incidence rate of a posterior ponticulus in the male population was 19.3%, whereas in the female population it was 12.8%. The incomplete type of posterior ponticulus was more common than the complete type. The mean age of the patients with an incomplete posterior ponticulus (55.7 years) was significantly younger (p = 0.018) than the mean age of patients with a complete posterior ponticulus (57.6 years). The incidence rate of a persistent first inter-segmental artery was 4.7% and the incidence rate of a fenestrated VA was 0.6%

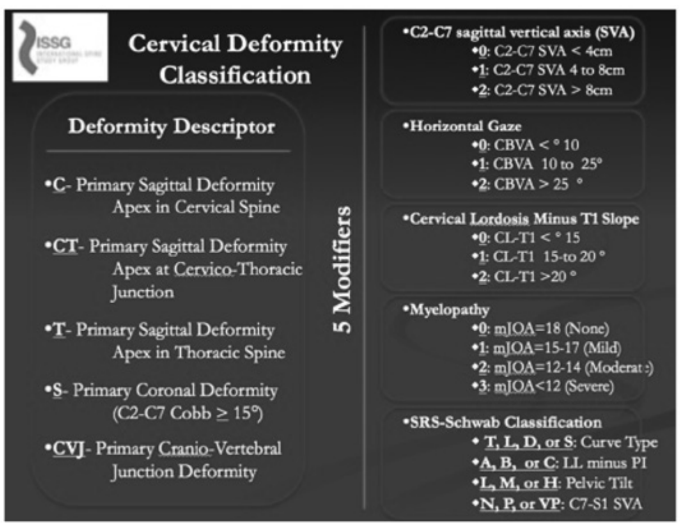
b. C7 pso Hong

i. 700 vertebral arteries on 350 three-dimensional CT angiographies were analyzedThe VA entered the C6 transverse process in 94.9% of the specimens (664 out of 700 VA courses). Abnormal VA entrance was observed in 5.1% of the specimens (36 VA courses), with entrance into the C4, C5, or C7 transverse foramen 1.6%, 3.3%, and 0.3%, respectively.In 2 of 36 cases (5.6%) of abnormal VA entrance, the extraosseous VA formed an unusual medial loop, and the center of VA was positioned medial to the longus colli muscle

7. Realignment planning

a. Towards a radiographic clinical impact classification for cervical deformity

b. Realignment targets



Radiographic Assessment in Complex Tumor

1. Angiography

a. VA Test Occlusion

b. Embolization of vascular lesions ABC, renal met

2. CT PET

a. Preop Assessment of malignancy in nerve tumors

b. Methionine PET

i. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of FDG PET in detecting MPNSTs in patients with NF1 were 95%, 72%, 71%, 95%, and 82%, respectively. Using 11C methionine PET in combination with FDG PET reduced the number of false-positive results from eight to two, which increased the specificity from 72% to 91%

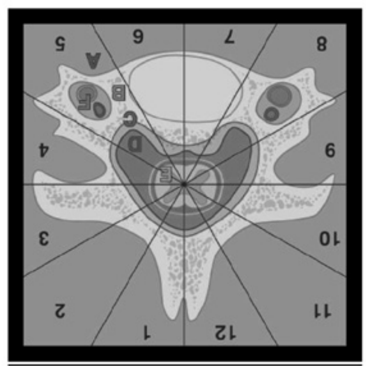
c. Determination of location for biopsy

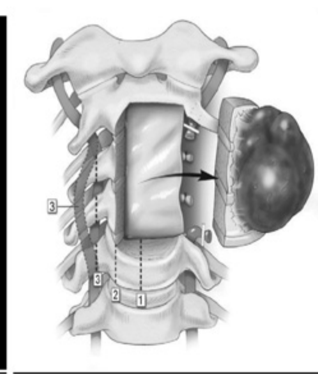
3. MRI

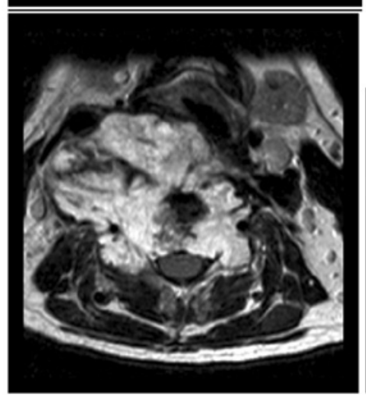
a. Adaptation of WBB grading to C spine

b. En Bloc Resection Planning

c. Vertebral artery involvement







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Notes

Advanced DISH with Dysphagia: Treatment Options

Justin S. Smith, MD, PhD
Associate Professor of Neurosurgery
University of Virginia
PO Box 800212
Charlottesville, VA 22908
USA
Phone: 434-243-9331
Fax: 434-243-1758
jss7f@virginia.edu

Key Points

1. What is DISH?
   a. DISH = Diffuse Idiopathic Skeletal Hyperostosis
   b. Systemic condition that leads to ossification of ligaments and entheses (bone attachments) of the spine and peripheral skeleton
   c. First described as senile ankylosing hyperostosis of the spine by Forestier in 1950[2]
   d. In 1970's, Resnick coined the term DISH and advocated 3 diagnostic criteria:[4]
      i. Presence of flowing ossification of the anterior longitudinal ligament of at least 4 contiguous vertebral bodies
      ii. Relative preservation of intervertebral disc height
      iii. Absence of apophyseal joint bony ankylosis and SI joint erosion, sclerosis, or intra-articular osseous fusion

2. Epidemiology of DISH
   a. Prevalence in men:women is at least 2:1
   b. Prevalence increases with age
      i. Estimated risk as high as:
         1. -32% for 80 y/o men
         2. -19% for 60 y/o men
      ii. Thoracic >> cervical

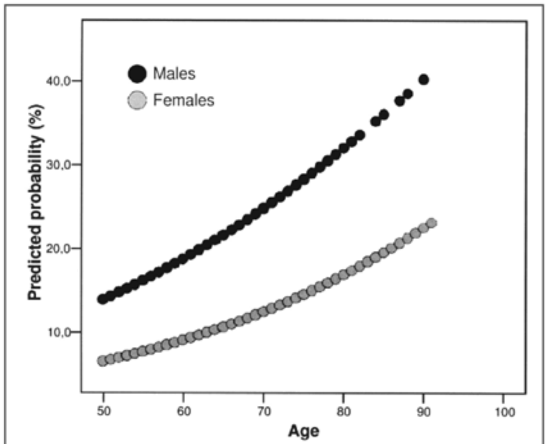


Figure 1. Individual predicted probability of developing DISH, according to age and sex.

Westerveld et al. *J Rheumatol* 35:1635-8, 2008.[7]

   c. Etiology of DISH is unknown
      i. Strong association with obesity and type II DM
      ii. Metabolic derangement?
      iii. Inflammatory mediators?

3. Clinical presentation of DISH
   a. Vast majority with DISH remain asymptomatic (especially thoracic forms)
   b. Systematic review by Verlann et al (2011)[6] on DISH identified 204 patients with dysphagia and/or airway obstruction from cervical DISH
   c. Most common symptoms/events (see next page) among these patients were: limited range of motion, dysphonia, weight loss, neck pain, and odynophagia
   d. Most common comorbidities reported in these patients (see next page) were hypertension, type 2 diabetes mellitus, coronary artery disease, and obesity

Symptoms/events attributed to DISH

Symptom	N (%)
Limited ROM	69 (34)
Dysphonia	29 (14)
Weight loss	26 (13)
Neck pain	21 (10)
Odynophagia	13 (6)
Difficult intubation	9 (4)
Sleep apnea/snoring	7 (3)
Myelopathy	6 (3)
Choking	6 (3)
Aspiration pneumonia	5 (2)
Respiratory insufficiency	4 (2)
Back pain	3 (1)
Thoracic outlet syndrome	3 (1)
Pharynx perforation	1 (0,5)
Radiculopathy	1 (0,5)
Reflux	1 (0,5)

DISH, diffuse idiopathic skeletal hyperostosis; ROM, range of motion.

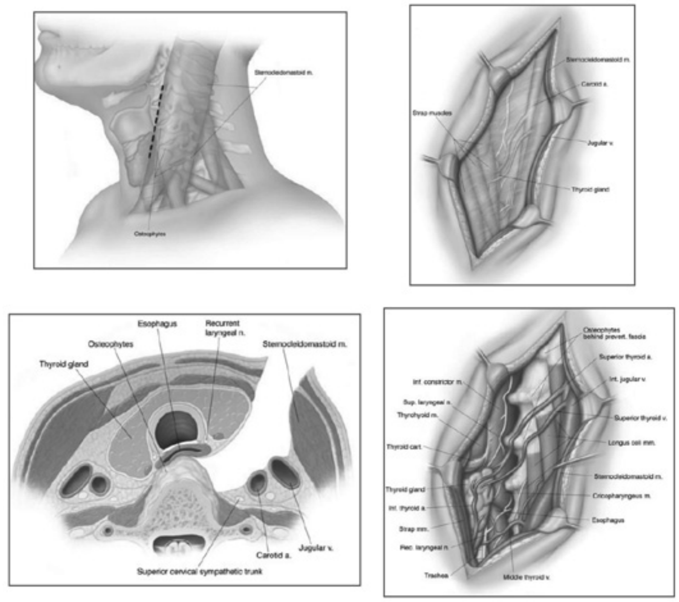
Verlaan et al. The Spine J 11:1058-67, 2011.[6]

Number of reported comorbidities

Comorbidity	N
Hypertension	20
Type 2 diabetes mellitus	18
Coronary artery disease	12
Obesity	9
Hyperlipidemia	7
Cerebrovascular accident	4
Arrhythmia	4
Arthrosis	4
Myocardial infarction	4
Chronic obstructive pulmonary disease	3
Peripheral artery disease	3
Hypervitaminosis A	3
Alcohol abusus	3
Miscellaneous	29

Verlaan et al. The Spine J 11:1058-67, 2011.[6]

4. Evaluation of dysphagia
    a. Diagnostic workup should help exclude other causes of dysphagia:
        i. Esophageal tumors
        ii. Esophageal stricture
        iii. Zenker's diverticulum
        iv. Motility disorders
        v. Plummer-Vincent's syndrome
        vi. Other mediastinal masses
    b. Routine physical otolaryngologic examination (ENT)
    c. Cervical spine imaging (x-rays, CT, MRI)
    d. Fiberoptic laryngoscopy
    e. Dynamic videofluoroscopy
5. Treatment of DISH
    a. In general, DISH only requires treatment when symptomatic
    b. Non-operative measures may be sufficient for mild/moderate dysphagia:
        i. Diet modification
        ii. NSAIDs
        iii. Corticosteroids
        iv. Antireflux drugs
        v. Prokinetics
    c. For severe dysphagia or recalcitrant moderate dysphagia, consider surgical treatment
        i. Typically involves direct resection of cervical ossifications



Carlson et al. Dysphagia 26:34-40, 20111

    d. Osteotomes, rongeurs, and/or burs can be used to approximate native anterior vertebral contour
    e. Instrumentation not usually necessary unless instability or need for concomitant neural decompression (e.g. corpectomy, ACDF)
6. Reported cases series
    a. Carlson et al.[1] (2011)
        i. Retrospective review of 9 patients with dysphagia and prominent ventral cervical osteophytes (6 had DISH)
        ii. All underwent anterolateral approach for osteophyte resection
        iii. All had significant improvement in dysphagia after surgery
        iv. 8 of 9 returned to unrestricted diet; 1 required post-operative abstinence from bulky foods

Table 1 Patient characteristics and treatment strategy for all nine patients who underwent osteophytectomy for the management of dysphagia and/or airway compromise caused by projecting anterior cervical osteophytes

	Diagnosis	Age/Sex	Symptoms (lb wt loss if known)	Surgical approach	Levels	Days in hospital	Complications
1	DISH	79/M	Dysphagia, NPR (40)	Anterolateral	C3–C7	2	None
2	DISH	76/M	Dysphagia solids only (100)	Anterolateral	C3–C7	3	None
3	DISH	71/M	Dysphagia, airway obstruction emergent tracheostomy	Anterolateral	C2–T1	10	Stroke
4	DISH	62/M	Dysphagia, positional airway obstruction	Anterolateral + trach (decan POD 6)	C2–C7	8	None
5	DISH	75/F	Dysphagia	Anterolateral	C3–C7	2	None
6	DISH	76/M	Dysphagia	Anterolateral	C3–C6	2	None
7	DJD	66/M	Dysphagia solids only	Anterolateral	C4–C7	1	None
8	DJD Trauma	32/F	Dysphagia	Anterolateral	C3–C4	4	None
9	DJD Trauma	77/M	Dysphagia	Anterolateral	C3–C5	2	None

DISH diffuse idiopathic skeletal hyperostosis; *DJD* degenerative joint disease; *NPR* nasopharyngeal reflux

Table 2 Pre- and post-surgical swallow function in all patients who underwent osteophytectomy for relief of osteophyte-associated dysphagia

Patient	Presurgical VFSS	Postoperative VFSS (POD)	Compensatory postures	Return to general diet without compensations
1	No	Yes (53)	Head turn to left	Avoids bulky food
2	No	Yes (2)	None needed	<3 months[b]
3	Yes[a]	Yes[a] (7, 21)	Chin tuck	4 weeks
4	No	Yes[a] (8)	Head turn to left	2 weeks
5	Yes	Yes[a] (1)	Chin tuck	
6	Yes[a]	Yes (2)	None needed	3 weeks
7	Yes	No	None needed	<6 weeks[b]
8	Yes	Yes (1)	None needed	<3 months[b]
9	Yes	Yes (2)	None needed	2 days

VFSS videofluoroscopic swallow study; *POD* postoperative day

[a] Aspiration

[b] Returned to general diet sometime between the VFSS and patient's return for follow-up appointment

b. Urrutia et al.[5] (2009)

   i. Retrospective review of 5 patients with dysphagia and DISH

   ii. All underwent anterolateral approach for osteophyte resection

   iii. No postoperative complications

   iv. All had complete resolution of dysphagia within 2 weeks

   v. No patient had recurrence of dysphagia or osteophytes at last follow-up (mean=5 yrs; range: 1-9 yrs)

c. Miyamoto et al.[3] (2009)

   i. Prospective study of 7 patients with dysphagia and DISH

   ii. All underwent anterolateral approach for osteophyte resection

   iii. Complete dysphagia relief within 1 month for 5; within 3 months for 2

   iv. Mean follow-up of 9 yrs (range: 6-13 yrs), all had recurrent osteophytes (~1 mm/yr)

   v. Incidence of recurrent osteophytes significantly higher in segments with maintained mobility (p=0.0013)

   vi. Authors recommend that surgeons should follow these patients post-op for prolonged period (>10 yrs)

   vii. Authors have started to add cervical fusions to simple osteophyte resections for patients >70 y/o

7. Summary

   i. DISH is common but most cases are asymptomatic

   ii. If mild to moderate dysphagia, consider non-op treatments (NSAIDs, diet modification, etc.)

   iii. If severe dysphagia or fail non-op treatments, consider surgical treatment

   iv. Surgery (osteophyte resection) has potential to provide good relief of symptoms

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Notes

Options for the Correction of Cervical Kyphosis in the Ankylosed Spine

K. Daniel Riew, MD
Mildred B. Simon Distinguished Professor of Orthopedic Surgery
Professor of Neurological Surgery
Chief, Cervical Spine Surgery Washington University Orthopedics
St. Louis, Missouri, USA

Because of the limited time (7min) for the presentation, the following syllabus is much more extensive than the presentation and meant to fill in the details that could not be covered during the lecture.

Pedicle Subtraction Osteotomy

As an alternative to the Simmons osteotomy, we have modified the technique of a pedicle subtraction osteotomy that has been described for thoracolumbar deformities for use in the cervical spine. This technique is similar to the decancellization procedure described by Tokala. Because it involves a decancellization of the vertebra and shortening of the posterior column, it leaves the anterior column intact, theoretically improving the stability of the spine.

Fixation:
If the occipital cervical joint remains mobile, it is best to leave this joint unfused. However, if the occipital cervical joint is already autofused, there are significant benefits to extending the instrumentation all the way up to the occiput. Even in the most osteoporotic patient, the external occipital protuberance has good bone density for screw purchase. The purchase at C2 is either a pedicle or a lamina screw. These are preferable to pars screws, which are more easily pulled out. We generally prefer to use C2 pedicle screws over laminar screws, as they are slightly easier to attach to rods and don't require lateral connectors. However, laminar screws are technically much easier and safer to use. In the subaxial spine, we use lateral mass screws at C3, 4 and 5. C6 screws sometimes cannot be utilized, as they can be too close to the T1 pedicle screws after the osteotomy is closed. This is especially true if one utilizes a domino to connect a cervical system to a thoracic system. In such cases, we usually put screws from T2 to T5 bilaterally. It is much easier to use a single cervical system with a larger diameter pedicle screw into the upper thoracic spine. Most systems have a 4.35 or a 4.5 diameter screw that can be utilized for upper thoracic pedicle purchase. A 3.5 mm diameter rod can be utilized to fixate the spine from the occiput all the way down to the thoracic spine, obviating the need for dominos. At the caudal end, we recommend six to eight pedicle screws in the thoracic spine below the level of the osteotomy (usually at C7). A preoperative CT evaluation of the upper thoracic spine can provide valuable information about the morphology of the upper thoracic pedicles.

It is critical to place all of the lateral mass screws, as well as the thoracic pedicle screws in as straight a line as possible so that the rods easily fall into the tulip heads of the screws without requiring complex coronal bends. This makes it much easier to drop the rods into the tulip heads after completing the osteotomy. A trial rod insertion is performed before bending the rod in the sagittal plane to make sure that it at least fits easily in the coronal plane. If this is not done, then it may be very difficult to fit the rod into the screw head after performing the osteotomy.

Osteotomy:
We first perform a complete C7 laminectomy. We use a high speed burr to cut the lamina bilaterally, just medial to the pedicles. The lamina and spinous processes then lifted up in one piece. The spinous process portion is then split in half sagittally and set aside as bone graft material. Next, the bottom half of the lamina of C6 and top half of the lamina of T1 is removed using a high speed burr. We then resect the lateral mass of C7, initially using a Leksell rongeur and saving the bone as grafting material. The entire lateral mass, including the articular facets, is completely removed along with the caudal portion of the inferior articular facet of C6 and the cranial portion of the superior articular facet of T1. The T1 pedicles must be exposed to the extent that there is no overhanging facet cranial to the pedicle. Any overhanging bone may compress the C8 root as the osteotomy is closed. This exposes the C7 and C8 nerve roots adjacent to the C7 pedicle. We then interpose a Penfield 1 and 2 to protect these nerves and use a high speed burr to remove the inside portion of the C7 pedicle. The walls of the pedicle are thinned out but left intact to protect the nerve roots. The burr is placed through the pedicle and partially into the vertebral body of C7 to begin the decancellization process. We utilize a 2 mm matchstick burr tip, which cuts more on the sides than at the tip. Once the central portion of the pedicle has been decancellized and the walls have been thinned out, these walls can be fractured into the central part of the pedicle using a small curette. During the extension osteotomy, the C7 root may migrate into the space that was vacated by the C7 pedicle resection. If there is any residual pedicle that prevents this, root injury may occur. Small curettes are then used to scoop the bone out from inside the body of C7 through the pedicles bilaterally. Next, reverse angle curettes are placed into the pedicles and the cancellous bone in the posterior superior portion of the C7 vertebral body is removed or compressed into the anterior portion of the vertebral body. This is done bilaterally. The purpose of all of this is to create a cavity in the posterior superior portion of the C7 vertebral body. Next a Woodson elevator is placed just ventral to the posterior longitudinal ligament and the dorsal cortex of the C7 vertebral body is pushed ventrally into the cavity that was created. Because patients with ankylosing spondylitis have osteoporotic bone, this is quite easy to do if enough of the C7 vertebral body has been decancellized. If the cortical wall is not easy to push

ventrally, more cancellous bone needs to be removed from within the vertebral body prior to repeating this maneuver. Hemostasis is achieved using liquefied, injectable collagen. Next, the rods are pre-bent to a desired angle of correction and fixed to the thoracic pedicle screws. The surgeon then grasps the head using the Gardner-Wells tongs and the neck is gently brought up into extension. If an adequate amount of bone has been resected at C7, little force is required to produce a controlled osteotomy. If one cannot easily extend the neck, then more bone needs to be resected from the ventral portion of C7. During the extension maneuver, the C7 and 8 roots should be examined for any signs of impingement. If an adequate amount of bone has been resected, they should remain free and mobile. Further undercutting of the C6 inferior facet or removal of any overhanging T1 superior facet may be necessary.

As the head comes up, the cervical lateral mass screws will begin to capture the pre-bent rod. Set screws are placed into the tulips of the lateral mass screws as the head is extended. At C2, if laminar screws have been utilized, a lateralizing connector will be necessary to capture the rod. All of the set screws are tightened and monitoring data is assessed to ensure that there are no changes. With a few systems, articulated rods that have an adjustable joint are available that makes the correction even easier. Alternatively, other systems have articulated and swiveling dominoes that serve a similar purpose. With either of these, both the cervical and thoracic rods are placed into the screw heads after the decancellization is completed. If occipital fixation is necessary, then a separate rod is used and dominoed onto the cervical portion around C2-3 or 3-4. After the decancellization is done, the rods are tightened into the screws but the articulation is kept loose. The neck is extended to the desired position and the articulation is locked in place. In patients who have mobile occipital cervical joints, we stop the instrumentation at C2. If the purchase is not deemed to be sufficient, we turn the patient to a prone position and expose the anterior cervical spine. We then place a long plate with screws into each hole above and below the side of the osteotomy. This is also done if while performing the osteotomy the anterior column fractures or if there has already been a fracture of C7 in the anterior column. The circumferential fixation provides a rigid and stable construct that obviates the need for a halo vest. If the patient's medical condition precludes even such a simple anterior operation, we recommend immobilizing the patient in a halo post-operatively.

Anterior-Posterior Osteotomy

If a single level is responsible for most of the deformity, a pedicle subtraction osteotomy may suffice. However, if the correction has to be at multiple levels, then we prefer doing multiple circumferential osteotomies. Most surgeons recommend a "540-degree" procedure (posterior-anterior-posterior) for deformity correction. However, we have found that the vast majority of these patients can be treated with a two-stage (anterior then posterior) procedure with similar results. The technique is possible because even with a solid posterior fusion with instrumentation, there is still some plasticity in the posterior fusion construct to allow some deformation.

Anterior Osteotomy:

The initial approach is anterior to osteotomize the anterior fusion mass. Wide exposure of the anterior cervical spine, lateral to the uncinates is necessary to perform the osteotomy. This is because the entire width of the disc space is often ossified and therefore must be drilled out. It can sometimes be surprisingly difficult to identify where the pre-fusion disc space used to be. One can use a c-arm to localize this or, as we do, use anatomical landmarks. By elevating the longus coli muscles far laterally over the costal process (the anterior roof of the foramen transversarium), we can identify the location of the uncinates. The location of the vertebral artery should have been verified on the preoperative MRI. If it is lying anterior to the costal process, a Penfield 2 can be used to bluntly dissect the longus laterally so as not to injure the artery. A Penfield 4 is then used to palpate and define the lateral margin of the uncovertebral joint. We then use a high-speed carbide 2 mm matchstick burr to take down the fusion at the level of the original disc space. In our hands, this burr has the perfect combination of aggressiveness with bone and safety with soft tissues that obviates the need for a diamond burr. If there is only a kyphotic deformity, a parallel cut must be made to prevent creating a new coronal deformity. With a concurrent coronal deformity, this osteotomy can be shaped asymmetrically to correct the deformity. The bone must be removed all the way posteriorly through the fusion mass until the posterior longitudinal ligament is visualized. Even if the posterior longitudinal ligament was resected, ventral scar tissue will protect injury to the dural sac. A greater amount of the posterior vertebral body is resected than the anterior, so that on a sagittal view, it appears to be a trapezoidal decompression. This will allow further correction posteriorly, as there will be a gap between the bone graft and the posterior endplates. To remove the fusion mass laterally, we place a Penfield 4 lateral to the uncinates to protect the vertebral artery while thinning down the uncinate. We then use a small curette to remove the remaining bone. Thorough foraminotomies must be completed at all osteotomized levels to prevent root injury as the spine is extended.

Caspar distractor pins are then placed with the tips divergent so that when the distractor is placed, it creates lordosis. Four Caspar distractor pins are then placed across the osteotomy site: two on the right side and two on the left. In addition, a vertebral body spreader can be placed into the disc space. The disc space is then gradually distracted one click at a time, using all three devices. If the posterior fusion mass is not massive, it often has some plasticity such that placing enough extension moment on the anterior spine can bend it. Slow, steady distraction causes plastic deformation of the posterior fusion mass and achieves relative extension across the osteotomy. By slowly performing this maneuver, one can often extend the disc space by 3-5 millimeters. Alternatively, start with the head supported by a folded sheet. Remove the sheet after the osteotomy such that the head is suspended in air. Then gently push the forehead down until the osteotomy is completed. The vertebral body spreader is then removed, and a structural graft is placed in the anterior half of the disc space that has been created. A structural graft, shaped with the anterior height taller than the posterior, is sized to fit snugly into the expanded osteotomy site. The ideal graft has good contact with the anterior aspect of the vertebral bodies but has some room to settle into further lordosis following the subsequent posterior osteotomy. The widest possible bone graft is then placed to distribute the forces across as wide an area as possible since the remaining endplates only have cancellous bone and are prone to graft subsidence. The graft should only occupy approximately the anterior two-thirds of the vertebral body so that there is no chance of retropulsion during the posterior operation. One should also take care to ensure that the posterior aspect of the endplates behind the graft is not touching, since one can get further extension after the dorsal osteotomy. A dynamic cervical plate, with 10-12 mm variable angle screws, which allows for translation and further lordosis, is then used to hold the graft in place. An alternative is a small buttress plate placed on the cranial side of the osteotomy. If it is placed on the caudal side, after the posterior correction, the top of the plate appears to be proud and impinging on the esophagus. Another alternative is to use two or more plates, depending upon how many levels are operated on anteriorly. A drain is placed and the anterior wound is closed.

Posterior Osteotomy:
The patient is then turned to a prone position, and the posterior osteotomies are performed. By placing the graft on the anterior portion of the disc space during the anterior operation, one can hinge off of this graft and extend the spine after removing the dorsal fusion mass. Using this technique, we can usually avoid having to perform a three-part operation with an anterior, posterior, followed by a repeat anterior operation. The only exception to this has been when we did not place a plate anterior to the graft to prevent it from extruding. When we extended the spine posteriorly, it gapped open the anterior disc space, and with the patient prone, it caused partial graft extrusion, necessitating a repeat anterior exposure to push the graft back in place. As a result of that case, we now make sure that there is a plate blocking every graft that we put in the anterior spine.

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Notes

How to Avoid and Treat Post-Traumatic Kyphosis

Jeffrey C. Wang, MD
Professor, Dept of Orthopaedic Surgery
UCLA School of Medicine
Los Angeles, CA, USA

1. Avoidance
    a. High index of suspicion for kyphotic lesions
        i. Understand fracture patterns
        ii. Frequently with post injury alignment issues
    b. Identification of posterior ligamentous/destabilizing injuries
        i. Recognition of posterior injuries
        ii. Important stabilizers of the neck
        iii. Muscle/ligament structural stability needed for maintenance of alignment
    c. Follow treatment/patient closely for signs of development of post-traumatic deformities
        i. Follow the patient carefully
        ii. Assess periodically
        iii. Pay attention to clinical alignment as well as radiographic issues
        iv. Global balance and functional assessments
    d. Support with external bracing while healing
        i. Appropriate external bracing if needed
        ii. Careful attention to compliance
    e. Surgical treatments paying particular attention to cervical alignment
        i. Avoid iatrogenic alignment issues
        ii. Avoid posterior distraction
        iii. Avoid anterior compression
        iv. Reconstruct unstable elements that can lead to progressive kyphosis
    f. Stabilize unstable spinal injuries that may progress to kyphotic alignments
        i. Understand fracture patterns and appropriate treatments
        ii. Understand biomechanics of injury
        iii. Understand biomechanics of fixation
    g. Perform appropriate surgical stabilization (anterior versus posterior)
        i. Initial appropriate surgery
        ii. Understand appropriate approaches and surgery
2. Identification
    a. Follow patient appropriately
    b. If lost to follow-up, need to warn the patient about potential kyphotic alignment
    c. Serial radiographs within appropriate post-operative period
    d. Look carefully for signs of healing or loss of alignment
3. Options for surgical management
    a. Anterior versus posterior approaches
    b. May preferentially address different types of pathology
    c. Prior surgery anteriorly
    d. Prior surgery posteriorly
    e. Airway issues, magnitude of surgery
4. Decision-making process
    a. Flexible versus rigid deformity
    b. Flexion/extension radiographs
    c. Radiographs lying down
    d. Amount of correction if flexible
    e. Other alignment issues – full length films to assess global balance
    f. Anterior versus posterior approach
        i. Releases anterior/posterior
        ii. Prior fusion requiring osteotomy
        iii. Prior fusion requiring removal of hardware to retain flexibility
    g. Alignment procedures in cervical/thoracic/lumbar spine
    h. How to gain enough proper alignment

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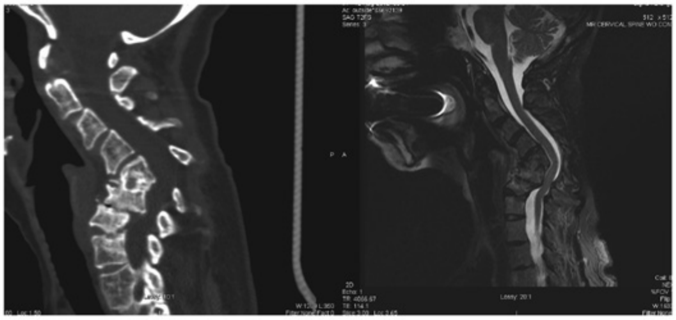
Notes

Case Presentations: Examples of Complex Cervical Reconstructions

Charles H. Crawford III, MD
Adult and Pediatric Spine Surgeon
Norton Leatherman Spine Center
Assistant Professor, Department of Orthopaedic Surgery
University of Louisville
Louisville, Kentucky, USA
chcraw01@gmail.com

Case History: A 58 year old female who works at one the local hospitals. Reports many years of increasing neck pain that has been managed conservatively to date (i.e she has no history of prior cervical spine surgery). Recently noticed more difficulty using hands with increasing numbness and weakness. She has been followed by a local neurosurgeon who has documented progressive neurologic decline (cervical myelopathy) and is considering surgical treatment. She was referred for a second opinion and potential assistance with the complex decompression and reconstruction. The patient has been diagnosed with a rare immunodeficiency syndrome due to a dominant mutation in STAT3 (Job's Syndrome or Autosomal Dominant Hyper-IgE Syndrome). She is followed by a specialist at the National Institutes of Health (NIH). A review of the medical literature and a phone conversation with her NIH physician confirmed an association between Job syndrome and destructive cervical degenerative changes that have features similar to other rheumatologic diseases, such as Rheumatoid Arthritis. Per the NIH physician, the patient has an increased risk of infection (especially post-operative respiratory infection and wound infection), but she is aware of a few other patients with Job Syndrome who have undergone successful cervical reconstruction. There are no absolute contraindications to surgery at this time.



Diagnoses:

1. Cervical Myelopathy
2. Sub-axial cervical subluxations and kyphosis
3. Cervical stenosis with anterior cord compression
4. Job's Syndrome (Autosomal Dominant Hyper-IgE Syndrome)

Concerns:

1. Poor bone quality (soft bone)
2. Increased risk of infection (pulmonary and surgical site)

Surgical Plan:

1. For discussion…

Notes

Treatment Options for Occipital/C1/C2 Instability in the Inflammatory Arthritis Patient

Todd J. Albert, MD
Richard Rothman Professor and Chair
Department of Orthopaedics
Professor of Neurosurgery
Thomas Jefferson University and Hospitals
President, The Rothman Institute
Philadelphia, PA, USA

- Inflammatory Disorders
  - Rheumatoid Arthritis (RA)
  - Ankylosing Spondylitis
  - DISH
  - OPLL / OLF
  - SLE
  - Psoriasis
  - Inflammatory Bowel Disease
  - Gout
  - CPPD
- Clinical Pathology
  - Instability
  - Joint Destruction
  - Osteoporosis (secondary to long-term steroid usage)
- Cervical Pathoanatomy (RA)
  - Occipital-Atlanto and Atlanto-Dental articulations are synovial-lined.
  - Erosive rheumatoid synovitis may attack the atlanto-axial, synovial lined bursa between C1, the odontoid and the transverse ligament (ruptures).
- Cervical Involvement
  - Atlantoaxial subluxation
  - Superior migration of the odontoid
  - Subaxial subluxation
- Atlantoaxial Instability
  - Anterior Atlantoaxial Dens Interval (AADI):
    - ◊ Normal <3.5 mm
    - ◊ >7 mm = Transverse Alar Ligament disruption and contraindication to elective surgeries
  - Space Available for the Cord SAC (= to Posterior Atlanto-Dens Interval [PADI]):
    - ◊ SAC > 13 mm = ↑ outcomes
    - ◊ No recovery if < 10 mm

    - ◊ Boden, Bohlman et al. *JBJS*, 1993.
- Basilar Invagination: Radiographic Measures
  - Ranawat's line < 13 mm
  - McRae's line
  - McGregor's line
  - Chamberlain's line
  - →NONE are perfect (<90% sensitivity and NPV): Riew, Bohlman, et al. *JBJS* 2001.
- Basilar Invagination: MRI Measure
  - Cervicomedullary Angle (CMA)→ < 135 degrees: 100% correlation with neurologic signs of cervicomedullary compression, myelopathy, or C2 nerve root pain
  - Bundschuh, Modic, et al. *AJR* 1988.
- Surgical Indications
  - SAC < 14mm
  - Clinical signs of myelopathy with demonstrable cord compression
  - Cord signal change on MRI
  - Intractable mechanical neck pain unresponsive to nonoperative treatment
  - Instability (PADI<14 mm AAI
  - Basilar invagination > than or equal to 5 mm cephalad to McGregor's line
  - CMA < 135 degrees
    Kim, Hilibrand. *JAAOS* 2005
- Surgery Goals
  - Stabilization and Fusion
  - Decompression [Direct vs Indirect]
- Role of Reduction: Mobile Deformity
  - Mobile and reduces on flex-ex views → Can be performed intraop with traction, manipulation, lateral fluoro
  - Severe Basilar Invagination: Admit preop, cervical traction with head in slight extension x 24 to 48 hrs to gradually reduce. Minimal to no benefit past 48hrs (Meijers, Cats et al. *Clin Exp Rheum* 1984)
- Mobile Deformity: Intraop Techniques of Reduction
  - Traction
  - Distraction device
    - ◊ between occiput and C1 or C2(Jian et al. *Neurosurgery* 2010)
    - ◊ between C1 and C2 (Goel et al. *JNS* 2005)
  - Allograft spacer in facet joint of C1/2 (Aryan, Ames et al. *JNS* 2008)
- Role of Reduction: Fixed Deformity
  - Fixed and severe deformity with compression that does not reduce with traction
  - → anterior decompression via transoral odontoid resection
- Role of Decompression
  - Basilar invagination: direct decompression unnecessary if cord and brainstem compression relieved with traction.
  - Stabilization of the atlantoaxial segment:
    - ◊ Causes regression of the periodontoid pannus and slow the progression of cranial settling.
    - ◊ Solid arthrodesis eliminates chronic mechanical irritation and decreases size
  - Posterior C1 or foramen magnum decompression as needed if significant compression exists after reduction.
- Occiput Anatomy: Osseous
  - Thickness of the occipital bone varies
  - Thickest in the midline at External Occipital Protuberance (EOP)
  - 11-17mm males, 10-12mm females
  - Thickness decreases radially from EOP
  - As thin as 0.3mm below Inferior Nuchal Line
    Vaccaro, *Operative Techniques: Spine Surgery*, 2010
- Occiput Anatomy: Vascular
  - Central venous sinus plexus (Torcula) below external occipital protuberance (EOP)
  - Always obtain preop CT to locate anomalous vasculature and location of transverse sinus
- Occipito-Cervical (OC) Fixation Options
  - In situ onlay bone grafting
  - Wire/cable fixation
  - Rod + wire or screw
  - Plate & screw fixation
  - PMMA+/- internal fixation
- OC Biomechanics: Screws vs Wires
  - Screws > Wire:
  - ↓# levels
  - Bicortical screws 50% stronger than unicortical
  - Unicortical = wire

-
  - Unicortical at EOP = bicortical elsewhere
    Haher, *Spine* 1999
- OC Biomechanics: Plates vs Rods
  - Rods stronger than plates (Grubb et al, *Spine*. 1997)
  - Plate problems:
    - Fixed hole-hole distance
    - Divergent Screws
    - Non-rigid connection
    - No space for bone graft
    - Nonlinear Screw Capture
    - Remove screw if change plate
    - No compress/distract
- Occipital Screw Placement
  - Risk of meninges/venous sinus injury
  - Scew lengths (mm) (Ebraheim et al, *Spine*. 1996)
    - EOP: 10 – 12
    - 20 mm lateral to EOP: < 8
    - 5 mm lateral and 20 mm caudal to EOP: < 8
  - Venous sinus penetration: do not attempt repair and place screw (patient will need antiplatelet therapy to prevent sinus thrombosis)
  - CSF leak: place screw
- Occipital Screws
  - Large Diameter, Smaller Pitch Occipital Screws
  - 4.5mm cortical screw - maximize rigid OC plate fixation (5.25mm rescue)
- OC Rod Placement/Contouring
  - Malrotation in the sagital, coronal, or rotatory planes is possible.
  - Occipitocervical angle: angle between the McGregor's line and C3 superior endplate (Phillips et al. *Spine* 1999) □ normal 44 degrees
  - Preop awake positioning of patient with lateral fluoro to establish position of comfort for fusion helpful
- OC Fusion: Clinical Outcomes (Winegar, Vaccaro, et al. *JNS* 2010.)
  - Systematic review of available studies (All Level IV) – 799 adults
  - Radiographic and clinical outcomes: fusion rate, neurological outcomes, complications
  - Screw/rod instrumentation compared to posterior wiring/rod, screw/plate, and onlay in situ bone grafting techniques.
    - lower complications($p < 0.0001$)
    - lower instrumentation failure ($p < 0.0001$)
    - improved neurological outcomes (81.58%) ($p < 0.0001$) when compared with
  - Posterior wiring and rods: highest fusion rate (95.9%) ($p = 0.0484$)
  - Screw/rod techniques also had high fusion rate (93.02%)
  - Inflammatory diseases: lowest rate of instrumentation failure (0%) and highest rate of neurological improvement (90.91%) following the use of screw/rod techniques
  - CONCLUSIONS. screw/rod constructs are associated with the most favorable outcomes in inflammatory disease requiring OC Fusion
- Atlanto-Axial Wiring & Clamps
  - Moderately flexible
  - Loosen under cyclical loading
  - Halo for better stability
    (Dickman *JNS* 1996)
    (Grob *Spine* 1992)
- Transarticular C1 - 2 Screws: Magerl
  - Stronger
  - High Fusion Rate
  - Technically Demanding
- Anomalous Vertebral Artery Groove
  - 18% incidence
  - Important to closely examine preop CT
    (Paramore. *JNS* 1996)
- Modern Magerl C1-2 Fusion: Navigation (Nagaria et al. *Spine* 2009)
  - 37 RA pts (Bilat in 33, Uni + wire in 4 for aberrant VA)
  - 97% had bony fusion.
  - No vertebral artery injuries
  - Computer Navigation used in 73%
- Harms Technique for C1-C2 Fusion
  - Posterior C1–C2 fusion with polyaxial screw and rod fixation
  - 37 patients, no neurovascular injuries, all fused
  - Original description called for C2 pedicle screws

  * Biomechanically equivalent to Magerl C1-2 transarticular screws
    (Harms, Melcher. *Spine* 2001; Melcher, Harms. *Spine* 2002)
- C1 Clinical Anatomy
  * Dissection posterior C1 ring – 12mm lateral to midline
  * Dissection superior aspect C1 ring – 8mm lateral to midline
    (Ebraheim. *Spine* 1998)
- C2 Clinical Anatomy
  * Pars: located between the superior and inferior articular processes
  * Pedicle is the region that connects pars to vertebral body
- C2 Pedicle vs Pars screw
  * Pedicle screws longer
  * Pedicle screws biomechanically stronger (Lehman, Riew et al. *Spine* 2008)
  * Pars screw: can palpate the medial wall of pars when drilling and inserting (i.e., safer)
- C2 Translaminar Screws
  * Alternative for aberrant vascular anatomy
  * Comparable biomechanical strength
  * Difficult to contour rods and can be prominent
    (Wright. *JNS* 2005)
- Posterior C2 Fixation: Clinical Outcomes (Bransford, Chapman, Bellabarba, et al. *Spine* 2011)
  * Large retrospective study at single center
  * 328 pts with 633 screws. Postop CT scan used.
  * 339 C2 pedicle screws→98.8% accurate
  * 154 C1-C2 transarticular→98.5% accurate
  * 63 C2 laminar→100% accurate
  * 77 C2 pars→94.6% accurate
  * Conclusion:
    ◊ Lower than previously reported incidence of complications associated with posterior C2 screw placement.
    ◊ Multiple techniques of posterior C2 fixation available allow for flexibility in determining ideal technique.

Notes

Treatment of Global Cervical Stenosis: When is Laminoplasty vs. a Posterior Laminectomy and Fusion Indicated

Manabu Ito, MD, PhD
Department of Advanced Medicine for Spine and Spinal Cord Disorders
Hokkaido University Graduate School of Medicine.
N15W7, Kita-ku, Sapporo, 060-8638, Japan
Phone: +81-11-706-7587
Fax: +81-11-706-6054
maito@med.hokudai.ac.jp

History of posterior decompression for global cervical stenosis

1. Miyazaki & Kirita (1968): Extensive Multisegmental Laminectomy for OPLL (Spine 1986;11:531-42)
2. Oyama & Hattori (1973): The first expansive laminoplasty called Z-plasty (Center Jpn J Orthop Traumatic Surg. 1973)
3. Hirabayashi: Unilateral open door laminoplasty (Spine 1983;693-9)

Disadvantageous of laminectomy

1. Postlaminectomy kyphosis especially in young patients
2. Delayed neurological deterioration (laminectomy membrane or scar tissue)
3. Persistent neck pain

Hopes for laminoplasty

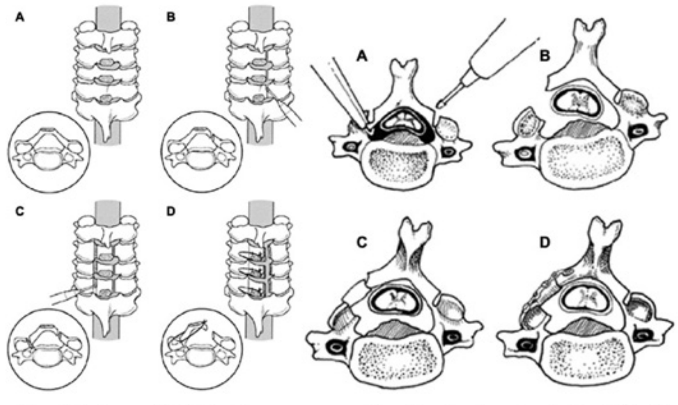
1. Adequate multilevel decompression
2. Avoid destabilization of posterior structures of spine
3. Preservation of cervical mobility
4. Reduce axial neck pain

Indications for Laminoplasty

1. Myelopathy or Radiculomylopathy due to multilevel cervical canal stenosis
   a. Sagittal canal diameter
   b. Absolute canal stenosis: 12mm or less
   c. Relative canal stenosis: from 12mm to 14mm
   d. Circumferential cord compression more than 3 disc levels
2. Pathological Indications
   a. Spondylosis
   b. Developmental canal stenosis
   c. OPLL
   d. Hemodialysis related spinal canal stenosis, etc.

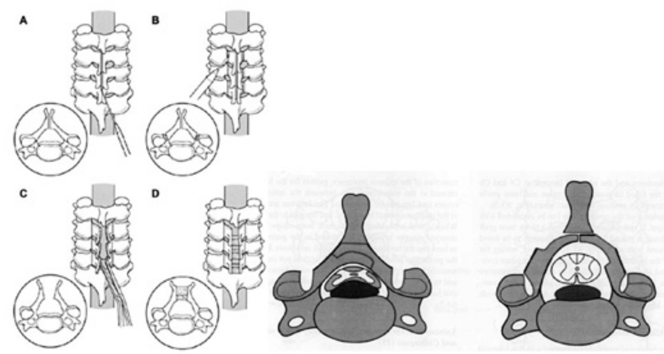
Types of laminoplasty

1. Unilateral open door laminoplasty



The Hirabayashi Method **En-bloc laminoplasty (Ito&Tsuji)**

2. Midline opening laminoplasty or French-door laminoplasty



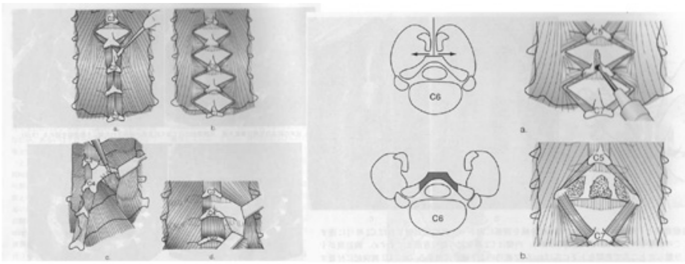
Spinous process splitting (Kurokawa Method) Opening arch laminoplasty (Tomita method)

Unsolved clinical problems related to conventional laminoplasty

1. Axial neck pain
2. Reduced cervical mobility
3. Progression of cervical kyphosis

Less invasive approach with preservation of deep extensor muscles

1. Preserve attachments of multifidus and semispinalis to spinous process
2. Skip laminectomy (posterior elements left intact at some levels)
3. Technique for muscle preserving double door laminoplasty (TEMPL)



The Shiraishi method (muscle preserving method: TEMPL)

Comparisons between different types of posterior decompression procedures

1. Improvement rate: 20 to 80% (avg.55%)
2. En-bloc laminoplasty vs. Spinous proc. splitting laminoplasty: no difference
3. Neurological recovery: laminectomy vs. laminoplasty: no difference
4. 35% of those w/ laminoplasty showed postop. worsening of c-alignment (10% kyphosis)
5. C-ROM decreases by 17 to 80% after laminoplasty.

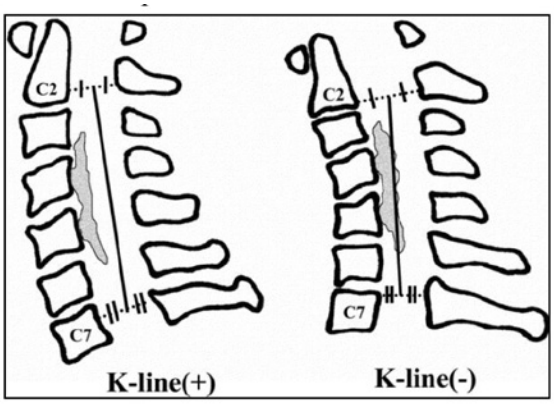
Preservation of muscle attachment

1. Muscles to C2 Spinous process:
   a. Axial pain reduction (Kato M, et al. Spine 2008.)
   b. Important for cervical alignment (Takeshita.Spine 2003.
   c. Better postop. neck ROM (Takeuchi. Eur Spine J 2008)
2. Muscles to C7 Spinous process
   a. Axial pain worse w/ C3-7 than w/ C3-6 (Hosono N. Spine 2007)
   b. Preservation of nuchal lig. at C6 & 7 prevents kyphosis. (Sakura. J Spinal Disord Tech 2008)

When to add posterior fusion with instrumentation

1. Lower neurological recovery in OPLL w/ kyphosis (Chiba et al. Spine 2006)
2. Local kyphosis more than 13 deg (Suda et al. 2003 Spine.)
3. K-line negative (kyphosis present) (Fujiyoshi,et al. Spine 2008.)

"K-line" as a Decision Making Tool for Correction& Fuison of Cervical Spine besides Posterior Decompression



C5 nerve palsy after laminoplasty

1. Incidence of postop. C5 palsy: 4.6% (Unilateral open 5.3%, French door 4.3%)
2. No relation to surgical procedures
3. No relation to disease etiologies.
4. Generally good prognosis for recovery
5. Longer recovery time in pts. w/severe neurological deficits
6. Cause unknown (Nerve root traction, Tethering effect, Spinal cord ischemia, Reperfusion injury, Segmental spinal cord disorder etc.)

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Notes

Reconstruction of the Kyphotic Spine With Pyogenic Osteomyelitis

Michael Ruf, MD
Center for Spine Surgery, Orthopedics and Traumatology, SRH Zentralklinikum Suhl, Germany
Pediatric Spine Surgery, SRH Klinikum Karlsbad-Langensteinbach, Germany

Vertebral osteomyelitis

- 2 to 4% of all bone infections
- consumptive process which may be life threatening
- jeopardizes the integrity of the spinal column
- neurologic deficits

Non-surgical Therapy

- in early stages
- antibiotic therapy according to antibiogram (biopsy, blood culture) [1,2]
- immobilization (brace, cast)
- periodical MRI examination

Indication for Surgery

- sepsis
- progression despite sufficient antibiotic therapy
- neurological impairment
- instability
- epidural abscess
- deformity / kyphosis

Kyphotis with Pyogenic Osteomyelitis

Problems to be addressed:

- Eradication of the infection
- Correction of the deformity
- Restoration of stability

Surgical Treatment of Spinal Infections

Principles:

- radical debridement with resection of all infected and necrotic disc and bony tissue
- excision or drainage of paravertebral abscesses
- irrigation to clear the spinal canal of pus and debris
- approach depending on localisation of the infection (the anterior structures are predominantly involved, the posterior elements are rarely affected [20])
- usually anterior-posterior procedure (one- or two-stage)
- local antibiotics

Deformity Correction/ Restoration of Stability

- requirements of load sharing and tension band principles
- restoration of anterior spinal column resistance
- restoration of the posterior tension band / posterior instrumentation

Restoration of Anterior Spinal Column Integrity

- bone loss due to infectious destruction and debridement
- bridging of the surgical defect with autologous bone graft is limited
- stable reconstruction with titanium mesh cages (filled with autologous cancellous bone and local antibiotics)
- correction of kyphosis by restoration of the original length of the anterior column and posterior compression instrumentation

Deformity Correction in Fixed Postinfectious Kyphosis

According to general principles of kyphosis correction:

- usually posterior-anterior-posterior with osteotomies, spacer and instrumentation in the cervical spine
- posterior-anterior-posterior or posterior only with apical vertebrectomy in the thoracic and lumbar spine

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Notes

Stabilization of Cervical Spine Following Tumorous Destruction

Praveen V. Mummaneni, MD
Professor and Vice-Chairman: UCSF Dept. of Neurosurgery
San Francisco, CA, USA

1. Introduction –
    a. Review common types of destructive bony tumors
        i. Primary bone tumor (i.e. Chordoma)
        ii. Metastatic bone tumor (i.e. breast cancer)
2. Discuss anatomy of tumorous destruction of the spine (including vertebral artery and cord/nerve root involvement)
3. Review indications for surgical stabilization
    a. Discuss biomechanics of stabilization
    b. Discuss instability and need for stabilization
    c. Highlight tumor staging and palliation vs curative surgery planning
4. Highlight anterior approaches and techniques for reconstruction
    a. Corpectomy
    b. En bloc resection
    c. Complication avoidance
    d. Anterior spinal instrumentation placement
5. Highlight posterior and combined approaches and techniques for reconstruction
    a. Laminectomy for tumor removal
    b. Facetectomy for tumor removal
    c. Osteotomies
    d. Vertebral column resection
    e. Posterior spinal instrumentation placement
6. Complication Avoidance and Management Strategies and Advice
    a. Preop Embolization
    b. CSF leak management
    c. Cord/nerve injury avoidance and management

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Notes

Debate How is Cervical Posterior or Anterior Approach in CSM – Neutral or Lorodtic Spine

Todd J. Albert, MD
Richard Rothman Professor and Chair
Department of Orthopaedics
Professor of Neurosurgery
Thomas Jefferson University and Hospitals
President, The Rothman Institute
Philadelphia, Pennsylvania, USA

A: The Disease

CSM is a multi-factorial disorder. There is not one clear cut etiology and the pathologic and radiologic findings typically include some portion of developmental or congenital stenosis, as well as stenotic pathologic lesions, anteriorly/ posteriorly whether it be from an osteo distal pathology or ligamentum flavum hypertrophy, as well as arterial or venous circulatory problems and dynamic flexion and extension compression to the cord occurs.

The natural history of this disorder has been well characterized over the past 50 to 60 years beginning with Clark and Robinson, and essentially has been described as a natural history progressing to severe disability in a large percentage of patients.

Given the poor natural history, surgical treatment is often indicated. Treatment goals are typically the goals of most spine surgery including decompression, stability in alignment, both maintenance and restoration, pain relief and minimization of complications with maximum durability of an operation.

B: Approach

Anterior or posterior decompression & stabilization are both successful in the right patients with CSM. For pathology involving less than three segments a kyphotic spine and typically disc herniations or anterior spondylosis, an anterior procedure is best performed. Posterior procedures are best indicated in multi-level segmental disease greater than three segments, a lordotic spine and one in which OPLL or OLIF is present. Debate rages regarding optimal approach in a straight spine. There are no level one or two studies to guide treatment. There are many level 3 studies, but they are flawed when comparing # levels addressed anteriorly and posteriorly with multiple techniques used.

Classic problems of anterior and posterior approaches are noted. Pseudoarthrosis, graft related complications, and ability to treat multi-level disease is a problem anteriorly. Laminoplasty is fraught with axial neck pain, loss of sagittal alignment, and the debate whether it is truly a motion preserving procedure. There has been a high report of C5 nerve palsy as well. Laminectomy and fusion is also associated with a loss of motion, increased complications with adjacent segment disease, graft related and cost.

When comparing anterior versus posterior surgery, a systematic review was performed by Liu in EUROPEAN SPINE JOURNAL 2011. Ten articles were analyzed and the neurologic recovery, the final JOA scores recovery rate in the short and early mid-term favor the anterior group. There were more complications noted in the anterior group in the short mid-term, however, in the long-term follow up of neurologic recovery rate and complications there is no difference in the anterior versus posterior groups. For OPLL occupying ratios greater than 60% favor an anterior approach.

- In Spine, Hirai et al reported midterm 5y f/u radiographic and clinical outcomes in an age matched Clinical Prospective Study in which pts with CSM were assigned to either ADF (even yrs=ADF. ('98, '00, '02) or Laminoplasty (Odd yrs='99, '01, '03
- Mean JOA scores and recovery rate were superior in ADF ($p<0.05$)
- C2-7 Lordotic Angle was Maintained in ADF, not in LAMP ($p<0.05$)
- Residual Ant Compression of Spinal Cord (ACS) occurred in 16/47 LAMP pts
  - These 16 had significantly lower JOA and recovery rates than ADF pts.
  - ROM: no difference b/tw ACF vs LAMP postop
- LAMP was safer / less invasive (complications / physical status)

CONCLUSIONS:

- ADF > LAMP for neurologic recovery when pts are not selectively screened out for sagittal alignment!!!!
- Poorer outcomes are due to residual anterior compression
- Baseline and 5y f/u radiographic data showed loss of lordosis with laminoplasty and equivalent ROM to ACF.
- LAMP pts with residual anterior cord compression (LAMP +) still had 10 degrees overall C2-7 lordosis but had significantly worse JOA & RR than LAMP (-) pts without residual anterior cord compression.

Classically a kyphotic/straight sagittal alignment favors an anterior procedure. However, laminectomy and fusion can be performed in some patients with a straight or even kyphotic spine with instability and allows an adequate decompression, immobilization, kyphosis correction with an intra-operative reduction after the fixation points have been placed and prior to rod connection, and limits mobility, but does add some morbidity.

Tashjian just recently published an article challenging whether a kyphotic or straight sagittal alignment requires an anterior procedure. He looked at the pre-op cervical sagittal alignment, as well as post operative MRI scans, and analyzed the amount of spinal cord drift. He found that patients with pre-op kyphosis or straight spines can still have significant spinal cord drift away from the anterior pathology with significant JOA score improvements and recovery rates and suggest that posterior decompression and stabilization is a viable option in even straight or non-lordotic spines.

Cervical laminectomy and fusion, although lacking level 1 and 2 studies, has some literature predominantly retrospective case series (mostly non-comparative) with mid-term follow up that demonstrated good results with this procedure with an average nurick grade improvement of typically one to two, as well as a 70-80% success rate. Complications are typically infection-related and some implant-related. There is a low incidence of axial neck pain. One study by Heller as noted is an outlier of this group with a significantly higher complication rate noted. This was reviewed in Ratliff and Cooper's meta-analysis and they concluded that given the small sample size of only 13 patients in both a comparative laminoplasty and laminectomy and fusion cohort that there was significant decreased statistical validity of the study.

Heller in his cohort analysis compared laminoplasty versus laminectomy and fusion. He essentially found that laminoplasty was a better procedure and recommended the laminoplasty in lordotic spines. Interestingly, the pre-operative sagittal alignment was significantly different in the two groups and as well as the Laminoplasty group did not maintain the pre-op sagittal alignment, whereas the laminectomy and fusion although starting in a kyphotic spine maintained their pre-operative alignment.

Ratliff and Cooper did a critical meta-analysis of cervical laminoplasty of 71 studies over 2,500 patients that reported JOA's recovery scores. They found that the main neurologic recovery rate was acceptable at 55%, however, had a significant amount of worsening alignment, 35% mean, 20-50% in general, and significant amount of patients that were induced into a kyphotic alignment. As well as they found it to be not truly motion sparing with 50% decreased range of motion, a significant amount of post operative axial neck pain, C5 nerve root palsy of 8%, and a significant amount of re-stenosis at both same segment and adjacent segment disease. The conclusion was that laminectomy and fusion is perhaps the period of laminoplasty.

Ratliff and Cooper recommended laminectomy and fusion at least as good of outcomes as compared to laminoplasty.

Matts, et al in the Journal of Neurosurgery Spine 2009, performed a systematic review of cervical Laminoplasty. Metdine and Cochran revealed 46 articles with no Class I or II evidence suggesting that Laminoplasty was superior to other techniques. There were two Level 2 studies and the rest were Level 3 or below studies. Since the 2004 Ratliff meta-analysis only six Level 3 studies have been performed. No additional comparative studies with laminectomy and fusion were noted and there was no significant difference in the overall Ratliff meta-analysis findings. They did report a better JOA neurologic recovery. In summary, no additional findings really can be supported for Laminoplasty compared to cervical laminectomy and fusion.

Cervical laminectomy and fusion accomplishes a good neurologic recovery in the 70% range with a much lower worsening of the cervical alignment and post operative neck pain. C5 root palsy, although occurring typically can occur at a lower rate than Laminoplasty. Symptomatic junctional disease can occur and hardware-related complications, pseudoarthrosis and CSF leak do occur as well.

What about Level 1 studies. Just recently the first prospective randomized trial comparing laminoplasty versus laminectomy and fusion for multi-level myelopathy was published by Manzano, et al in Neurosurgery in August 2011. Unfortunately, the sample sizes are extremely small with only 7 and 9 in the laminectomy and fusion versus laminoplasty groups. The neurologic recovery is measured by nurick and JOA scores were similar in each group. The range of motion did favor the Laminoplasty group and the canal area was significantly greater in the laminectomy and fusion group. Unfortunately, the sample sizes are too small to make meaningful conclusions.

A comparative study focusing on cost and outcomes was published by Hismith, et al in the Journal of Neurosurgery Spine 2011. The retrospective match study of 25 to 30 patients in each group reported similar neurologic recovery rates. There is increased neck pain in the Laminoplasty group, excellent odom outcomes were obtained in both groups. The costs were noted to be almost three times higher in the laminectomy and fusion group for the implants. There were not related to the use of polyaxial screws. The sagittal alignment they found both groups to lose 3 to 4 degrees. Of note, the Laminoplasty group selectively was patients with more lordosis than the laminectomy and fusion patients for which some patients were kyphotic or straight spine. Complications were similar in each group so long as the laminectomy and fusion did not cross the cervicothoracic junction. In summary, cervical laminectomy and fusion was found to have increased cost, decreased neck pain, and possible expanded indications in kyphotic patients. Whereas, there was no difference in neurologic improvements or complications if limited to the cervical spine.

C: Summary / Conclusion

In summary, a single approach is unlikely to solve a complex disorder like cervical spondylotic myelopathy. Sagittal alignment is one of the most important factors in choosing the correct surgical approach. Some patients are unable to tolerate an anterior procedure and perhaps Laminoplasty is not best fitted for these patients and a laminectomy and fusion might be tolerated as well as allow decompression.

In conclusion, high quality comparative studies are lacking comparing laminoplasty to CLF. Minimal to no support for

Laminoplasty over laminectomy and fusion exists in straighter kyphotic spine alignment. Laminectomy and fusion appears to in general achieve better radiographic decompression, though neurologic recovery rates are similar. Laminectomy and fusion can eliminate dynamic cord compression in same segment re-stenosis better than Laminoplasty. It can be effective in kyphotic patients if appropriate intra-operative reduction techniques are used. Laminectomy and fusion is associated with decreased post operative axial neck pain. Although costs are higher, complication rates and re-operation rates are similar.

D: BOTTOM LINE: THE SURGEON MUST BE VERSATILE AND SKILLED ENOUGH TO PICK THE RIGHT OPERATION FOR THE RIGHT PATIENT.

Notes

How is Cervical Stenosis Treated Globally: Anterior vs. Posterior Treatment of Cervical Myelopathy

Christopher I. Shaffrey, MD
University of Virginia Medical Center
Charlottesville, VA, USA

Surgical management of cervical spondylotic myelopathy (CSM) has been shown in a number of studies to achieve significant improvements in functional status compared with nonsurgically managed patients. Considerable controversy exists in the medical literature over which surgical approach yields the best outcome, the fewest complications and the longest durability of results. Surgical options include anterior procedures including anterior cervical discectomy and fusion (ACDF) or multilevel corpectomy (CORP) and posterior procedures consisting of laminectomy (LAM), laminoplasty (LP) and laminectomy and fusion (LF). Most of the medical literature consists of relatively small retrospective series comparing the different surgical treatment options. There are almost certainly small subsets of patients with cervical myelopathy with profound neurological deficits, kyphotic alignment, multilevel involvement or other factors that would preferentially benefit by a particular approach. Despite the clear recognition for over twenty years that an appropriately powered, controlled trial is needed to best define optimal surgical management decisions are based on lower levels of evidence (1).

Cunningham and colleagues performed a systematic review of retrospective cohort studies in order to determine which surgical treatment is the most effective in patients with cervical spondylotic myelopathy: anterior cervical discectomy and fusion (ACDF), CORP, LP, or LF to prevent progression and aid in recovery of myelopathy and obtain the best clinical outcome specifically evaluating: range of motion of the neck, axial neck pain, sagittal alignment, and operative complications (2). Although 591 abstracts were screened, only 11 studies met the criteria for selection for the review. Four studies compared multilevel CORP versus LP, one study compared LF with LP, and 2 studies compared ACDF with LP (2). Certain patients were excluded from direct comparison based upon factors such as diameter of spinal canal, curvature of spine, and number of levels to be decompressed (3,4,5). It was concluded that each of the approaches yielded similar neurological recovery rates. LP had a significant incidence of neck pain compared with multilevel CORP. ACDFs increase the rate of adjacent secondary spondylosis compared with

LP. Multilevel CORP and LF had significantly higher rates of graft, instrumentation, and approach related complications. Multilevel CORP and LF have a significant decrease in neck range of motion compared with LP (2). It was noted in the discussion that LAM and LP were typically avoided in patients with kyphotic or neutral alignment. One- or 2-level involvement was often approached anteriorly, while 3- or more level involvement is addressed posteriorly. Location of disease involvement may also influence the approach, with retrodiscal pathology removed with ACDFs, retrobody pathology with CORP (2,6). Similar patient selection preferences were noted in the AOSpine North America Cervical Spondylotic Myelopathy Study (7).

Zhu and associates also recently completed a systemic review and meta-analysis comparing the clinical outcomes, complications, and surgical trauma between anterior and posterior approaches for the treatment of multilevel cervical spondylotic myelopathy (8). A total of eight studies were included in the metaanalysis but none of them were randomized controlled trials. For the five studies that used the JOA score as a method of functional assessment, it was found that the postoperative JOA score was significantly higher in the anterior surgery group compared with the posterior surgery group ($P < 0.05$) (8). The postoperative complication rate was significant higher in the anterior surgery group compared with the posterior surgery group ($P < 0.05$) (8). Blood loss and operation time were significantly higher in the anterior subtotal corpectomy group compared with the posterior surgery laminectomy/laminoplasty group ($P < 0.05$) (8).

Hirai and colleagues performed a prospective, comparative, single-institute trial of two surgical procedures (ACDF, LP) for the treatment of CSM (9). Eighty-six patients (ACDF n = 39; LP n = 47) could be followed for more than 5 years (follow-up rate 91.5%). Demographics were similar between the two groups. The mean JOA score and recovery rate in the ACDF group were superior to those in the LP group from 2-year follow-up data ($P < 0.05$) (9). The patients treated with ACDF required significantly longer operative time (211vs. 149 minutes), and had more blood loss (340 vs. 188 mL) and longer duration of neck collar wear (9.6 vs. 3.8 weeks) than the patients treated with LP (9).

Selection of the surgical approach for the treatment of multilevel CSM remains controversial because of the heterogeneity of the patients treated. Ghogawala and associates performed a study assessing eligibility for randomization to surgical approaches in the treatment of CSM. In the study, the authors sent 20 images associated with actual cases to 239 surgeons and asked the surgeons to provide demographic information, their preferred surgical approach, and eligibility for randomization for 10 cases. Of the 20 cases, only 12 were considered to be potentially eligible for randomization (10).

Advantages of ACDF or CORP include ability to directly decompress offending ventral pathology, restore cervical lordosis, and potentially better address axial neck pain. Multilevel ACDF is preferred in certain situations over CORP where the pathology is confined to the level of the disc spaces. Anterior approaches are usually the procedure of choice for case of CSM involving one or two spinal segments, those with kyphotic spinal alignment and those with substantial axial neck pain.

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Notes

Concurrent Morning Sesssion 2:
A Worldwide Viewpoint on the Treatment of Congenital Scoliosis

Moderators:

Noriaki Kawakami, MD, DMSc & Michael J. McMaster, MD, Dsc, FRCS

Faculty:

John P. Dormans, MD; Jean Dubousset, MD; John B. Emans, MD; Frances A. Farley, MD; Daniel J. Hedequist, MD; Ilkka J. Helenius, MD, PhD; Lori A. Karol, MD; Noriaki Kawakami, MD, DMSc; Steven M. Mardjetko, MD, FAAP; Richard E. McCarthy, MD; Michael J. McMaster, MD, DSc, FRCS; B. Stephens Richards, III, MD; Daniel Sucato, MD, MS; Reinhard D. Zeller, MD, FRCSC

Identification of Abnormalities Associated with Congenital Deformity of the Spine: Intra-Spinal, Renal and Cardiac

Lori A. Karol, MD
Texas Scottish Rite Hospital for Children
Dallas, Texas, USA

1. Embryology
    a. Neurulation, neural tube closure, and vertebral segmentation occur at 6 wks of gestational age
    b. Up to 61% of infants with congenital vertebral malformation will have another congenital abnormality of another organ system
    c. VATER
        i. vertebral anomalies, imperforate anus, tracheoesophageal fistula, and renal anomalies
    d. VACTERL
        i. VATER with cardiac and limb anomalies
    e. Vertebral abnormalities commonly associated with other rare syndromes
2. Associated anatomic abnormalities
    a. Renal abnormalities
        i. 12 - 20%
        ii. Range from asymptomatic single kidney to obstructive nephropathy
        iii. Renal ultrasound indicated in young infants
        iv. May substitute MRI when available (if evaluating spinal cord)
        v. 1/3 of infants with congenital scoliosis and renal involvement require urologic treatment
    b. Cardiac congenital defects
        i. 14 - 18%
        ii. Usually identified by pediatrician as murmur
        iii. Echocardiogram preoperatively
        iv. Most common mitral valve prolapsed or VSD
        v. Tetralogy of Fallot 3.3%, ASD, , PDA
    c. Sprengels deformity
    d. Auditory
        i. Most common if malformation in cervical region (Klippel Feil)
    e. Gastrointestinal associations
        i. Imperforate anus
        ii. Tracheoesophageal fistulae
        iii. Omphalocoele
    f. Upper limb malformations
        i. Radial clubhand
        ii. Thumb hypoplasia
    g. Lower limb abnormalities
        i. Higher prevalence of clubfoot and developmental dysplasia of the hip
    h. Intracanal anomalies
        i. Up to 24 - 43% neural axis abnormalities
            1. McMaster study of 251 patients found 18% cord abnormalities
            2. Mixed or segmentation defects most common
            3. Diastematomyelia, Chiari, syringomyelia, and tethered cord
            4. Most likely with thoracic congenital malformations
            5. Hemivertebrae associated with 15% intracanal abnormalities
            6. Spinal cord may be smaller in diameter than normal
            7. Usually clinically silent
                a. Could present with foot abnormalities
                b. Bowel/bladder symptoms
                c. Hemiatrophy
                d. Reflex findings
            8. Up to ½ of patients with cord pathology on MRI undergo neurosurgical procedures, many of these were clinically silent

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Notes

International Classification Systems of Congenital Scoliosis: Which Ones are Effective

Michael J. McMaster MD, DSc, FRCS
Scottish National Spine Deformity Centre Edinburgh
Edinburgh, UK

Congenital scoliosis is a lateral curvature of the spine due to the presence of developmental vertebral anomalies which produce a localized imbalance in the lateral longitudinal growth of the spine.

These vertebral anomalies are present at birth, but the scoliosis may not become obvious until later childhood when the diagnosis is made radiographically. Some patients present with small curves which do not progress whereas others progress rapidly to become a severe deformity at an early age.

.The classification of congenital scoliosis is based on

- The embryological maldevelopment of the spine and the type of vertebral anomaly causing the scoliosis.
- Site at which they occur

Objective to identify those types of curves which require early prophylactic treatment

The first good classification was by Winter et al (1968). This was later enlarged by McMaster and Ohtsuka (1982). These classifications were based on plain spinal X-rays. More recently Nakajima and Kawakami (2007) have used 3D CT to identify anomalies of the posterior elements.

There are 3 groups of vertebral anomalies which can produce a scoliosis

- First, those due to a unilateral defect of vertebral formation – the most common of which is a hemivertebra.
- Secondly, those due to a unilateral defect of vertebral segmentation of two or more vertebrae
- Finally, a third group which can not be classified because they have a complex mixture of anomalies.
- A wedged vertebra and a block vertebra do not cause a clinically significant scoliosis by themselves

A HEMIVERTEBRA is the most common cause of a congenital scoliosis but the severity of the deformity varies greatly, and there is debate as to the necessity and timing of treatment.

The potential for a hemivertebra to cause a significant scoliosis depends on 3 factors.

First, and most importantly, the pathological anatomy and relationship of the hemivertebra to the adjacent vertebrae in the spine. The hemivertebra may be fully segmented, which is most common, semisegmented or incarcerated which is least common.

Secondly, the site of the hemivertebra is important, especially those occurring at the lumbosacral junction.

Thirdly, the number of hemivertebrae – one or two hemivertebrae and are they on the same side or are they opposing?

A fully segmented hemivertebra can occur anywhere in the spine.

The prognosis for a scoliosis due to a *single fully segmented hemivertebra* can be difficult to predict and requires careful monitoring. The majority of curves usually progress relatively slowly at one or two degrees per year.

A *lumbosacral hemivertebra* is the most pernicious and deforming type of hemivertebra. Here it causes an oblique take-off of the lumbar spine from the sacrum and the patient lists to one side. This requires early surgical treatment.

Two unilateral hemivertebrae are less common but have a much worse prognosis. These curves usually progress at 3 to 4 degrees per year and the majority will exceed 50 degrees by the age of 10 years and requires early prophylactic surgical treatment. By skeletal maturity, the majority will exceed 70 degrees.

Two opposing hemivertebrae have a more variable prognosis depending on the site and types of hemivertebrae.

If the hemivertebrae are close together in the same region, the spine remains balanced and there is only a minimal cosmetic deformity.

If, however, the hemivertebrae are widely separated in different regions, the spine is often unbalanced which is much more deforming. May require surgical treatment.

Not all hemivertebrae are fully segmented. They may be semi segmented or incarcerated.

A semi-segmented hemivertebra is synostosed to the neighbouring vertebra and usually occurs in the lumbar region. The resulting scoliosis progresses only very slowly resulting in a mild deformity which may not require treatment.

An incarcerated hemivertebra is a small ovoid piece of bone lying in a niche in the spine which remains straight. The spine remains straight and no treatment is required.

Let us now look at Defects of Segmentation

A UNILATERAL UNSEGMENTED BAR is due to a unilateral failure of segmentation of two or more vertebrae.

This may occur anywhere in the spine – affecting a mean 3 vertebrae - and no one region is more commonly affected than the other. Without treatment the majority of patients have a bad prognosis. Mean rate of curve progression 5° per year with the scoliosis exceeding 50° by the age of 10 years. This requires early prophylactic surgical treatment.

There is also a smaller less well recognised group of patients who have an even worse prognosis. These patients have not only a UNILATERAL UNSEGMENTED BAR, BUT ALSO ONE OR MORE HEMIVERTEBRAE ON THE CONTRALATERAL SIDE OF THE SPINE AT THE SAME LEVEL.

These anomalies occur in all regions of the spine

This results in the most severe and rapidly progressive of all types of congenital scoliosis. Mean rate of curve progression 6-7° per year before 10 years. Majority will exceed 50° by age 2 years. Requires very early prophylactic surgical treatment.

There is severe vertebral rotation with constriction of the rib cage often associated with congenital rib fusions. This occurs at an early age and will impair lung growth and development leading to a thoracic insufficiency syndrome. This requires early prophylactic surgical treatment.

Untreated the majority will have a very severe spinal deformity.

The key to successful treatment depends on 3 principles

- Early diagnosis and classification of the congenital scoliosis
- The ability to anticipate what is likely to happen based on the classification
- The application of prophylactic surgical treatment to balance the growth of the spine.

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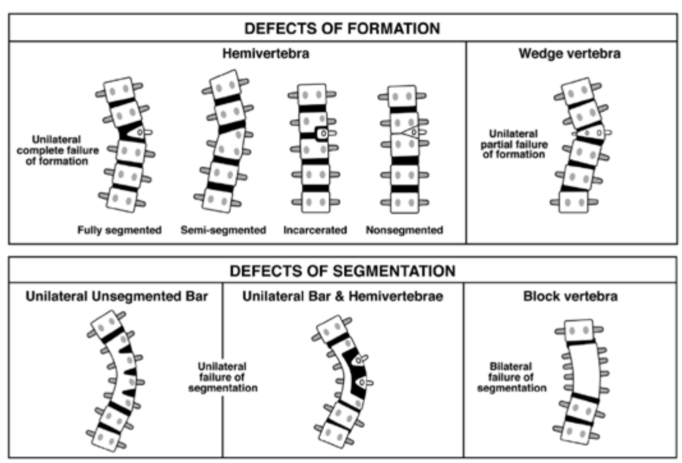
CONGENITAL SCOLIOSIS



Notes

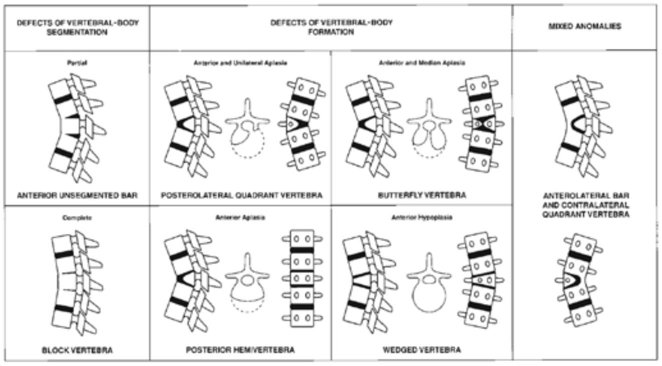
Classification and Treatment of Dorsal Hemi-Vertebrae Presenting with Neurologic Symptoms

Daniel J. Sucato, MD, MS
Texas Scottish Rite Hospital
Professor, Department of Orthopaedic Surgery
University of Texas at Southwestern Medical Center
Dallas, Texas, USA

Congenital Scoliosis

- Characterized by
  - * Abnormal vertebra
    - ◊ Failure of formation- (hemivertebra)
    - ◊ Failure of segmentation - (bars, block vertebra)
    - ◊ Mixed pattern of formation and segmentation defects
  - * McMaster and Singh- JBJS, 1999, Expansion of classification of Winter et al JBJS 1968
    - ◊ Description of congenital malformations and kyphotic deformity
      - » Four types (expansion of original Winter et al classification)
        - Type I- Anterior failure of vertebral body formation
          - * Posterolateral quadrant vertebra
          - * Posterior hemivertebra
          - * Butterfly vertebra
          - * Anterior or anterolateral wedged vertebra
        - Type II-Anterior failure of vertebral body segmentation
          - * Anterior unsegmented bar
          - * Anterolateral unsegemented bar
        - Type III- Mixed anomalites
          - * Anterolateral unsegemented bar with contralateral posterolateral quadrant vertebra
        - Type IV- Unclassified
      - » Location of anomalies
        - Most common level- between T10 and L1
      - » Severity of kyphosis not dependent on location of abnormalities
      - » Progression
        - Most rapid during adolescent growth spurt
        - Stopped at skeletal maturity
        - Greatest for Type III then Type I
        - Variable for type II

- Neurologic deterioration can occur to due progression and compression of the spinal cord



- Specific Progression of Congenital Scoliosis (with some kyphosis) based on Types of Deformity (McMaster and Singh,)
  - * Posterolateral Quadrant Vertebra N=34
    - ◊ Presentation <10 years (N=19).
      - » Initial Kyphosis 42 deg with 2.5 degree /yr ,10 yrs of age= 9 had surgery
      - » Other 10 patients not treated by 10 yrs and kyphosis was 51 deg (21-92)
    - ◊ Presentation > 10 years
      - » No treatment and mean progression over 3 yrs was 5°/ year (N=10)
      - » Fusion at 12.7 yrs- Mean kyphosis 81° (N=10)-
        - 2 patients had spastic paraparesis (111 and 60°)
      - » Presented at skeletal maturity with mean kyphosis of 62° (N=10)
        - 1 had spastic paraparesis
      - » Adjacent posterolateral quadrant vertebrae N=5
        - Mean kyphosis 53°
          - * 1 treated with fusion at 1 yr
          - * 3 Patients observed- with progression of 5°/ yr
            - ◊ 1 became paraparetic
            - ◊ 2 patients- fusion at 68° and 78°
          - * 1 patient first presentation at 17 yrs with 127° kyphosis and spastic paraparesis who had decompression and fusion but no improvement
- Anterior and Anterolateral Wedged Vertebrae
  - * Single Wedged vertebra- 2 patients (33 and 43° kyphosis)
    - ◊ Two adjacent anterolateral wedged vertebrae- 4 patients (85 to 99°)
- Measured coronal Cobb deformity of isolated curves but overall reasonable coronal balance
  - * Sucato et al, SRS 2011
    - ◊ Preoperative Main curves 50-57° depending on type of congenital curve
    - ◊ Coronal balance and coronal trunk shift: 1.3 to 2.0 cm.
    - ◊ Coronal and Sagittal plane
      - » Overall positive sagittal balance that does not improve with surgery
      - » Clinically did not seem to be significant

	Preop	Postop	5 Years	Final
Sagittal Balance	3.3 cm	3.0 cm	2.8 cm	2.8 cm
Coronal Balance	1.7 cm	1.7 cm	1.9 cm	1.8 cm

- Clinical evaluation
  - * Careful assessment of the deformity
  - * Look for sagittal component of the deformity
  - * Careful neurologic examination
- Radiographic Imaging
  - * Any congenital scoliosis requires careful assessment of the lateral xray for kyphosis
    - ◊ Sagittal plane deformity is the one that can result in significant problems (neurologic)
  - * MRI-
    - ◊ Neural axis abnormalities-
    - ◊ Cord impingement with kyphosis
      - » Can lead to paraparesis
- Surgical Treatment
  - * Indications focusing on the sagittal plane in congenital scoliosis
    - ◊ Young patient with kyphosis greater than 45 degrees
      - » Posterior fusion to allow continued anterior growth
      - » Growing rods to allow greatest spine and trunk growth
        - May need halo-gravity traction prior to growing rod placement
    - ◊ Older patients
      - » Posterior only fusion and instrumentation with posterior Ponte osteotomies

- Relatively flexible spine – based on bolster films
- Younger age may take advantage of the continued anterior growth

» Anterior release with rib strut graft/Posterior instrumented fusion

» Vertebral column resection

- Challenging with increased risk for neurologic deficit

* Indication and outcomes for fusion only (McMaster et al, Spine 2001)

◊ Prior to age 5 and <50 degrees- posterior alone

◊ Posterior arthrodesis not indicated for

» Children >5 years,

» Curves >60 degrees

◊ Posterior resection of congenital kyphosis

» More dangerous neurologically

» Indications:

- Severe deformity
- When anterior-posterior approaches are not indicated

» Technique

- Fixation proximal and distal
- Posterior laminectomy, Rib resections at apex
- Ligate and tie-off thoracic roots
- Resect anterior column
  * Begin on anterior-most body
  * Most difficult (and dangerous) is the posterior wall of the vertebral body (floor of the canal)
  * NEED TWO temporary rods near the completion of the resection to avoid correct stretch

» Results

- Overall good results however complication rate may be high
  * Neurologic deficits initially between 3 and 40%

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Notes

Congenital Abnormalities of the Cervical Spine: Treatment of Basilar Impression, Occipital Synotosis and Odontoio Dysplasia: A Global Perspective

Jean Dubousset, MD
Paris, France

Automatic reactions: Contents/ Container- Stenosis/Freedom-Stability/instability, Static/ dynamic ,- Time/Space

Diagnostic: Clinical, neurological , imaging , Neurophysiology

Six typical Indications:

1. Pure "Orthopedic problem" congenital torticollis(expel hemi atlas)
2. Prevention of acute instability(cong pseudo odontoid without neuro)
3. Combined Neuro& Orthop treatment (Cong Pseud. odontoid + neuro signs , stenosis + instability)
4. Neuro- Orthop treatment prevention of late or delayed neuro signs(Chiari malf + Syrinx + scoliosis) Children, Teen Age, Adult)
5. Iatrogenic instability post neurosurgical decompression
6. Limits of Indications: -Mild deformity without compression, stenosis or instability
   a. Considerable deformity without neuro signs , stenosis, or instability

Conclusion: Congenital abnormalities of the Cranio-cervical junction

Always the treatment must be understood & realized globally

But be careful, in Medicine everything is relative al the way of the life

Notes

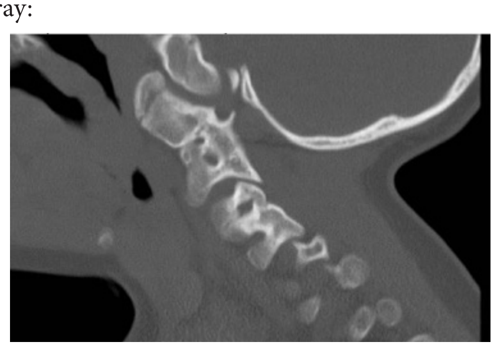
Pediatric Congenital Cervical Spine Cases for Discussion

John B. Emans, MD
Children's Hospital, Harvard Medical School
Boston, MA 02115
john.emans@childrens.harvard.edu

1. Case 1: Hypotonia and Congenital Cervical Kyphosis:
    a. 10 mo old with hypotonia since premature birth:

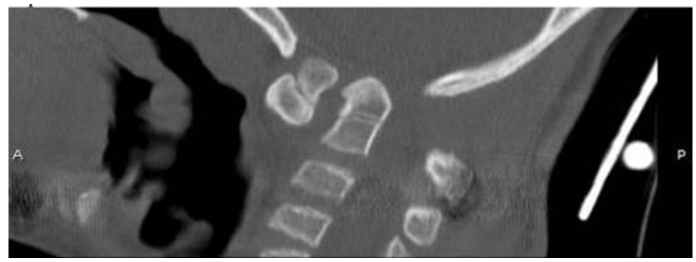
    b. Treatment:
        i. Extension collar with resolution of C3 and C4 kyphosis, wedging
        ii. C2-3 fusion eventually needed for instability
    c. Teaching points:
        i. Infant developmental deformity may mimic congenital deformity with different prognosis and treatment options

2. **Case 2: Progressive Congenital Occipito-Cervical Extension Deformity with Klippel Feil and VACTERL:**
    a. 4 y.o. with VACTERL and progressive functionally troublesome extension deformity. Maximum flexion xray:



    b. Treatment:
        i. Halo gravity traction, posterior instrumentation and fusion
    c. Complication:
        i. Failed emergent re-intubation
    d. Teaching points:
        i. Post-operative halo immobilization after cervical surgery for Klippel Feil presents special risks, challenges

3. **Case4: Basilar Invagination after Posterior Decompression for Os Odontoideum:**
    a. 10 y.o with weakness, apneic episodes 3 months after 'decompression and posterior fusion' for os odontoideum at OSH



    b. Treatment:
        i. Halo-gravity traction, complete reduction, posterior instrumentation and fusion
    c. Teaching points:
        i. Established occipito-cervical displacement can be treated by halo gravity traction. Odontectomy not always needed

Notes

The Treatment of Syndromic Cervical Deformities Associated: How do Techniques Differ Worldwide?

John P. Dormans, M.D.
Professor of Orthopaedic Surgery
University of Pennsylvania
Chief of Orthopaedic Surgery
The Children's Hospital of Philadelphia
2nd Floor, Wood Building – Orthopaedic Surgery
3400 Civic Center Boulevard
Philadelphia, PA 19104
Phone: 215-590-1527
Fax: 215-590-1501

Etiology

Autosomal dominant or autosomal recessive inheritance
Skeletal dysplasia

Mutation in filamin B gene (FLN B) on chromosome 3

- Cytoskeletal protein implicated in osteochondrodysplasias
- Cross links actin to allow communication between cell membrane and cytoskeleton – controls and guides proper skeletal development

Prognosis variable

Incidence unknown

Clinical presentation

- Multiple joint dislocations (elbows, hips, knees)
- Facial anomalies (prominent and flat forehead, depressed nasal bridge, flat midface, wide spread eyes and round face)
- Clubfoot
- Heart defects
- Cleft palate
- Neonatal tracheomalacia
- Abnormalities of the spine

Cervical spine deformity

- More commonly affected than thoracic or lumbar regions (Madera et al)
- Dangerous due to risk of cord compression
    - * Result: paralysis

Cervical Kyphosis

- Alters cervical spine biomechanics; load bearing
    - * Normal cervical lordosis
        - ◊ Weight bearing axis during loading is posterior to C2-C7
        - ◊ Anterior column shares less of the axial load than posterior column
    - * Kyphosis: increased anterior column's share of the axial load, resulting in further progression of the kyphosis
    - * Shift of spinal cord to anterior portion of spinal canal
        - ◊ Increased mechanical stress on anterior portion of spinal cord
- Progressive if not treated early
- Cord compression → paralysis and/or death
- Surgical stabilization indicated

Surgical Correction

- Surgical intervention as soon as possible → long term risk of neurological deterioration
- Dependent upon three variables, according to Madera et al:
    - * Age of patient
    - * Severity of kyphosis
    - * Severity of Larsen syndrome
- Goal: neural decompression and correction of the deformity

Methods of Surgical Correction

Two approaches (JBJS 78:538)

- Posterior spinal fusion only
    - * PROS
        - ◊ Relative ease of multilevel decompression
    - * CONS
        - ◊ Only successful in patients with mild, flexible kyphoses
    - * Cervical pedicle screw fixation may be used
    - * Avoid posterior decompression alone!
        - ◊ Risk of affecting the posterior tension band, leading to an increased progression of kyphosis
        - ◊ May be too little too late
- Combined posterior and anterior
    - * PROS:
        - ◊ Access to all portions of spine, allowing for removal of all compressive lesions
        - ◊ Allows for combined shortening of the posterior column with lengthening of the anterior column
        - ◊ Resists translation and torsion of the spine
            - » Reduction in the risk of graft migration and pseudoarthrosis

Halo is usually recommended postoperatively to ensure proper fusion

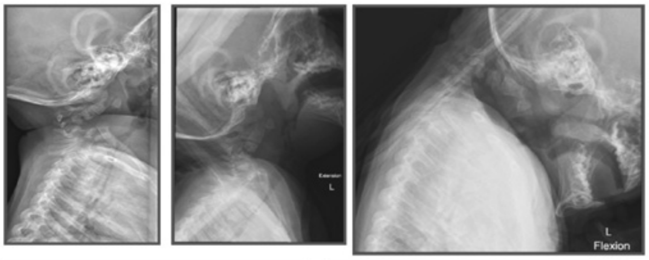
Case Example

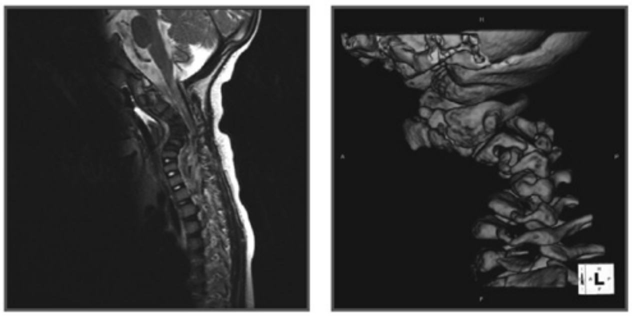
Background:

3 y/o male with Larsen syndrome

Extensive congenital abnormalities of the cervical spine

Preop Radiographs, MRI, and 3D CT scan





Severe kyphotic deformity (C4/C5 apex) → moderate compression of the spinal cord; slightly relieved by extension

Lateral masses of C1 and C2 fused

Hypoplastic vertebral bodies in mid-cervical spine.

Spinous processes of entire cervical spine are unfused in the posterior midline

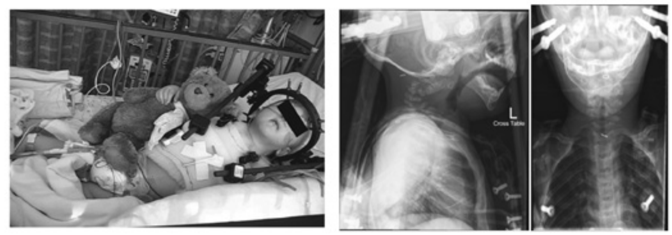
Multiple limb deformities

Treatment:

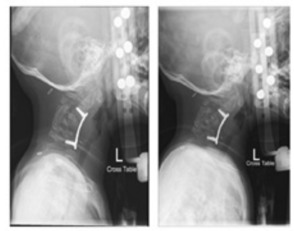
Posterior spinal fusion of C2-C6 with ICBG autograft & Synthes DBX bone paste. Suture /staple fixation

Partial laminectomies to decompress cervical kyphosis

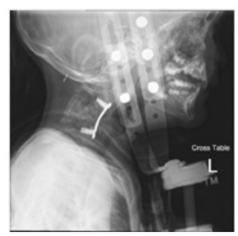
Multi-pin halo ring



Immediate Post-Op



3 months post-op



6 months post op (lateral only)

6 months post op (lateral only)

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Notes

Klippel Feil Syndrome: Diagnosis, Treatment Options and Sports Participation

Steven Mardjetko, MD
Rush University, Chicago
Asst. Professor Orthopedic Surgery
Shriner's Hospital for Children
Illinois Bone & Joint Institute
Morton Grove, IL, USA
www.pedspine.com

disclosures

- History
- Klippel and Feil's initial report in 1912 describes a 46 yo M who died of chronic renal failure with
  - Classic Clinical Triad (20-50% of KFS cases)
    - ◊ extremely short neck
    - ◊ low hairline
    - ◊ Decreased cervical spine motion.
  - Autopsy revealed a completely fused cervical spine with abnormal Occipito-cervical junction. A single cervical vertebra with ribs resulted in the conclusion that the cervical spine was "absent" and the patient had a "cervical thorax"
- First identified case noted in a 3000 yo egyptian mummy
- KFS Spectrum
- History
- Feil's follow up report in 1919 includes a literature review and classification of 13 cases
  - Type 1- massive fusion of the cervical spine
  - Type 2- persistence of 1 or 2 disc spaces
  - Type 3- Cervical failure of Segmentation with lower thoracic or lumbar segmentation failures
- While this classification is descriptive it does not correlate clinical with radiographic findings
- Definition of KFS
- Klippel-Feil Syndrome is defined as any failure of segmentation of the cervical spine from Occiput to T-1
  - Assimilation of C-1 to the occiput
  - C1-2 fusion (rare)
  - C2-3 through C7-T1 fusion
- Radiographic Features KFS
- One level fusion most common (C4-5, C5-6)
- C1-C2 and C7-T1 rarely involved
- Variable patterns of anterior / posterior / lateral fusion
- Extensive KFS vs Isolated Segment

- Isolated KFS C5-6
- Morquio's Syndrome with KFS, Os Odontoideum, Quadriparesis and No Pain
- Extensive KFS with Cervico-Thoracic Congenital Deformity
- Winter/SRS Classification of
  Congenital Spinal Anomalies as applied to the Cervical Spine
- Defined by the morphologic abnormality
  - * Type I- Defects of formation
  - * Type II- Defects of segmentation
  - * Type III- Defects in formation and segmentation
  - * Create imbalance in growth and spinal deformity
- Failure of Segmentation
  Block Vertebra
  Unilateral Unsegmented Bar UUSB
- Embryogenesis of Vertebral Malformations
- Week 0-3: Blastema, neural tube, notochord and lateral somite formation
- Somatogenesis: 44 pairs of somites occiput to coccygeal
- Re-Segmentation Week 5-8: Fissure of Von Ebner and Notochord form future disc
- Pathogenesis of KFS
  Prevailing Theories
- Experimentally induced failures of segmentation
  - * Teratogens-EtOH
  - * Maternal hypotension, hyperthermia, hyper/hypoglycemia
  - * Neural tube overdistention (Gardner), with notochord dysfunction
  - * Failure of re-segmentation (fissure of Von Ebner)
- Genetics of KFS
- Genetic transmission of failures of segmentation is not typical
- One family with Chromosome q8 abn was reported to have a 71% incidence of KFS
- Failure to segment has been associated with defects in notch signaling pathways (Notch-1, Delta 1 &3, Lunatic Fringe) and Homeobox genes (HOX), PAX gene system
- KFS and Associated Genetic Conditions
- Goldenhar syndrome
- Pierre-Robin sequence
- Poland Vascular Disruption Sequence
- Spondyocostal/thoracic dysplasia (Jarco-Levin)
- Larsen's Syndrome
- Diagnostic Evaluation
- Cervical spine radiographs with Flex/Extension
- PA/Lat Scoliosis radiographs
- MRI cervical and spinal cord screen
  - * MRI dynamic views flexion/extension
- CT scan with sagittal/coronal/3-d recons
- Radiographs
- Lateral C-spine radiographs in infancy may suggest anterior segmentation in spite of congenital fusion "pseudosegmentation"
  - * F/E views will reveal lack of segmentation
- Posterior element fusion may be evident prior to anterior column fusion
- Cine-radiography may be rarely utilized to identify abnormal patterns of movement of open segments
- Pseudo-subluxation of C2-3 and C3-4 of up to 4 mm is common to age 8
- Anterior "Pseudosegmentation"
  Posterior Facet Fusion
- High Quality F/E Radiographs
- Radiographic Characteristics of KFS vs. acquired fusions
- KFS-
  - * narrowed at vestigial disc creating a "wasp waist" shape
  - * Facet joints fused
  - * Disc vestigial or absent
- Acquired
  - * Disc is frequently preserved centrally
  - * The disc spaces are wider than the VBs
  - * Facet joints frequently not fused
- Congenital vs. Acquired
- Differentiating Features
  KFS vs. Acquired Fusions
- Acquired Conditions that induce cervical fusions
  - * Juvenile arthritis
  - * Cervical spondylitis
  - * Cervical disc calcification
  - * Ankylosing spondylitis
  - * Tuberculosis
  - * Advanced degenerative changes
- Associated Organ Malformations

- Cardiac (10%) VSD most common
- Renal (30%) renal aplasia most common
- Genital- malformations in organs of reproduction
- GI- esophageal, anal atresias
- Pulmonary- congenital atresia, Thoracic insufficiency syndrome due to fused ribs or congenital deformity
- Nervous system (10-20%)
- ENT- hearing loss (30%) neurogenic/conductive/mixed
- VACTERL sequence
- MRI reveals Renal Malformation and Congenital Spinal Stenosis
- Central Nervous System Abnormalities
- Inienecephaly-Cervical spina bifida
- Chiari Malformations
- Dandy-Walker Malformation
- Hydrocepalus
- Syringomyelia
- Posterior cervical myelomeningocele
- Tethered Cord syndrome
- Cervical congenital Spinal stenosis
- Cervical spinal instability with spinal cord compression
- Synkinesia (mirrored movements) -incomplete pyramidal tract decussation (seen in 20% before age 10)
- The Exam can go from Subtle to Overt! Cutaneous Evidence of Dysraphysm
- Ulmer et al. JCAT (17) 1993
- 24 patients with KFS
    * 7/24 reportedly normal except for KF fusion
    * 10/24 with adjacent segment degeneration
    * 2/24 with Chiari Malformation
    * 5/24 with spinal cord malformation
    * Intraspinal Anomalies

Diastematomyelia Syringomyelia/Chiari Tethered cord

- Spinal Abnormalities Associated with KFS
- Congenital vertebral abnormalities of thoracic or lumbosacral spine
- Idiopathic appearing Scoliosis
- Myelodysplasia
- Sacral agenesis
- KFS can be associated with virtually every type of Spinal Deformity

KFS with Idiopathic Congenital NTD syndromic

- Hensinger et.al. JBJS (54-A)1974
- Limitation of motion was the most consistent clinical finding
- Flexion extension can be maintained even with massive fusion pattern.
- Lateral bending most sensitive physical finding Head Tilt and/or Rotation
    * Congenital head tilt
    * Congenital rotatory subluxation
- Most Common presentation- Normal appearance
- Orthopedic concerns
- C1-2 instability with rotatory fixation
- Occ-Cx abnormality with Head tilt
- Congenital Cervical scoliosis
- Congenital Cervico-Thoracic scoliosis (50%)
- Congenital Thoracic Scoliosis
- Sprengel's Deformity 30% (cong. Elevation of Scapula)
- Congenital abnormalities of upper extremities (20%) and feet
- KFS Sprengel's Deformity with Omovertebral Bone
- Spectrum of Radiographic Presentations-Upper Cx
- Occipito-C-1 fusion/Assimilation of Atlas
- Occipito-C-1 Failure of Formation
    * Dubousset's reported on unilateral Atlas Aplasia as a cause for head tilt in 6 children (JPO, 1995)
- C1-2 abnormalities
    * Odontoid hypoplasia/aplasia
    * Os Odontoideum
    * C1-2 instability- TAL and secondary restraint failure
- C2-3 fusion
- Spectrum of Radiographic Abnormalities Lower Cervical spine
- Single level fusion
- Two level fusion
- Three level fusion
- 4-6 level fusions (C2-3 to C7-T1)
- Two fused segments with an open single segment

- Neurosurgical Concerns
- Congenital spinal stenosis
  * In the fused segment (Hensinger)
  * In adjacent open segments
- Cervical Instability
  * C1-2
  * C2-3
  * Subaxial Cervical spine
- Neural Evaluation
- Mental Status evaluation
- Gait Evaluation- one leg stand, hopping, Romberg test, deterioration in balance, "refusal" to walk (ambulatory lethargy)
- Cranial Nerve evaluation
  * Duane's (C-6), Glossopharyngeal, C-8, hypoglossal
- Motor evaluation- ASIA classification
- Sensory evaluation- PP/LT/posterior column
- DTR's
- Pathologic reflexes- Hoffman's, Tromner's Babinski, Reflex spreading, clonus, spasticity
- KFS Natural History
- Mechanical pain syndromes (20-40 yo)
  * Degeneration/hypermobility/instability in segment adjacent to KFS fusion
- Neural Syndromes
  * Radiculopathy- subaxial KFS effecting C4-5, C5-6, C6-7 (20-40 yo)
  * Myelopathy-
    ◊ Occipito-Cervical instability (0-20 yo)
    ◊ Subaxial cervical instability (10-40 yo)
  * "sudden death" syndromes
- Radiographic Classification of KFS
- Pizzutillo all KFS lesions (Spine 1994)
  * Type 1- occipito-cervical fusions with assimilation of C-1 to occiput
  * Type 2- extensive fusions with one or two open segments
  * Type 3- one or two segment fusions
- Shen et al. Subaxial KFS lesion (Spine 2006)
  * Type 1 one or two fused segments
  * Type 2- one or two open segments contiguous
  * Type 3- one or two open segments non-contiguous
- Radiographic Hypermobility vs Instability
- Pizzutillo (Spine (19), 1994)
  * Defined pathologic hypermobility as asypmptomatic increase of motion greater than 20 degrees at any subaxial cervical level or C1-2 hypermobility as ADI of > 4 mm
  * Of those with hypermobility associated with occipito-cervical KFS 33% developed neural symptoms
  * Of those with hypermobility associated with subaxial KFS 1/3 developed degenerative changes
- Clinical Presentations correlated with Radiographic Pattern (Pizzutillo)
- High Risk Patterns Occ-Cx Subaxial
- *A Radiographic Classification System*
  for identifying
  Klippel-Feil patients
  at increased risk for developing
  Clinically significant Cervical Symptoms
- Frank H. Shen, MD, Steven Mardjetko, MD,
- Jean Herman, RN, MS, MBA, John P. Lubicky, MD
- Shriners Hospital for Children
- Chicago, Illinois
- *Methods and Materials*
- Computer database
- Clinical and radiographic study
- Single institution
- 20 yr period from 1979 to 1999
- Identified 96 patients with the diagnosis of Klippel-Feil Syndrome Minimum 2 year follow-up
- Avg clinical f/u: 9.2 (2.0 – 19.1 yrs)
- Avg radiographic f/u: 8.7 (2.0 – 18.9 yrs)
- *Methods and Materials*
  * Single fused cervical segment
  * 25% of cohort
- *Methods and Materials*
  * Multiple contiguous
  * congenitally fused
  * cervical segment
  * 50% of cohort
- *Methods and Materials*
  * Multiple non-contiguous

  * congenitally fused
  * cervical segment
  * 25% of cohort
- *Clinical Results*
  * Average age of presentation 7.1 yrs
  * 20% symptomatic at initial visit
  * 80% developed symptoms an average of 6.4 yrs after initial visit (12.9 y.o.)
- *Discussion*
  * 54% of patients had cervical complaints
  * 73% of these cases were axial symptoms
  * Type I patients had only axial neck complaints over this period of observation
  * All 4 patients with symptomatic radicular and myelopathic symptoms had Type II and III radiographic patterns
  * Treatment of KFS
- Perform Associated Organ System evaluation. Audiology, Renal US (MRI), Neural axis evaluation-MRI spinal cord screening, Spinal evaluation with standing scoliosis radiographs, cardiac/pulmonary evaluations, upper extremity evaluation
- Patients should avoid contact sports or occupations that can put them at risk for excessive cervical spine force application
- Recommend regular follow-up schedule with F/E radiographs at 1-3 year intervals, follow spine carefully!
- Give patients and parents the "warning signs" to trigger unscheduled evaluation, ie. increasing pain, neurologic symptoms
- Treatment of KFS
- Consider Spinal stabilization for hypermobility/ instability with or without a neurologic lesion
- Consider decompression/fusion via anterior/posterior or combined for instability with spinal stenosis and SCC.
- Currently available "Modern" techniques of fixation can be safely applied to pediatric patients including screw fixation of occiput, C-1, C-2, and C3-T1
- Crushed and structural allograft with rigid fixation and BMP can negate the need for autogenous iliac crest graft
- Post-op Immobilization should be based on: Assessment of biomechanical loads, quality of fixation, and the patient's ability to cooperate
- Fixation Options for Children are the same as for Adults
- Case Presentations
- Rotatory Subluxation/Torticollis
- 14 year-old male admitted to Shriner's SCI program noted to have torticollis on admission 4 months after scoliosis surgery
- Past history: Hypotonia with cognitive deficits, cleft lip/palate surgery, hip dysplasia surgery, progressive T-L scoliosis, therapeutic ambulator
- Underwent scoliosis correction T2 to L4 with instrumentation. Within 24 hrs after surgery it was noted that the patient had loss of all motor movement in the upper and lower extremities, with little respiratory effort. Thoracic CT reveals a lumbar screw intrudes into canal, this is repositioned.
- Gradual recovery of respiratory effort is appreciated and patient is weaned from ventilator over two weeks. Some weak upper extremity movements are noted, but no lower extremity movements.
- Based on diagnostic studies, SCI secondary to a Feilding III fixed rotatory subluxation of C1 on C2 is suspected. KFS (fusion of C2-C3 and possibly C3-C4; also possibly no anterior C1 arch; no other noticeable spine malformations)
- Rotatory Subluxation/Torticollis
- Torticollis developed at about 2 months post op. Transferred to Shriner's for SCI Inpatient Rehab program.
- Pre and Post Reduction
- Treatment
- Halo application with HG traction achieves reduction within 24 hr.
- Occiput to C-3 fusion with Rod-Screw system, auto/allo,
- Radiographs at 1 yr reveal solid fusion
- Neural recovery from B to D in lower extremities with return of therapeutic walking.
- Upper extr. improve C to D
- Subaxial KFS Type 2
- 6 yo F with c/o neck pain. No neural complaints. Head tilt noted since birth. Excellent F/E, limited side bending
- Presents with extensive subaxial KFS with single open segment and segmental instability
- KFS Type 2
- Complete work-up included: scoliosis x-rays, full column MRI, CT scan, Audiology evaluation, renal US, and echocardiogram
- Underwent PSF C4-7 with rod-screw system and allograft, Aspen collar
- Solid fusion at 1 year. Symptoms relieved. Mild head tilt persists

- Klippel-Fiel Syndrome Predisposes the Adjacent segment to Injury
- Cong. Scoliosis Rib Fusions Thoracic Insuff. Syndrome
  KFS Type 2 with two open segments
- Treatment for TIS
  * VEPTR procedure with expansion thoracoplasty
  * Secondary correction of congenital scoliosis
  * Observation of KFS with F/E views prior to OR
  * "In-line" Flexible laryngoscopy for q 6 mo lengthenings. With major post-op airway issues
- Down's syndrome with KFS and Os Odontoideum
- "High Risk"
  Os Odontoideum
- Associated disease processes
  * Congenital abnormalities
  * Down's syndrome
  * Morquio's
  * SED, MED,
  * other dystrophic spinal conditions
- Neuro abnormalities related to Spinal cord compression! Not intracranial pathology!
- AAI on flexion/extension radiographs
- Morquio's- Os Odontoiduem CR/Occ-C2 fusion
- Advanced KFS with Odontoid Hypoplasia
  No instability and no Sx
- Extensive KFS with Odontoid hypoplasia
- Teaching Points
- Search for congenital cervical fusions should be performed during the evaluation for patients with congenital scoliosis
- Screening for craniovertebral instability/rotary subluxation of C1/C2 should be evaluated in all KFS patients, irrespective of how extensive congenital fusion process is or is not
- Craniovertebral instability/rotary subluxation of C1/C2 in KFS patient can develop without major trauma
- Advanced imaging is a must for proper diagnoses and evaluation of underlying pathology in KFS patients etc….
- Draw connection with past literature addressing C2-C3 fusion (and possibly improper formation of C1) as risk factor(s) for instability etc
- Early surgical intervention should be considered to prevent new or continued insult to neurologic function etc

Thank You For Your Attention!!

Notes

Surgical Options for the Treatment of Congenital Scoliosis

Noriaki Kawakami, MD, DMSc
Director of Dept. of Orthopedics & Spine Surgery
Meijo Hospital,
1-3-1 Sannomaru Naka-ku
Nagoya, 460-0001, Japan
Phone: +81-52-201-5311
Fax: +81-52-201-5318

Headings

- Options of Surgical treatment
- Which type?
- How?
  - Short fusion vs. growth sparing surgery.
  - Natural history and the time of surgery.
  - Osteotomy in short fusion
  - Surgical approach

Recent progress of medical devices and diagnostic modalities has dramatically changed the treatment of congenital spinal deformity. In particular, 3D-CT images, MRI. intraoperative neuromonitoring, and computer-oriented navigation system now makes it possible to correct even severe spinal deformity with much better correction rate without neurological deficits, which was once thought to be impossible with surgical treatment. Thanks to the endeavor of surgeons who invented or modified previously existing surgical equipments and procedures in the 20th century, we have now many options of surgical procedures for the treatment of congenital spinal deformity (CSD) at present as below.

- Hemiepiphysiodesis or In-situ fusion
- Posterior, Anterior, or Combined anterior & posterior correction & fusion with spinal instrumentation
  - Without any osteotomy
  - With osteotomy
    - ◊ SPO, PSO, or VCR,
    - ◊ Combined
- Growth sparing surgery
  - Growing rod, VEPTR, Shilla, etc.

Recent trends are concentrated into two directions: aggressive correction for the mature, and growth sparing surgery for the very immature to save time for trunk and chest cage growth while preventing spinal deformity.

Although the aforementioned options are very effective, we still have not reached a consensus about what type of procedures are appropriate, which type of deformity should be treated, and when is the best time for intervention during the growth period. At present, there are no widely accepted rules due to the limitless variability of CSD. Strategic planning has been mainly conducted based on surgeon's experience and preferences. It is very difficult to compare each procedure as there are so many factors affecting surgical outcome: types of CSD (as below), severity of CSD, age at surgical intervention, etc.

- Types of CSD
  - Location of VAs: Cervical, thoracic, lumbar, sacrum
  - Number of VAs: solitary, multiple
  - Area of VAs: small or large area
  - Type of classification: FF, SF, Mixed
  - Relation to adjacent vertebra: Segmentation, disc
  - Discordancy:
  - Rib anomalies: fusion, defect, mixed, proximity
  - Sacral anomalies: sacral tilt, asymmetrical sacrum
  - Pelvic obliquity: pelvic tilt, asymmetrical pelvis, leg length discrepancy

In addition, there are other factors related to surgeons and surrounding environment that influence the decision making process for the surgical treatment of CSD.

- Environment surrounding Surgeons & Patients
  - Heath care system
    - ◊ Insurance (social or private)
  - Hospital Facilities
  - Number of medical staffs
- Factors of Surgeons
  - Experience
  - Surgical skill

To make strategic planning much more simple, I would like to divide CSD into deformities due to isolated abnormal vertebra and those due to consecutive multiple vertebral anomalies. In the presentation, I will focus on surgical options before the adolescent period.

- **Short fusion vs. growth sparing surgery.** Short fusion is the mainstream for surgical treatment of deformities due to isolated abnormal vertebra, while for those due to consecutive multiple vertebral anomalies, short fusion or growth-sparing surgeries are two main options for their treatments depending on the location, severity of the curvature, age of the patient, etc. Long fusion at the younger age in pediatric patients is regarded as what should be avoided as it suppresses not only trunk growth but also growth of both thorax and the lung.

- **Natural history and the time of surgery.** CSD should be corrected before the development of severe rigid deformations and secondary structural curves to allow for normal growth of the unaffected parts of the spine (Ruf, 2003). However, Winter warns against the inappropriate aggressive surgery even for very young patients with CSD by presenting spontaneous regression of scoliosis in patients with hemivertebra (Winter). Natural history should be taken into consideration when planning surgical strategy.
- **Osteotomy in short fusion**
  - * Osteotomy of post. structure (Facet joints or/and Lamina)
    - ◊ Unilateral or bilateral (Smith-Petersen Ponte)
    - ◊ Fusion mass osteotomy (Smith-Petersen)
  - * Osteotomy of ant. structure (Vertebral body)
    - ◊ Wedge resection
  - * Osteotomy of both ant. & post. structure
    - ◊ Wedge resection
      - » Subtraction osteotomy from posterior approach
      - » Combined ant. & post. wedge resection
    - ◊ Decancellation
    - ◊ Vertebrectomy (VCR)
      - » From ant. & post. approach (APVCR)
      - » From posterior approach (PVCR)
- Surgical approach

Many surgeons report excellent outcome of vertebrectomy via a posterior approach as well as combined anterior and posterior approach. The advantages of both approaches are outlined as below:

- Posterior-only approach
  - * Less invasive
  - * No access to the chest cavity and negative impact on the RF
  - * Shorter operation time
  - * Shorter hospital stay
  - * Easy access to the kyphotic angular apical segments
- Combined anterior and posterior approach
  - * Easier resection of vertebral body without retraction of neural tissue
  - * Lower incidence of neurological complications
  - * Almost no amputation of nerve root
  - * Secure placement of ant. column support
  - * Additional release and bone graft adjacent to the VCR site

Although most of the severe deformities can be corrected by vertebrectomy via a posterior approach by well-experienced and skillful surgeons, an anterior approach combined with a posterior approach in correction of CSD with vertebrectomy may be indicated for better outcome if vertebral anomalies

- are consecutively multiple
- exist in mid-thoracic spine
- belong to the complex type
- much more severe curve

Conclusion: There are many options of surgical treatment of CSD.

Decision about the type of procedure, the timing and type is still a controversial topoc when deciding on a surgical plan. However, surgeons must understand characteristics of spinal deformities and their own surgical ability in order to determine which strategic procedure is the best for both the patients and surgeon.

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Notes

Sacral and Lumbosacral Agenesis: Diagnosis and Global Treatment Options

Frances A. Farley, MD
Robert N. Hensinger Collegiate Professor
Chief of Pediatric Orthopedic Surgery
University of Michigan
Mott Childrens Hospital
1540 East Hospital Drive
Ann Arbor, MI 48109, USA
Phone: 734-936-5694
Fax: 734-647-3291
fafarley@umich.edu

- Sacral and lumbosacral Agenesis is a congenital disorder which occurs in 0.01-0.05 per 1,000 live births.
- Sacral Agenesis (SA) is the absence of part or all of the sacrum.
- Lumbosacral Agenesis (LSA) is the absence of part or all of the lumbar spine and sacrum.
- Both SA and LSA are associated with Neurologic (spinal cord and cervical spine), Genitourologic, and Thoracic abnormalities.

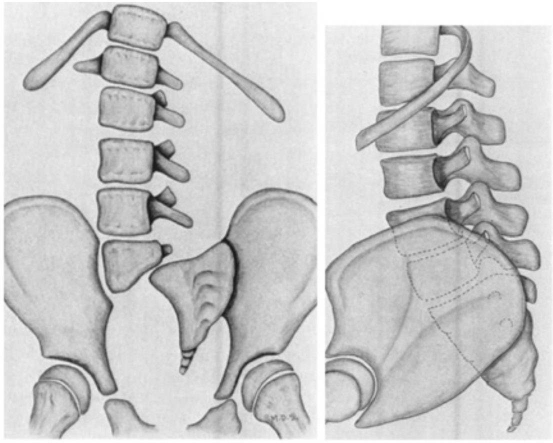
Etiology

- The etiology of SA and LSA is unknown.
- Maternal diabetes is associated with SA and LSA (16-50%).
- Pouzet (1938), Detweiler (1954), Rosenthal (1968), Freedman (1950) all have postulated etiologies for SA and LSA which range from inherited genetic factors, exaggerated cell death, failure of early embryonic mechanisms.
- Genetics: Candidate gene mutations have been mapped to 7q36 and T a transcription factor for posterior mesodermal structures.

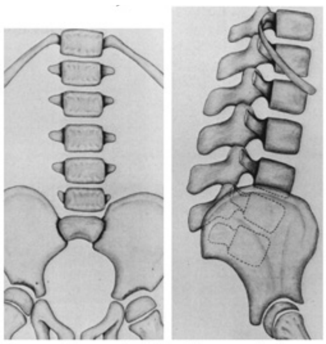
Diagnosis

Renshaw Classificationnesis

- Type I: total or partial unilateral sacral agenesis



- From Renshaw TS. Sacral Agenesis; A classification and review of twenty three cases. J Bone Joint Surg (Am); 60A;373-83.
- Type II: partial sacral agenesis with a partial but bilaterally symmetrical defect and a stable articulation between the ilia and a normal or hypoplastic first sacral vertebra (most common).



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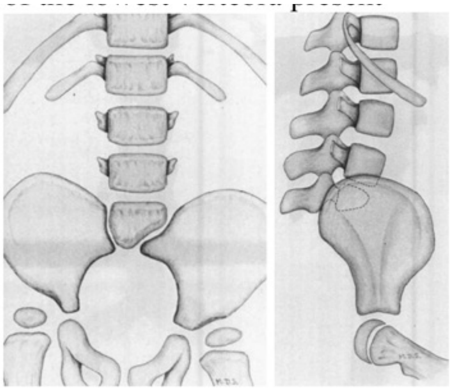
- Type III: variable lumbar and total sacral agenesis with the ilia articulating with the sides of the lowest vertebra present



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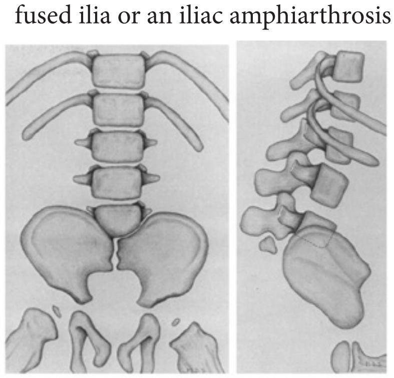
- Type IV: variable lumbar and a total sacral agenesis, the caudal end-plate of the lowest vertebra resting above either fused ilia or an iliac amphiarthrosis



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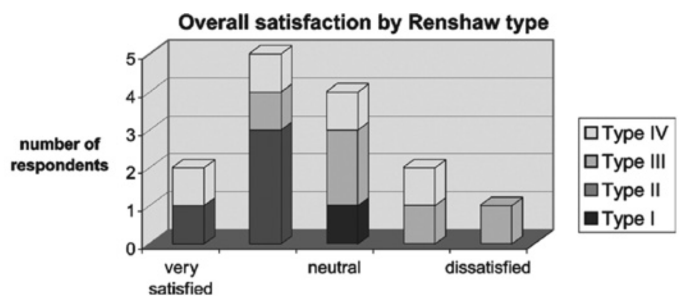
- For complete sacral agenesis and lumbosacral agenesis there are often nonfunctional lower extremities which have severe pterygyium and the child sits in a "Budda" like position.

Treatment Options

- Type I and II do not require spine surgery typically.
- Scoliosis is reported in 40 to 68 percent of patients (Phillips, 1982, Van Buskirk, 1997). The most common type is Type 3. No novel treatment of the scoliosis has been reported.
- Type III and IV have the option of fusion of their remaining lumbar spine to the pelvis. Winter (1991) described the lumbar-pelvis fusion combined with through knee amputations using the tibias as structural autograft.
- Some authors feel that spinal pelvic motion is an advantage for sitting with hips that have a fixed flexion deformity. (Phillips, 1982)

Outcomes

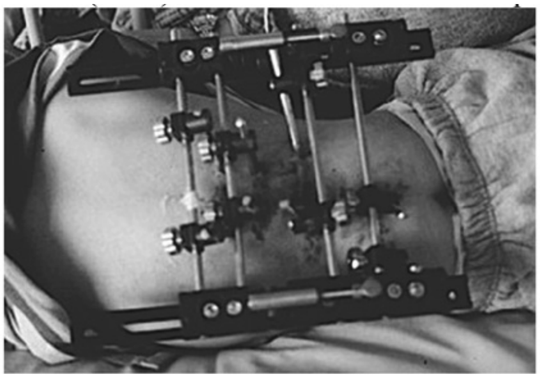
- Very few studies (Phillips, 1982, vanBuskirk, 1997)
- Caird (2007) surveyed 16 patients and found half of them had back pain or lower extremity pain. The satisfaction was not related to Renshaw classification.



- Figure from Caird MS. Hall JM. Bloom DA. Park JM. Farley FA. Outcome study of children, adolescents, and adults with sacral agenesis. Journal of Pediatric Orthopedics. 27(6):682-5, 2007 Sep.

Global Treatment Options

- Giffet (2011) in France described lumbopelvic stabilization with an external fixator.



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- Polish, German, Portuguese, and Indian review article on SA has been published (van Baalen, 2008, Garcia, 2001, Kumar, 1994).

Conclusion

- SA and LSA are very rare and associated with back pain and scoliosis.
- Lumbopelvic fusion is controversial.
- There are a variety of methods for lumbopelvic fusion.

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Notes

Hemivertebra Excision[1-7]

Daniel J. Hedequist, MD
Boston, MA, USA

Benefits

1. Correction of deformity
2. Sparing of normal spine levels
3. Limited fusion

Indications

1. Isolated hemivertebra
2. Growing child
3. No severe global deformity (i.e. healthy mobile spine above and below)
4. Relative health of patient

Contraindications

1. Multiple anomalies
2. Severe spinal imbalance
3. Poor host
4. Surgeon inexperience/comfort

Approaches

1. Anterior-posterior
2. Posterior only

Pre/Intra-operative necessities

1. MRI and CT
2. Neuromonitoring
3. TXA
4. Segmental screw fixation

Complications

1. Neurologic
2. Vascular
3. Incomplete resection

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Notes

Hemivertebra Excision vs. Growth Arrest Procedures

Ilkka J. Helenius, MD, Orthopaedic Surgeon
Department of Paediatric Orthopedic Surgery. Turku University Central Hospital, Turku, Finland

A fully segmented or semisegmented hemivertebra producing congenital scoliosis has been traditionally treated with anteroposterior convex side hemiepiphyseodesis (typically four dics) with the expectation of spontaneous curve correction with continued growth (Roaf R, JBJS Br 1963;45:637-651; Winter RB et al. J Pediatr Orthop 1988;8:633-8).

Most of the patients have responded well with a mean difference of 3.1 degrees between preoperative progression (+1.9 deg/yr.) vs. postoperative correction rate (-1.2 deg/yr.) (Thompson AG et al. Spine 1995;20:1380-5.), while in some of the patients the outcomes were highly unpredictable and sometimes only anterior spinal fusion occurred resulting in extremely severe kyphoscoliosis necessitating VCR for curve correction (Figure) (Helenius and Pajulo JBJS Br 2012;94:950-5). Transpedicular approach for obtaining anterior spinal fusion has also been described (Keller et al. Spine 1994;19:1933-9.), but this has resulted in a smaller epiphyseodesis effect.

Traditional uninstrumented hemiepiphyseodesis necessitates anterior approach and limits growth of spine, which both are detrimental for normal lung development. Karol et al. (JBJS 2008;90:1272-81) have reported that spinal fusion extending above T6, length of thoracic spine less than 18 cm or spinal fusion more than four thoracic segments are significant risk factors for significantly abnormal lung volumes (vital capacity less than 50% of predicted).

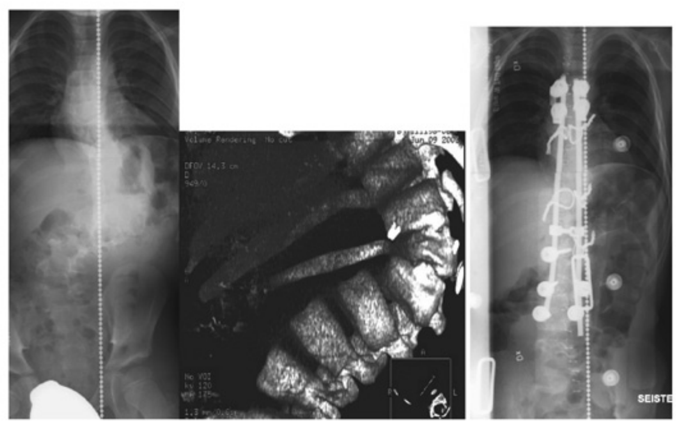
For a single hemivertebra without associated bar all posterior hemivertebra excision with transpedicular screws above and below as described by Ruf and Harms (Spine 2002;27:1116-23) can be regarded as the treatment of choice. There appears to be no difference in the radiographic correction between anteroposterior and posterior approach for hemivertebra excision and multiple excisions can be performed at different levels using all posterior approach (Jalanko et al. Spine 2011;36:41-9).

Yaszay et al. (Spine 2011;36:2052-60) recently compared hemiepiphyseodesis with instrumented non-resection or resection in a large retrospective multicenter trial. Convex hemiepiphyseodesis patients had less correction but lower complication rate than instrumented hemivertebra excision (23% vs. 44%).

Anteroposterior spinal fusion w/o instrumentation is the surgical option when a short congenital spinal deformity typically caused by an unsegmented bar is treated (McMaster MJ, Spine 1998;23:998-1005; Marks DS, Eur Spine J 1995;4:296-301). In these cases the fusion should be performed at an early age before the age of 5 years. Prophylactic posterior spinal fusion is an option for congenital kyphosis less than 55 degrees before the age of 5 without compression of spinal cord. This has resulted in a gradual reduction by a mean 15 degrees (McMaster MJ et al. Spine 2001;26:2146-54). AP instrumented spinal fusion is also an option for congenital dislocation of the spine (Type A, Shapiro and Herring JBJS 1993;75:656-62), although author usually prefers VCR for both congenital kyphosis and dislocation.

The traditional convex hemiepiphyseodesis technique has been recently modified to include posterior only approach with pedicle screw fixation of the anomalous convex levels allowing increased correction rate and better trunk balance for mixed or long segment congenital spinal deformity. Concave distraction side is instrumented using two pedicle screws on the top and two at the bottom with distraction every six months to promote continued spinal growth (Alanay A et al. CORR 2012;470:1144-50). This has resulted into 44% correction of the major curve, but four out of five patients had pedicle screw pullout at follow-up necessitating revision surgery without neurologic complications.

Figure. A failed thoracolumbar hemiepiphyseodesis at the age of 3 years has resulted in severe kyphoscoliosis with spinal cord compression 5 years later. An anteroposterior VCR was performed at the age of 8 years with hybrid instrumentation.



Notes

Combined Afternoon Session 1:
Techniques for the Preservation of Sagittal Balance: An International Perspective

Moderators:

John R. Dimar, II, MD & Pierre Roussouly, MD

Faculty:

Ahmet Alanay, MD; Laurel C. Blakemore, MD; Kenneth M.C. Cheung, MD; Hubert Labelle, MD; Lawrence G. Lenke, MD; B. Stephens Richards, III, MD; Pierre Roussouly, MD; Suken A. Shah, MD

The Evolution of the Concept of Pelvic Parameters and Their Relationship to Sagittal Spinal Alignment

Hubert Labelle, MD
Hospital Sainte-Justine Ortho Dept, Montreal, Canada
Jean-Marc Mac-Thiong, MD
CHU Sainte-Justine, Mont Royal, Canada

1- The pelvis: from quadrupeds to humans.

Posture is defined as the alignment or orientation of body segments while maintaining an upright position. The posture of a human standing subject can be viewed as a set of mutually articulating body sections: the head is balanced on the trunk by the cervical spine, the trunk and thoracolumbar spine articulate on the pelvis which, in turn, articulates with the lower limbs at the hip joints, in order to maintain a stable posture and to expend a minimum of energy. There is a narrow range in which the body can remain balanced without external support and with minimal effort. Human posture is relatively simple to understand in the frontal plane, with a normal vertical straight spine delineating an axis that passes through the middle of the head, sacrum and pelvis, with the limbs symmetrically distributed on each side. The situation is much more complex in the sagittal plane: the spine has multiple curves and the pelvis plays a unique role in this equation by virtue of its shape, which can be conceptualized as a circle in which the lower limbs articulate on the acetabulums and on which the spine articulates eccentrically on the sacrum, creating an asymmetric configuration and potentially unstable situation when compared to the frontal plane.

Evolution from the quadrupedal to the bipedal posture in primates and humans has been allowed by progressive and very significant changes in the shape and position of the pelvis and spine and of their supporting ligaments and muscles (Figure 2). A quadruped has no lumbar lordosis and a more longitudinal and narrow shaped pelvis, such as in the skeleton illustrated in figure 2. In sharp contrast, a human has a well developed lumbar lordosis and a much ‘’rounder” pelvic shape, a situation which has gradually evolved in primates along with the transition to the bipedal posture. As discussed in the following section, Pelvic Incidence is a simple measurement that characterizes the shape of the pelvis, and this angle has increased significantly from quadruped to bipeds. These changes in shape and morphology of the pelvis are crucial to the understanding and management of many spinal disorders, such as L5-S1 spondylolisthesis, a disorder which does not occur in quadrupeds, but which is frequently associated with activities involving a lordotic effect on the lumbar spine in bipeds, such as gymnastics. It is therefore very important to have a basic understanding of the role of the pelvis in normal human posture.

2- Spino-pelvic measures and their variations in normal humans.

How can the shape/morphology of the pelvis be quantified in a simple but useful way for clinicians? Different parameters have been used to describe pelvic morphology based on standing lateral radiographs[1], but our preference goes to Pelvic Incidence (PI), a simple measurement introduced by Duval-Beaupère et al.[2-3] PI is a fundamental pelvic anatomic parameter that is specific and constant for each individual and determines pelvic orientation as well as the size of lumbar lordosis (LL). PI remains relatively constant before walking age and thereafter, it increases significantly during childhood and adolescence until reaching its maximum and thereafter constant value in adulthood[4-5]. PI is defined as the angle between a line perpendicular to the sacral plate and a line joining the sacral plate to the center of the axis of the femoral heads. It is important to understand that PI is a descriptor of pelvic morphology and not of pelvic orientation: therefore, its angular value is unaffected by changes in human posture and will remain the same whether a subject is standing, sitting, or lying down, with the assumption that there is no significant motion occurring at the sacroiliac joints. In contrast, the pelvic tilt (PT) and the sacral slope (SS) are position dependent variables, and are very useful to characterize the spatial orientation of the pelvis. SS is defined as the angle between the sacral endplate and the horizontal line, while PT is defined as the angle between the vertical line and the line joining the middle of the sacral endplate and the axis of the femoral heads (Figure 3). Because they are measured with respect to the horizontal and to the vertical, respectively, SS and PT describe the orientation of the pelvis in the sagittal plane and not its morphology. PI, SS, and PT are particularly useful because it can be demonstrated that PI is the arithmetic sum of the sacral slope (SS) + pelvic tilt (PT), the two position-dependent variables that determine pelvic orientation in the sagittal plane (Figure 3). Because of this mathematical association between PI, SS, and PT, the morphology of the pelvis, as quantified by PI, is therefore a strong determinant of the spatial orientation of the pelvis in the standing position: the greater PI, the greater has to be SS, PT, or both. PI, PT and SS are best measured from a standing lateral radiograph of the entire spine including the pelvis when evaluating the global sagittal balance.

Vaz et al[6] have studied and reported the association and ranges of PI, PT, SS, Lumbar Lordosis (LL), and Thoracic Kyphosis (TK) in 100 young normal adult volunteers and have shown that all these parameters are closely linked and balance themselves, by muscular activity, to maintain the global axis of gravity over the femoral heads. The pelvic shape, best quantified by the PI angle, determines the position of the sacral end. The spine reacts to this position by adapting through LL, the amount of lordosis increasing as the SS increases to balance the trunk in the upright position (Figure 4). Berthonnaud et al[7], in a review of 160 normal adult volunteers, have shown that the pelvis and spine in the sagittal plane can be considered as a linear chain linking the head to the pelvis where the shape and orientation of each anatomic segment are closely related and influence the adjacent segment, to maintain a stable posture with a minimum of energy expenditure. Changes in shape or orientation at one level will have a direct influence on the adjacent segment. Knowledge of these normal relationships is of prime importance for the comprehension of sagittal balance in normal and pathologic conditions of the spine and pelvis. Mac-Thiong et al[8-9] have reported similar results in a reference pediatric and adolescent population of 180 subjects aged 4 to 18 years.

A balanced pelvis and spine results in a global spino-pelvic balance that is typically maintained within a narrow range of values in normal individuals. As shown by Mac-Thiong et al.[9-10], the C7-plumbline of 85% of normal adults and children aged >10 years stands behind the hip axis. In order to maintain an adequate global spino-pelvic balance (with minimum energy expenditure) throughout life despite ongoing degenerative changes, adjusting pelvic orientation is the key. Accordingly, a small increase in PT and a reciprocally small decrease in SS can occur with aging, thereby causing retroversion of the pelvis in an effort to prevent forward displacement of C7-plumbline[11]. Similarly in conditions that will tend to move the C7-plumbline forward, such as in spondylolisthesis or post-traumatic kyphosis, retroversion of the pelvis can also decrease the incidence of global sagittal imbalance. In addition, young patients with healthy discs and muscles also can increase their lordosis in an attempt to prevent the forward displacement of the C7-plumbline.

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N.B. The current text is extracted from:

Labelle, H and Mac-Thiong JM, ''Role of the pelvis in the diagnosis and management of L5-S1 Spondylolisthesis", chapter in Textbook ''Spondylolisthesis: Diagnosis, Non-Surgical Management and Surgical Techniques", Wollowick A, Sarwahi V, Eds. Springer. Status: submitted.

Notes

Lumbosacral Segmental Kyphosis: Selection Criteria for the Reduction of a Balanced and Unbalanced High Grade Spondylolisthesis

Pierre Roussouly, MD
Chief of the vertebral unit
Croix Rouge Francaise-CMCR des Massues
92 Rue Edmond Locard
69005 Lyon, France
Phone: +33 4723848555

Introduction:

If the surgical treatment and stabilization of HGS is now well admitted, the way of reduction of L5 slipping remains subject of controversy.

During a long time, in situ fusion was considered the gold standard of HGS treatment. More recently the sagittal balance evaluation of HSG has brought some authors to reconsider the necessity of reduction. By this way, it is mandatory to recognize the sagittal organization of the spine and pelvis in HGS.

HGS is defined as a spondylolisthesis of L5 on S1 with a slipping superior to 50% of the sacral plateau length. In fact the severity of HGS is not only due to the level of slipping but mainly to the kyphotic tilt of L5 which follows the slipping. Instead of SS in normal population, in HGS lumbar lordosis is dependent on L5 superior plateau orientation. To evaluate the lumbo-sacral kyphosis, Dubousset has described the Split angle between a line following the posterior cortex of the sacrum and L5 superior plate. L5 Incidence (IL5) brings additional information of L5 positioning regarding the femoral heads. In addition of L5 positioning, Hresko brought Pelvis Tilt (PT) evaluation as a criterion of severity of balance in HGS. The importance of retroversion of the pelvis correlated well with lumbo-sacral kyphosis. Another well known factor of unbalance is the forward displacement of C7 which reflect the global balance assessment of the spine. Hresko and all, proposed a classification of HSG balance in Balanced, balanced non retroverted, and unbalanced retroverted. The authors suggested to privilege in situ fusion in case of balanced HGS and to reduce unbalanced decompensated. Dividing the same population of HGS regarding the shape of the sacral extremity, it was shown that unbalanced retroverted were more frequent in dome shape sacrum rather than in flat sacrum. Previously, the aim of the reduction was correction of the slipping. Sagittal analyze of HGS brings a new dimension and the aim of surgical reduction is to restore a better balance by decreasing the lumbo-sacral kyphosis, mainly in unbalanced retroverted HGS. "In situ" fusion could stay a good option in balanced non retroverted HGS.

How to assess biomechanical parameters of Sagittal Balance in HGS?

To assess SB of spine and pelvis, it is mandatory to have long standing lateral x-rays. Classically three groups of parameters have to be evaluated: pelvic parameters, C7 positioning, lumbar lordosis (LL) shape. In HGS, there are two specificities: the high frequency of dome shape plateau and the separation between L5 and the sacrum, which gives L5 a specific role.

Pelvic parameters. Depending on the sacral plateau shape, there are two situations: flat sacral plateau where Pelvic Incidence (PI) and Sacral Slope (SS) may be calculated and dome shape sacrum where PI and SS cannot be. In case of round plateau a way of calculation of PT is generally admitted using the middle of the segment of the most anterior and posterior points of the proximal extremity of the sacrum.

L5 positioning. As L5 is separated from the sacrum, orientation of LL is no more linked with the sacral end, as in common situation. LL is directly depending on L5 superior plate (L5SP) orientation. To assess lumbo-sacral kyphosis, Split Angle was drawn between a line following the posterior sacral cortex and L5SP. Due to the curvature of the sacral cortex the orientation of this line may be a cause of error. L5 Incidence was designed with the same rules than PI but using L5SP instead of the sacral plateau. The points used for IL5 drawing are well identified anatomical landmarks (L5SP and femoral heads contouring), providing a better accuracy and inter observer reliability.

Lumbar Lordosis. LL is calculated from L5SP until the Inflexion Point (IP) where lordosis transitions in kyphosis. Orientations of both L5SP and last vertebra involved in the lordosis determine the Lordosis Angle. Number of vertebrae involved in LL gives the length of LL. The Lordosis Tilt (LT) is the angle between vertical and a line drawn from the Inflexion Point to the center of the vertebral plateau. When IP displaces forward the sacrum, LT is negative and an element of anterior unbalance.

C7 positioning. Instead of distance which may be cause of error, angles and distance ratio were described to assess C7 positioning. Spino sacral angle and C7 tilt are angles describing the position of C7 regarding respectively SS and vertical line. A ratio of distances relative to the center of femoral heads (FH) and posterior edge of the sacral plateau (SP), describes the position of C7plumb line regarding those anatomical landmarks. Global balance may be defined as balanced behind SP, slightly unbalanced between SP and FH, unbalanced when in front of FH.

Sagittal Balance in HGS

Different studies (Vialle, Hresko) have noted significant changes in sagittal parameters in HGS compared to asymptomatic population. They found patients with higher PI more than 70°, PT more than 30°, LL more than 60°. Split angle (Vialle), and IL5 (Hresko) correlated well with unbalance severity. Using a cluster analysis Hresko was able to find two statistically different populations in HGS: balanced non retroverted (PT averaged 21°) and unbalanced retroverted (PT averaged 36°). The unbalanced retroverted group had significant greater IL5.

Dividing the population of HGS regarding the shape of the sacral plateau, we found greater PT, IL5, LL angle, LT, and forward C7 positioning in dome shape sacrum than in flat sacrum.

Whatever the pathology, the spine always compensates a local kyphosis by two ways: extension of the spinal segments above and below the kyphosis level, and increasing pelvis retroversion. In case of severe kyphosis C7 plumb line displaces in front of FH, and to overpass hip extension, knees flexion is a way of increasing PT. In case of HGS, the initial cause of unbalance is the lumbo-sacral kyphosis. The dome shape increases the kyphotic course of L5 around the sacrum. Split angle and IL5 give a good indication of lumbo-sacral kyphosis. We demonstrated that IL5 is a better indicator of kyphosis severity. With a same value of Split angle we may have different values of IL5 regarding PT. This is the reason why IL5 correlates better with PT. In case of slight lumbo-sacral kyphosis, IL5 is low; there is no need of compensation. PT and LL are normal or slightly increased, and C7 remains behind FH. This is the balanced non retroverted situation. In case of sever lumbosacral kyphosis, IL5 increases strongly over 50°; the set spine and pelvis has to compensate by increasing pelvis retroversion, and LL. When compensatory mechanisms are overpassed, PT may reach more than 30°, LL increased (angle and length), LT becomes negative. C7 plumb line is in front of FH, and knees are in flexion. This is the unbalanced retroverted situation.

Aim of the treatment. In situ vs reduction.
Until now the aim of surgical treatment was stabilization of HGS by L5S1 fusion. In situ fusion was considered as less neurologically damaging and improving the balance by diminishing the local pain. The proposal of reduction technique was addressing mainly the slipping reduction. The sagittal balance analysis brings the idea that severity of unbalance is linked to severity of lumbo-sacral kyphosis. By this way the aim of the surgery is to reduce the lumbo-sacral kyphosis when necessary.

Labelle described an improvement of all the sagittal balance parameters after reduction technique surgery. On another hand numerous papers enhanced good functional results with in situ fusion. Both are probably right but several parameters have to be token in consideration to evaluate the post-operative balance result. The young age of the patient, is an important factor; an initial good result with an acceptable hyper lordosis when young, may bring to a painful situation in adult. The reality of in situ technique has to be demonstrated by post-operative kyphosis reduction parameters such as IL5. Some technique with cast preparation may provide a partial reduction which improves the post-operative balance. If in situ fusion may be acceptable in children HGS, in adult an insufficient reduction of the lumbo-sacral kyphosis is unacceptable with sever functional troubles due to residual fixed unbalance.

Conclusion.
Comprehensive analyze of Sagittal Balance in HGS, focuses on the importance of lumbo-sacral kyphosis evaluated by importance of IL5. When the HGS is well balanced, an "in situ" fusion technique is acceptable. In case of unbalanced retroverted HGS, reduction of the kyphosis seems to be a better option in children and is mandatory in adults. Longitudinal prospective studies has to be done to validate surgical treatment after a long term follow up and to compare the advantages of both strategies

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Notes

Abnormal Sagittal Alignment in Neuromuscular Scoliosis: When is Treatment Required?

Ahmet Alanay, MD
Acibadem Maslak Comprehensive Spine Center
Buyukdere Cad. 40 Maslak
Istanbul, Turkey

SAGITTAL PLANE ABNORMALITIES

- Usually is a major problem in conjuction with scoliosis
- Thoracic hyperkyphosis
- Lumbar kyphosis
- Lumbar hyperlordosis

NATURAL HISTORY

- Depends on etiology
- 8°/year progression in myelomeningocele

CONSEQUENCES OF SAGITTAL PLANE ABNORMALITIES

- Difficulty in sitting balance
- Cardiovascular and pulmonary side effects
- Nutritional problems
- Pressure sores due to huge kyphosis
- Difficulties in daily care

TREATMENT

- Observation
- Non-surgical treatment (braces, exercise)
  * Usually to buy time
  * No effect on the natural history
  * Cooperation difficulties
  * Seizure
  * Constriction of chest wall!
  * Decubitis ulcers

ABSOLUTE SURGICAL INDICATIONS

- Deformity progression
- Functional deterioration

FACTORS INFLUENCING THE DECISION FOR SURGERY?

- Age of appearance
- Risk for progression
- Natural history
- Efficacy of conservative tx
- Behaviour of coronal plane deformity

ABSOLUTE SURGICAL INDICATIONS

- Deformity progression
- Functional deterioration

FACTORS INFLUENCING THE DECISION FOR SURGERY?

- Severe
- Rigid
- Pelvic extension
- Three-planar

SURGERY

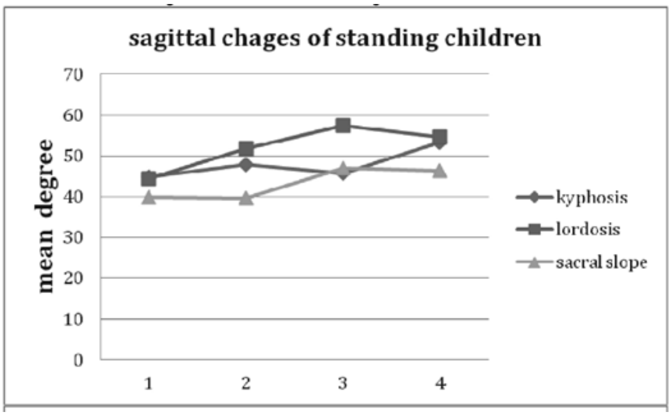
- *Pros*
  * Sitting balance
  * Independent use of upper extremities
  * Effectice respiration and pulmonary clearance
  * Better nutrition and improved GI functions
  * Indirect treatment of GE reflux and SMAS
    ◊ Easy nursing
  * *Cons*
  * Complicated, tough, expensive
  * Remarkable results for deformity, but functional recovery may not be as remarkable

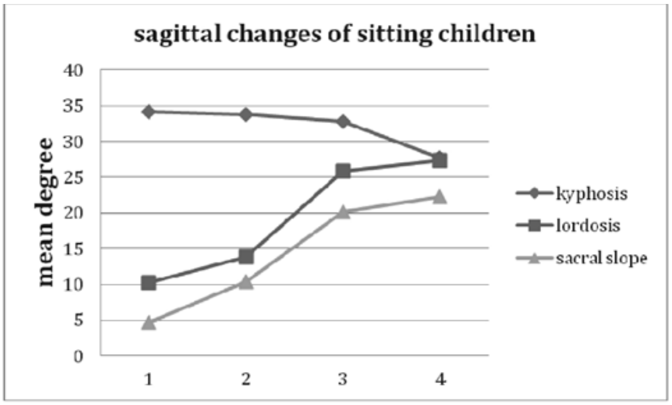
DECISION MAKING FOR SELECTION OF FUSION LEVELS

- Nonambulatory vs. Ambulatory
  * -Static -Dynamic
  * -Levels straightforward -Levels difficult to decide
  * (usually T2-pelvis) (pelvis should be avoided)

DECISION MAKING FOR SELECTION OF FUSION LEVELS

- What should be sagiital contour in a sitting child ?





- Sagittal spinal alignment in the sitting position is different than that in the standing position and it changes as the child grows.
- This should be taken into account for correction of sagittal malalignment

SURGICAL DIFFICULTIES

- Growing spine
- Osteoporosis
- Skin conditions
- Cardiopulmonary problems
- Higher complication rates than the other sagittal plane abornmality etiologies

SUMMARY

- Sagittal plane abnormalities usually accompany scoliosis in patients with neuromuscular diseases
- Natural history is usually progressive and may influence the quality of life and shorten the life span
- Non-operative treatment methods usually fail
- Surgeries are challenging and complication risks are higher
- Correction of sagittal plane mal-alignment helps to improve patient and caregiver quality of life.

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Notes

Scheuermann's Kyphosis and Roundback: Current Treatment Guidelines

B. Stephens Richards, III, MD
Professor, Orthopaedic Surgery
Texas Scottish Rite Hospital
Univ Texas – Southwestern
Dallas, Texas, USA

Clinical Features

- Sharp-angled kyphosis (most evident on forward-bend test)
- Compensatory hyperlordosis in lumbar region and, sometimes, cervicothoracic region
- Inability to actively correct the kyphosis
- Occasionally, mild scoliosis accompanies
- +/- discomfort
- Progression of kyphosis not related to increased pain
- QOL: deficits in self-image, general function, activity

Radiographic Features

- >5o anterior wedging three (or more) consecutive vertebral bodies at apex
- Narrowed, degenerated end plates
- +/- Schmorl's nodes
- Occasionally, bony ankylosis at apex
- Negative sagittal balance is common

Current Treatment Guidelines

Nonoperative Treatment

- Indications
  * Cosmetic concerns, progressive
  * Discomfort
  * Skeletal immaturity
- Goals: Control deformity, reconstitute anterior vertebral height through hyperextension forces
- Brace Treatment
  * Considered for deformities of lesser magnitude, as success is minimal in larger magnitude
  * Compliance with program is very difficult
  * Milwaukee brace
  * TLSO with anterior sternal /infraclavicular extensions
  * Full-time, continued until skeletal maturity (boys through Risser 5)

Notes

- Cast Treatment
  * Complete commitment to compliance is required, as extended period of treatment is expected

    * Indicated when passive correction is <40% on hyperextension lateral radiograph over a bolster
    * Two or three casts (changed Q 2-3 months), then converted to brace

Operative Treatment

- Indications
    * Pain that persists despite nonoperative management
    * Rigid deformity, curve exceeding 70o-75o
    * Unacceptable cosmetic appearance to patient
- Goals: Stable, well-balance spine in sagittal plane without neurological complications
    * Approach 50% correction, but rarely more in order to avoid junctional kyphosis

Current Recommendations:

- Preoperative Evaluation
    * Lateral radiograph over a bolster to assess flexibility of spine
    * Precise neurological examination
    * MRI to assess status of thoracic discs remains debatable, not absolute indication
- Operative Approach
    * Intraoperative neuromonitoring is mandatory
    * Recent concepts focus on the use of multiple pedicle screw anchors to allow for
        ◊ segmental compression to shorten the posterior column, or use of cantilever
        ◊ maneuvers pushing the kyphotic apex ventrally instead of the concept of elongating
        ◊ the anterior column with anterior column support. The use of anterior
        ◊ releases/support can now, in nearly all cases, be considered unnecessary.
    * Fusion levels determined on standing lateral radiograph
        ◊ Upper instrumentation must include proximal vertebra tilted into kyphosis
            » (generally T2). This will minimize risk of proximal junctional kyphosis
        ◊ Inferior instrumentation should include first lordotic disk space, and will usually
            » includethe stable sagittal vertebra. Failure to do so will risk the development
            » of distal junctional kyphosis
    * Methods
        ◊ Posterior column shortening osteotomies over the apical region of the kyphotic
            » deformity, followed by segmental compression with multiple anchors is
            » current method of choice. This can be achieved through progressive
            » cantilever techniques, or with the temporary use of a threaded rod (replaced
            » with solid rod after correction is achieved).
        ◊ Anterior releases should be considered only for stiff, very large curves in mature
            » patients
        ◊ Localized correction of severe angular deformity using vertebral column
            » resection has been reported (Lenke). Rarely should this be considered in this
            » condition.

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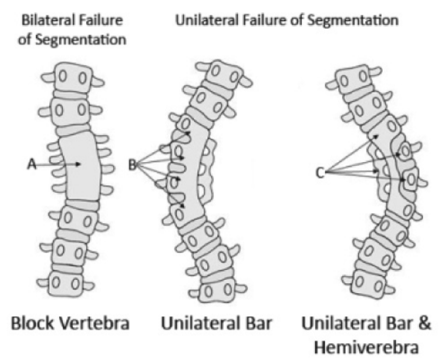
Notes

Sagittal Imbalance Due to a Congenital Dorsal Hemi-Vertebra: When is Treatment Indicated?

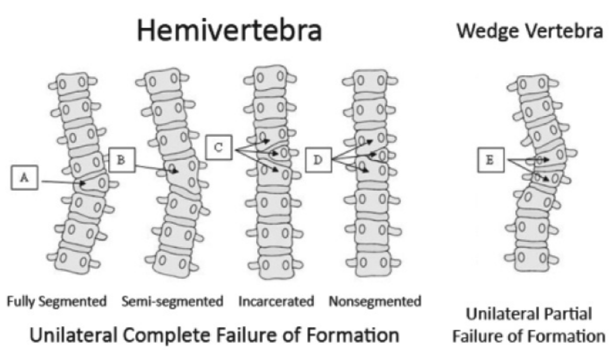
Lawrence G. Lenke, MD
The Jerome J. Gilden Distinguished Professor of Orthopaedic Surgery
Professor of Neurological Surgery
Chief, Spinal Surgery
Co-Chief, Spinal Deformity Service
Director, Complex Spinal Deformity Fellowship
Washington University Medical Center
Saint Louis, Missouri, USA

Sagittal Imbalance Due to a Congenital Dorsal Hemivertebra

1. Specific Type of Anomaly
    a. Defects of Segmentation
        i. Fully segmented
        ii. Partially segmented
        iii. Non-segmented



    b. Defects of Formation
        i. Fully
        ii. Semi-segmented
        iii. Incarcerated
        iv. Non-segmented



    c. Mixed → *most* common

2. Treatment Indications
    a. Progression
    b. Angular deformity *without* myelopathy
    c. Angular deformity *with* myelopathy
    d. Sagittal deformity creating sagittal imbalance
    e. Revision cases that meet any of the above + any of those w/pseudarthrosis
3. Treatment Options
    a. PSF alone – RARE
    b. ASF/PSF
    c. PSF w/3-column resection – MOST common!
4. Surgical Treatment of Post-based Resection (VCR)
    a. Exposure, Costotransversectomy, Pedicle Screw Placement

    b. Laminectomy, Temp Rod Placement, Vertebral Body Exposure

5. Surgical treatment with Pedicle Subtraction Osteotomy (PSO)
    a. Indications
        i. Severe/stiff deformities
        ii. Fixed coronal/sagittal imbalance
        iii. Performed in TL/L spine primarily
    b. Procedure
        i. Removal of posterior ligaments/facets/pedicles & decancellation of the vertebral body
        ii. Post-based closure to improve lordosis

iii. Allows for simultaneous correction of stiff coronal/sagittal plane deformities

c. Results

i. Motion segments ↑/↓ may not fuse, especially with facet excision/open discs anteriorly

ii. Approx. 30 to 35° of lordosis obtained

iii. Varying amounts of sagittal balance improvement

iv. 10% rate of transient neurapraxia (Buchowski, Bridwell, et al. IMAST 2006, Spine 2007)

v. 10% rate of pseudarthrosis (Dickson, Lenke, et al. SRS 2012)

COMPARISON
SPO/PO vs. PSO vs. VCR

	SPO	PSO	VCR
Location	T/T-L	Lumbar	Thoracic
Correction	+	++ (30-35º)	+++ (40-50º)
Neuro Risk	+*	++	+++
ASF	-	-	++
Pseudo Risk	Low	Moderate	Very Low

6. Conclusions

a. Fairly uncommon scenario but important to recognize

b. Treatment is geared toward posterior resection & circumferential reconstruction from all-posterior approach

c. Good outcomes should be expected – risks are real thus optimal surgical treatment required

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Notes

Debate: Three Cases of Pediatric Patients and Global Perspectives on the Various Treatment Options

Laurel C. Blakemore, MD
Chief, Orthopaedics and Sports Medicine
Children's National Medical Center, Washington, D.C., USA

CASE #1: POST-TRAUMATIC SAGITTAL IMBALANCE

Pediatric:

J Pediatr Orthop. 2011 31(7):741-4. Arkader A et al Pediatric Chance fractures: a multicenter perspective.

J Pediatr Orthop. 2009 29(7):713-9. Vander Have KL et al. Burst fractures of the thoracic and lumbar spine in children and adolescents.

Adult:

Spine (Phila Pa 1976). 2008 Apr 20;33(9) 1006-17.Stadhouder A et al. Traumatic thoracic and lumbar spinal fractures: operative or nonoperative treatment: comparison of two treatment strategies by means of surgeon equipoise.

Clin Orthop Relat Res. 2012 Feb;470(2):567-77. Gnanenthiran SR, Adie S, Harris IA Nonoperative versus operative treatment for thoracolumbar burst fractures without neurologic deficit: a meta-analysis.

Late Treatment:

Spine 2008 Apr 20;33(9):1006-17 Xi YM et al. Correction of post-traumatic thoracolumbar kyphosis using pedicle subtraction osteotomy.

Spine 2012 Sep 1;37(19):1667-75. Kim KT et al. Outcome of pedicle subtraction osteotomies for fixed sagittal imbalance of multiple etiologies: a retrospective review of 140 patients.

Spine 2005 Jul 15;30(14):1594-601.

Saraph VJ et al. Evaluation of spinal fusion using autologous anterior strut grafts and posterior instrumentation for thoracic/thoracolumbar kyphosis.

CASE #2: POST-INFECTIOUS SAGITTAL MALALIGNMENT

Spine J. 2011 Aug;11(8):726-33. Li M et al. One-stage surgical management for thoracic tuberculosis by anterior debridement, decompression and autogenous rib grafts, and instrumentation.

J Pediatr Neurosci. 2011S101-8. Kumar R et al. Surgical management of Pott's disease of the spine in pediatric patients: A single surgeon's experience of 8 years in a tertiary care center.

J Spinal Disord Tech. 2007 Jun;20(4):263-7. Zhang HQ et al.One-stage surgical management for multilevel tuberculous spondylitis of the upper thoracic region by anterior decompression, strut autografting, posterior instrumentation, and fusion.

CASE #3: PJK AFTER SPINAL INSTRUMENTATION IN NEUROMUSCULAR PATIENTS

Spine 2003 Jul 1;28(13):1396-403. Sink EL et al. Maintenance of sagittal plane alignment after surgical correction of spinal deformity in patients with cerebral palsy.

Spine 2012 Apr 1;37(7):583-91. Lonstein JE et al. Results and complications after spinal fusion for neuromuscular scoliosis in cerebral palsy and static encephalopathy using luque galveston instrumentation: experience in 93 patients.

J Bone Joint Surg Am. 2010 3;92(15):2533-43. Bess S et al. Complications of growing-rod treatment for early-onset scoliosis: analysis of one hundred and forty patients.

Notes

Combined Afternoon Session 2:
Adult Sagittal Deformity:
Etiology, Identification, Classification & Outcomes

Moderators:

Sigurd H. Berven, MD & Khaled Kebaish, MD

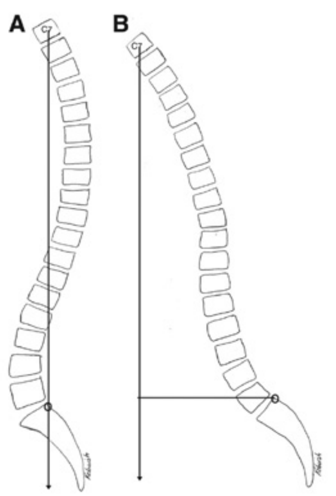
Faculty:

Sigured H. Berven, MD; Charles H. Crawford, III, MD; Marinus De Kleuver, MD, PhD; John Dimar, II, MD; Youssry M.K. El- Hawary, MD; Munish Chandra Gupta, MD; Kamal N. Ibrahim, MD, MA, FRCS(C); Khaled Kebaish, MD; Ronald A. Lehman, Jr., MD; David W. Polly Jr., MD; Frank J. Schwab, MD; Mark Weidenbaum, MD

The Etiology of Positive Sagittal Balance Within the Aging Population

Khaled M Kebaish, MD
John Hopkins Unviersity
Baltimore, Maryland, USA

A balanced spine has the head positioned and centered over the pelvis and sacrum. Numerous methods are used to more accurately evaluate the degree of sagittal spinal balance. The best-known radiographic marker is the C7 plumb line. Typically, a plumb line dropped from the center of the C7 vertebral body should fall over the posterior corner of the L5-S1 disk space at the lumbosacral junction (Fig. 1). It is of paramount importance to obtain a lateral full-length film with the patient standing, the hip and knees extended, the elbows flexed, and the hands touching the anterior aspect of the shoulders. Patients with a plumb line that falls anterior to this point are considered to be in positive sagittal balance, while those with the plumb line falling posterior to this point are considered to be in negative sagittal balance. However, some studies disagree on exactly how much anterior variance constitutes sagittal imbalance (range, 2-5 cm). Nonetheless 2 cm has become the clinical standard. Most radiographic studies of normal spines generally indicate that most normal lordosis occurs at the lumbosacral junction, from L4 to S1, the normal range of lumbar lordosis varies greatly. In a study of 102 asymptomatic adolescents (mean age, 12.8 years), Bernhardt and Bridwell found that the average lordosis was 44°, with a range of 4° to 69°. Stagnara et al found similar values for lordosis in 100 volunteers aged 20 to 29 years. However, Jackson and McManus radiographically compared 100 asymptomatic patients with 100 symptomatic patients. These 2 groups were matched for age (mean age, 38.9 and 39.4 years, respectively), weight, sex, and height. The degree of lumbar lordosis was significantly different: 60.9° vs 56.3°, respectively.



(Fig 1) Diagram showing the C7 plumb line. (A) A plumb line dropped from the center of the C7 body should intersect the posterior superior corner of the L5-S1 disk space. (B) With a positive sagittal balance alignment, the plumb line lies anterior to this point

The frequency of fixed sagittal plane deformities being seen by spine surgeons is increasing. These deformities have numerous etiologies in the older population, including degenerative causes, iatrogenic causes (such as previous fusion or wide decompressive lumbar laminectomies), ankylosing spondylitis as well as adult presentation of adolescent idiopathic scoliosis. In an attempt to reestablish sagittal balance, most patients stand and walk with hips and knees flexed. Over time, this posture may lead to fixed flexion contractures. This fixed positive sagittal imbalance will lead to substantial biomechanical stresses in the spine with accelerated disk degeneration, stenosis, additional spinal decompensation, and impaired overall function. This presentation reviews the normal ranges of sagittal plane alignment and addresses the most common causes of fixed positive sagittal imbalance.

Causes Positive Sagittal Balance Within the Aging Population

Positive sagittal balance can result from one or more of the following causes:

1. *Multiple levels spinal canal stenosis.* This one of the most common etiologies in the elderly population. Often patients with significant lumbar spinal canal stenosis tend to stoop forward to relieve some of their stenosis symptoms. Early on, their positive sagittal balance is not fixed, but over time patient may develop progressive degenerative changes leading to more fixed positive sagittal balance.
2. *Short or long segment lumbar fusions without restoration of lumbar lordosis*. Iatrogenic sagittal spinal deformities are often caused by a shortened anterior column, a lengthened posterior column or both. Obtaining adequate lumbar lordosis during spinal fusion starts by proper patient's positioning with the patient prone using the OSI frame, with the hips extended and the pads underneath the iliac crest. It may also be related to inadequate posterior release, or for not performing adequate facetectomy or Ponte type osteotomies when indicated. Choosing the proper level to stop the fusion at as well as contouring the rods are also important technical factors.
3. *Scoliosis progression in adult patients.* There is often associated sagittal plane deformity in patients with degenerative de novo scoliosis that does progress over time. Although large adolescent idiopathic curves can progress at a rate of 1° per year into adulthood, degenerative adult scoliosis is associated with a greater progression rate of up to 3.3° per year. With scoliosis, curve progression often leads to exacerbated coronal and sagittal imbalance.

4. *Degenerative changes below a long fusion, particularly at the lumbosacral spine*. As in patient with prior AIS fused to the upper lumbar spine. This can also be seen following fusions for Scheuermann's Kyphosis.
5. *Postlaminectomy kyphosis.* When multiple levels laminectomy is performed in patients with some degree of segmental instability especially in the sagittal plane. Excessive or overzealous lumbar laminectomy can lead to a compromised posterior tension band. A common mistake is to perform a multilevel laminectomy in a patient with inadequate preoperative lumbarlordosis; doing so invariably leads to additional fixed sagittal plane deformity
6. *Fractures above or below a long fusion.* This is one of the more common causes for revision surgeries. As these patients tend to quickly decompensate and may develop neurological symptoms.
7. *Posttraumatic deformities.* Especially following fractures in the lumbar or thoracolumbar spine and when there is a significant kyphotic deformity that was not addressed, either with nonoperative treatment, or when adequate restoration of normal regional alignment was no achieved when surgery was performed. Patients with posttraumatic deformities may present many years after the initial injury with significant sagittal plane deformity.
8. *Osteoporotic deformities.* This is becoming an increasingly common problem in the aging population, given increasing number of patients undergoing surgical treatment for spinal problems at an older age. These deformities can be particularly challenging to treat surgically .
9. *Inadequate anterior column support when indicated.* Restoration of the anterior column especially at the lumbosacral junction when indicated. It is important to restore adequate lumbar lordosis and prevent the development of pseudoarthrosis.
10. *Pseudarthrosis in long posterior spinal fusions.* As with any fusion surgery, pseudarthrosis can lead to interbody graft resorption and implant failure, with subsequent disk height collapse and kyphosis.
11. *Harrington posterior distraction instrumentation.* Used to be of the more commonly encountered causes of positive sagittal plane deformities, because it causes lengthening of the posterior column. This is less frequently seen nowadays, given that most of those patient where done over 25 years ago and many of them have already undergone corrective surgery. However this used to be one of the most common causes especially in fusion extending into the lumbar spine.
12. *Ankylosing spondylitis.* More often seen in the 4th and 5th decade of life. It may be encountered in older patients especially after sustaining a fracture through their osteoporotic ankylosed spine. Patients with ankylosing spondylitis typically have decreased lumbar lordosis and increased cervical and thoracic kyphosis, which lead to the fixed and often severe positive sagittal imbalance.
13. *Older generations anterior instrumentation.* Anterior column shortening, such as with older anterior instrumentation (Zeilke and Dwyer). Used to be one of the common causes. Newer segmental more rigid anterior systems are less like to cause this problem.

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Notes

What are the Available Preoperative Measurement and Classification Techniques: Are They Effective and Useful?

Frank J. Schwab, MD
Clinical Professor, Department of Orthopedic Surgery
New York University Hospital for Joint Diseases

Evolution of radiographic analysis for spinal deformity

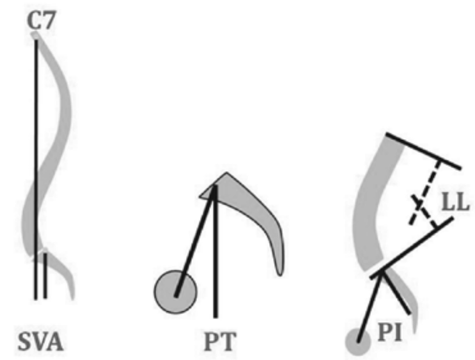
In the past, pediatric spinal deformity was most commonly defined by the presence of scoliosis, and thus, radiographic analysis for spinal deformity was chiefly based on deformity in the coronal plane, with the Cobb angle being the defining aspect of the deformity pattern. In the setting of adolescent idiopathic scoliosis (AIS) and adult spinal deformity (ASD), previous radiographic analysis provided surgeons with information regarding the severity of the curve and aided in the treatment decision. If curves were severe, early instrumentation systems relied on correcting the coronal deformity via distraction. The consequence of merely addressing deformity in the coronal plane was a significant rate of sagittal plane malalignment, which over time could develop into flat-back syndrome. However, an increased awareness about the three-dimensional characteristics of spinal deformity has since changed surgical approaches and has resulted in radiographic analysis to include sagittal standing views and appreciation of the axial plane as well.

While spinal deformity evaluation in the past focused on the spine as a distinct entity, research illuminating the global nature of spinal deformity resulted in the gradual incorporation of spino-pelvic parameters into radiographic analysis. The pelvic vertebra concept, in which the entire pelvis can be considered as one unique vertebra, underscored the importance of the pelvis in global alignment and truncal positioning.[1] Legaye et al found a relationship between spinal sagittal balance and pelvic orientation.[2] Furthermore, Jackson et al found lumbar lordosis and sagittal vertical axis to be the reliable radiographic assessments for evaluating sagittal balance.[3] Finally, Lafage et al reported the fundamental role of the pelvis as the main regulator in a chain of correlation between the spine and the lower limbs.[4] Based on these findings, radiographic analysis evolved to include several key spino-pelvic parameters in the evaluation of spinal deformity.

Spino-pelvic parameters:

- **Sagittal vertical axis (SVA):** the offset from the plumb line of the C7 vertebra and to the posterior-superior corner of the sacral end plate.
- **Pelvic tilt (PT):** the angle between a line drawn from the center of the femoral head axis to the midpoint of the sacral plate and the vertical.
- **Pelvic incidence minus lumbar lordosis (PI-LL)**: the difference between the angle measurement of PI and the angle measurement of LL.

* **PI:** the angle between a line drawn from the center of the femoral head axis to the midpoint of the sacral plate and the perpendicular to the sacral plate.
* **LL:** the angle between the plane defined by the superior S1 plate and the superior L1 plate.



Sagittal spino-pelvic parameters used for the evaluation of spinal deformity

Correlating radiographic measures with HRQOL

Spino-pelvic parameters have provided a guide for patient assessment and surgical planning and have been found to be highly correlated with the pain and disability of patients.[4, 5] The negative impact of sagittal malalignment with regard to disability, pain, and poor health related quality of life (HRQOL) has been well documented.[6-9, 4, 10, 11] This has lead to the development of threshold values of spino-pelvic parameters for pain and severe disability. In a cohort of patients with ASD, values of PT greater than 22º, PI-LL greater than 11º, and SVA greater than 46mm have been shown to correlate with Oswestry Disability Index (ODI) scores greater than 40, signifying severe disability.[12] Based on these findings, surgical realignment guidelines have been developed to improve spino-pelvic parameters and ultimately decrease pain and disability for patients.

Surgical realignment guidelines:

- SVA <50mm
- PT < 20º
- LL=PI +/-9º

Preoperative surgical planning is essential to predict optimal postoperative parameters and advanced spino-pelvic alignment formulas have been developed to ensure improved operative outcomes. The spino-pelvic realignment formulas use the surgical realignment guidelines above to classify whether outcomes are successful or unsuccessful. Current formulas have been validated to predict an unsuccessful outcome, however, preoperative surgical planning should be improved in order to predict successful outcomes.[13] It is anticipated that the use of spino-pelvic alignment formulas will lead to better surgical planning and improved outcomes for patients with spinal deformity.

Building on measurements to develop classification systems

In the setting of spinal deformity, classification systems have been created to assess the extent of spine deformity, evaluate severity, and offer a framework for surgical treatment. Ideally a classification system would also guide the need (or likelihood) for surgical treatment (prognostic value), and assist in planning for surgical realignment. Classification systems in the spinal field have traditionally been oriented towards adolescent idiopathic scoliosis (AIS). In the past, the King-Moe classification for AIS has been the standard classification system to describe scoliosis.[14] This classification system provided a treatment algorithm based on five different curve types and remained the principal classification system for more than 20 years. However, the King-Moe classification system was not comprehensive and solely evaluated deformity in the coronal plane, failing to recognize the three-dimensional nature of scoliosis.[15] Furthermore, the King-Moe classification system was found to have poor inter- and intra-observer validity, reliability, and reproducibility.[16, 17]

In response to these shortcomings, the Lenke classification system was developed.[18] The Lenke classification system is comprehensive and evaluates deformity in the coronal and sagittal planes. It describes three curve regions (proximal thoracic, main thoracic, and thoracolumbar/ lumbar) and two curve types (major curve and minor curve). The Lenke classification system has been widely adopted for the evaluation and treatment of AIS.

Further research on AIS found that growth in childhood and puberty has a major effect on the severity of spinal curvature, resulting in the need for surgery. Dimeglio et al found that at the beginning of puberty, a curve of above 30º at the onset of puberty or a curve progression of greater than 10º per year results in a 100% surgical risk.[19] These parameters, in addition to the Lenke classification system, allow surgeons to easily evaluate pediatric and adolescent patients with (AIS) spinal deformity.

Evolution of adult deformity classification systems

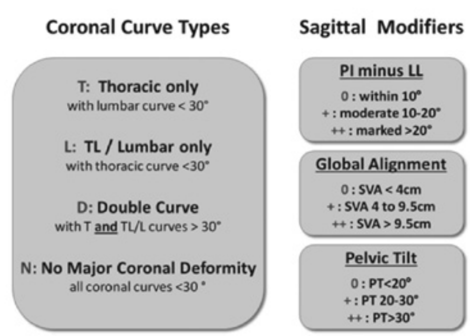
Although AIS receives substantial attention, ASD is poorly understood and classified. Unlike AIS, there has until recently been no widely accepted classification system that provided clinical impact categories and prognostic value or guidelines for the surgical treatment of ASD. Evaluation for AIS is based purely on radiographic data as these pediatric patients are generally asymptomatic. ASD evaluation however, is driven by clinical symptoms and thus evaluation is based both on radiographic data as well as disability. Furthermore, while AIS deformity is most common in the coronal and axial planes, ASD presents in the coronal, axial, and importantly the sagittal plane as well. Malalignment in the sagittal plane has been correlated with significant pain and disability for the ASD population, thus, these clinical symptoms are essential for understanding adult deformity.

Historic classifications for ASD tended to neglect the evaluation of sagittal spinopelvic parameters and thus lacked clinical relevance. The Aebi classification system composed of 4 groups based on etiology and was difficult to use for prognosis and treatment planning. [17] An earlier SRS classification proposed a system using 7 curve types (6 coronal and 1 sagittal) and 3 modifiers (regional sagittal modifier, lumbar degenerative modifier, and global alignment modifier). [18] These early classification systems described radiographic parameters; however, they failed to integrate the clinical component of pain and disability in its correlation with x-ray findings for patients with ASD.[20, 21]

_ENREF_16 A new classification system was thus pursued through an improved method to categorize patients according to drivers of pain and disability for adults with spinal deformities. The initial Schwab classification system integrated radiographic parameters with HRQOL parameters.[22] It described five types of scoliosis based on the apical level of the curve (type I, thoracic only; type II, upper thoracic major; type III, lower thoracic major; type IV, thoracolumbar major curve; type V, lumbar major curve). Furthermore, it incorporated sagittal modifiers, such as LL and intervertebral subluxation, which correlated with HRQOL modifiers and denoted the clinical component of the classification. This system was reported to be both clinically relevant and reliable. Furthermore, it was used as a prediction model for surgical outcomes and complications after ASD surgery.

The original Schwab classification integrated SVA, the offset from the C7 plumbline to the posterosuperior corner of S1, into the system because it was also found to be a predictor of poor HRQOL. However, further research found that LL and SVA alone did not provide a complete picture of global sagittal malalignment. The classification system was thus revised in a multicenter effort with incorporation of pelvic parameters, which have been found to play a fundamental role in the radiographic evaluation of patients with spinal deformities.[23-26, 11, 27, 4, 10]

The SRS-Schwab classification system:



Guide to the classification system, including curve type and 3 sagittal modifiers.

Is the SRS-Schwab classification system useful and effective?

The SRS-Schwab classification system is clinically relevant, reliable, and useful for the evaluation of spinal deformity and the prediction of operative outcomes. The classification system has improved clinical relevance over previous classification systems because it includes the spino-pelvic parameters highly correlated with HRQOL scores. Moreover, it improves the description of deformities and allows for a global assessment of spinal deformity. This Classification system has also shown excellent inter and intra-observer reliability on pre-marked and unmarked x-rays for curve type and each modifier. [28] By using the Classification system, it is possible to accurately evaluate and classify the severity of the deformity in clinically relevant terms (disability/pain), which is essential for the assessment of spinal deformity and surgical planning.

Conclusion

There has been much advancement in the radiographic analysis and classification of spinal deformity, particularly in the setting of ASD. There have been marked improvements in measurement validation, resulting in a reliable classification system for the assessment of spinal deformity. Large multicenter efforts have demonstrated the effectiveness, reliability, and clinical usefulness of the SRS-Schwab Classification system. Thus, the Classification system allows for an effective guide to surgical treatment. Further evolution of classification systems will include surgical modifiers to better predict operative outcomes. In the near future, it is anticipated that predictive formulas using the Classification system modifiers will lead to better surgical planning and improved outcomes for patients with spinal deformity.

Currently, efforts to understand additional sagittal parameters are in evolution. These include parameters that combine SVA and PT, such as the T1 pelvic angle, measured by the angle between the hips-T1 line and the hips-S1 endplate line, which will allow for a more comprehensive analysis of spinal deformity. The future of the assessment and classification of spinal deformity will also include more advanced imaging techniques, such as EOS imaging, which takes a radiographic image of the entire body, from head to foot. This will enable radiographic analysis of the entire body and allow for the assessment of other parameters, such as feet and lower extremities. The EOS imaging shows the full axis, which is an integral tool in the creation of a three-dimensional representation of the spine. Though the impact of three-dimensional analysis of spinal deformity is uncertain, it is anticipated that it will be useful in evaluating deformities in the coronal, sagittal, and axial planes. Finally, the future of classification efforts aim to personalize the assessment and classification of spinal deformity, which will allow for the combination of radiographic images, HRQOL scores, patient expectations, and risk/benefit patient choices for the optimal treatment of spinal deformity on a patient-by-patient basis.

Key Facts:

- The radiographic analysis of spinal deformity has evolved to include the sagittal plane.
- The pelvis plays a key role in regulating global alignment, especially between the spine and lower extremities.
- Spino-pelvic parameters correlate with Health Related Quality of Life (HRQOL) survey scores and can be used to predict pain and disability.
- The SRS-Schwab Classification system incorporates spino-pelvic parameters and can be used to plan the surgical correction of spinal deformity.
- With the additional knowledge of the importance of radiographic parameters, physicians will be able to make more informed decisions on a patient-by-patient basis.

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Notes

Can Prospective Operative Planning Prevent a Flatback Deformity in the Multiply Operated Low Back?

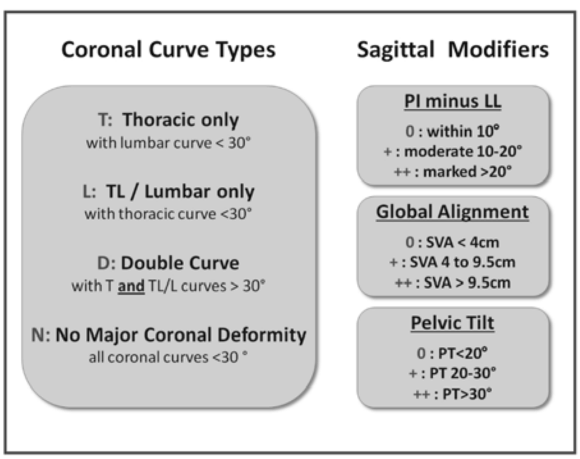
Sigurd Berven, MD
Professor in Residence
Department of Orthopaedic Surgery
UC San Francisco
San Francisco, CA, USA

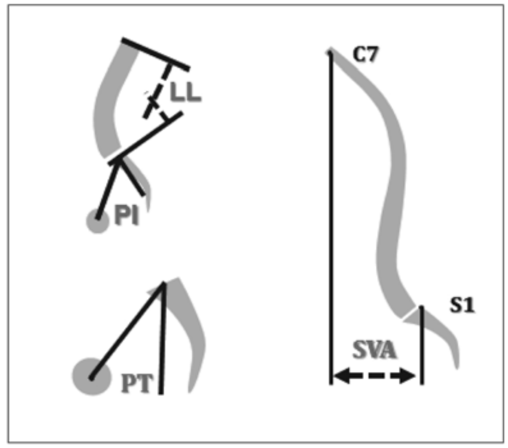
1. Goals of Deformity Correction:
   a. A clear definition of the goals of deformity correction is fundamental to execution of a plan intraoperatively.

"Those who plan do better than those who do not plan even thou they rarely stick to their plan."

- Winston Churchill

   b. Quantifying Goals of Deformity Correction:
      i. Segmental
         1. Restoration of trapezoidal intervertebral disc space
      ii. Regional
         1. Match Lumbar Lordosis to Thoracic Kyphosis
         2. Anticipate reciprocal thoracic changes
      iii. Global
         1. C7 Plumbline within 4cm of SVA
         2. T1 behind CG
         3. PT<20 degrees
   c. SRS-Schwab Adult Deformity Classification[1]
      i. A clinical-impact based classification of adult deformity





2. Post-operative Deformity
   a. Post-operative Deformities- Immediate post-op
      i. Flatback Deformity
      ii. Kyphotic Decompensation Syndrome
      iii. Coronal deformity
      iv. Rotational Deformity
   b. Incidence
      i. Variable over time
      ii. Role of segmental fixation
      iii. Recognition of sagittal parameters
   c. Cost of Care
      i. Incidence of revision surgery
3. Pre-operative Planning
   a. Priority of 36" standing films
   b. Flexibility Classification[2]
      i. Flexible
      ii. Stiff
      iii. Fixed
   c. Techniques and Resources for Pre-operative Planning
      i. Pre-operative Case Conferences
         1. The value of collaboration
      ii. Trigonometric Method[3]
         1. Utility and Limitations
      iii. FBI Technique[4]
         1. Utility and Limitations
      iv. Computer assisted Planning
         1. Surgimap[5]
4. Evidence for Utility of Pre-operative Planning

a. Accuracy of Mathematical Modelling[6]

b. Limitations of Modelling due to reciprocal changes[7]

5. Case Presentations

(Endnotes)

1 Schwab F, Ungar B, et al: SRS-Schwab Adult Deformity Classification System: A Validation Study.

Spine 27(12):1077-1082, 2012

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Notes

Post-Surgical Proximal Junctional Kyphosis: Etiology and Avoidance Techniques

David W. Polly, Jr. MD
Professor and Chief of Spine Surgery
University of Minnesota
Minneapolis, MN, USA

Definition of Terms:

- Proximal Junctional Kyphosis (PJK)
  - * Proximal junction sagittal cobb angle ≥10°
  - * Proximal junction sagittal cobb angle at least 10° greater than pre-op measurement
- Proximal Junctional Failure (PJF)
  - * "topping-off syndrome"; Proximal junctional acute collapse; Fracture of vertebra on top of long pedicle construct
  - * Subset of PJK patients who are more debilitated
    - ◊ Increased pain
    - ◊ Spinal instability
    - ◊ Risk of neurologic injury
    - ◊ Need for revision surgery
- Categorical Causes for Junctional Kyphosis
  - * Osteoporotic fracture
  - * Adjacent segment soft tissue disruption
  - * Under correction of existing deformity
  - * Over correction of existing deformity
- Risk Factors for Proximal Junctional Pathology
  - * Age > 55yo
  - * Osteopenia (low BMD)
  - * Obesity
  - * Neurologic conditions (e.g. Parkinson's)
  - * Increased sagittal malalignment at presentation
  - * Combined AP surgery
  - * Use of rigid instrumentation in long fusions (e.g. segmental pedicle screw fixation, fusion to sacrum)
  - * In the elderly, overcorrection of sagittal plumbline
- Osteoporotic Fracture
  - * Okuyama Spine 2000
    - ◊ Threshold BMD for screw purchase
    - ◊ Stable = 0.974 gm/cm2
    - ◊ Loosening <0.752 gm/cm2
    - ◊ Fracture <0.545 gm/cm2

- Strategies to Avoid Screw Loosening
  * Bigger
  * Longer
  * Bicortical
  * Vertebral augmentation
- Strategies to Avoid Fracture
  * Pre-op medical optimization (teriparatide)
  * Minimum 3 months?
  * Less stiff construct?
  * End segment and adjacent segment vertebral augmentation
- Over Correction/Under Correction
  * Goal is a stable, balanced spine, in the sagittal and coronal planes fusing as few motion segments as possible
  * Balanced sagittal correction remains a challenging goal requiring matching the native fixed pelvic parameters of the patient to the rest of the spine
- Sagittal Plane Correction in the Eldery
  * Mendoza-Lattes:
    ◊ the more positive the sagittal balance the lesser the risk of PJK
    ◊ Plumbline to 0 may be an overcorrection
- Best Data To Date
  * Pelvic incidence = lumbar lordosis + 10 degrees (advocated by Schwab ISSG and others)
  * Roger Jackson estimation technique
- Does Type of Correction/Osteotomy(ies) Matter?
  * Focal over correction (VCR/PSO)
  * Segmental harmonious correction (multiple SPO's)
- Do Correction Mechanics Matter?
  * Rod cantilever
  * Centripetal compression
  * Table based (or manual manipulation)
- What Would A Clinical Trial Need to Look Like? For Correction Mechanics
  * Age and sex matched similar sagittal deformity
  * BMD matched
  * Same fusion levels
  * Same surgical strategy (posterior only vs. anterior posterior)
  * Same osteotomy strategy
  * Only 2 differences
- My Current Strategy?
  * Optimize bone density preop- teraperatide
  * Multiple points of fixation including iliac (S2AI)
  * Interbody support at the base
  * More than 2 rods across a PSO or VCR
  * If screw insertional torque is 'soft' the cement augmentation
  * Vertebroplasty at the level above
  * #5 Ticron suture spinous process UIV to level above

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Notes

Are Sagittal Plane Re-Alignment Procedures Cost Effective?

Charles H. Crawford III, MD
Adult and Pediatric Spine Surgeon
Norton Leatherman Spine Center
Assistant Professor, Department of Orthopaedic Surgery
University of Louisville
Louisville, KY, USA
chcraw01@gmail.com

Acknowledgement of contributions:
Jacob M. Buchowski, MD, MS and Keith H. Bridwell, MD
Washington University in St. Louis

Introduction

- Changes in societal expectations regarding health care delivery have increased the demand for cost effectiveness studies.
- The willingness of governmental agencies and private insurance companies to pay for surgical treatments will increasingly rely on proof of cost effectiveness (i.e. that the benefit to the patient is worth the monetary cost of the treatment).
- As you may guess, this is not as simple as it seems. This presentation will briefly review the terminology and calculations that are commonly used to determine cost-effectiveness.
- Sagittal plane re-alignment procedures will then be analyzed as an example.

Terminology

Quality Adjusted Life Year (QALY) =
Measures both quantity and quality of life gained. Can be used to compare various treatments for various diseases. Typically as spine surgeons we are improving quality of life and not necessarily quantity of life. Reduced pain and disability is considered an improved quality of life. – **Good news for much of what we do in spine surgery!!!**

QALY calculations consider duration of improvement in addition to improved quality of life. **– Treatment effects that last many years (durability) accumulate value in an additive fashion.**

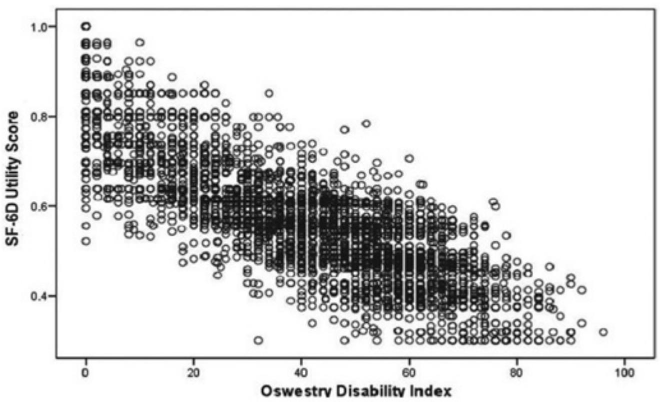
Pain, mobility, general mood, and other factors are considered when measuring quality of life. Ratings can range from negative values below 0 (worst possible health) to 1 (the best possible health). Death is typically considered as a value of 0 with some disease states considered worse than death by some health care economists. **– Calculated using patient reported outcome measures (EQ-5D, SF-36/SF-6D, ODI/NRS).**

In the United Kingdom, treatments are typically considered cost effective if they are less than 20,000 – 30,000 British Pounds per QALY.

Adapted from http://www.nice.org.uk

Prior Relevant Work

- In the United States, a threshold of **$50,000 per QALY** has been commonly used since the early 1990's partially based on the cost of dialysis treatment for end-stage renal disease. Others suggest **$100,000 per QALY** may be a more realistic threshold.
- Direct costs of treatment are frequently based on the Medicare fee schedule. Indirect costs can be calculated based on loss of work productivity, etc...
- Carreon LY, Glassman SD, McDonough CM, Rampersaud R, Berven S, Shainline M. Predicting SF-6D utility scores from the Oswestry disability index and numeric rating scales for back and leg pain. Spine (Phila Pa 1976). 2009 Sep 1;34(19):2085-9.



- Glassman SD, Polly DW, Dimar JR, Carreon LY. The cost effectiveness of single-level instrumented posterolateral lumbar fusion at 5 years after surgery. Spine (Phila Pa 1976). 2012 Apr 20;37(9):769-74.
    * total cost (direct and indirect) per QALY gained ranged from $53,949 to $53,914 at 5 years postoperatively
- Adogwa O, Parker SL, Davis BJ, Aaronson O, Devin C, Cheng JS, McGirt MJ. Cost-effectiveness of transforaminal lumbar interbody fusion for Grade I degenerative spondylolisthesis. J Neurosurg Spine. 2011 Aug;15(2):138-43.
    * total cost per QALY gained for TLIF was $42,854 when evaluated 2 years after surgery
- Adogwa O, Parker SL, Shau DN, Mendenhall SK, Devin CJ, Cheng JS, McGirt MJ. Cost per quality-adjusted life year gained of laminectomy and extension of instrumented fusion for adjacent-segment disease: defining the value of surgical intervention. J Neurosurg Spine. 2012 Feb;16(2):141-6.
    * 2-year cost per QALY gained of $62,995

Input determines Output – variability in current clinical practice

- Sagittal realignment procedures are likely to be cost effective, when the effectiveness of the surgery is increased and/or the cost is decreased.
  Cost/QALY < $50,000 - $100,000
- Increase effectiveness:
    * Patient selection
        - ◊ Potential benefit > potential risk
        - ◊ Need to start with substantial disability
        - ◊ Need to be healthy enough to tolerate proposed surgery
    * Surgical planning
        - ◊ How aggressive to be with osteotomies, interbodies, etc…?
    * Technical execution
        - ◊ Implant positioning
        - ◊ Decompressions/Osteotomies
        - ◊ Deformity correction
        - ◊ Fusion
    * Durability
        - ◊ Avoid infection
        - ◊ Avoid pseudoarthrosis
        - ◊ Avoid junctional breakdown
- Decrease cost:
    a. Minimize staged surgery/number of procedures/materials cost
    b. Minimize complications
    c. Durability

Notes

What Patient Outcomes Data is Available to Justify the Use of Major PSO Procedures for the Restoration of Sagittal Alignment vs. Conservative Treatment?

Mark Weidenbaum, MD
Columbia University
New York, New York, USA

- Goals of PSO Surgery
  - * Pain relief/functional improvement
  - * Prevent curve progression
  - * Restore global balance
- Assessment of Patient Outcomes Data
  - * Many outcomes instruments
  - * Assess:
    - ◊ Physical function
    - ◊ Pain
    - ◊ Activity
    - ◊ Self-Image
    - ◊ Mental Health
    - ◊ Disability
    - ◊ Other – Social function, vitality, etc
- Global sagittal malalignment clearly significantly impacts the patient
  - * Outcomes measures show significant impact on HRQOL [1, 2]
    - ◊ High degree of correlation between positive sagittal balance and: SF-12 Physical Health Composite Score (PCS), SRS-29 scores (Pain, Activity, Total) , and Oswestry Disability Index (ODI)
  - * Pelvic Tilt [3]
- Non-operative treatments do not change HRQOL significantly
- Patient Outcomes Measures - Evidence in favor of PSO[4-19]
  - * Preop → Postop:
    - ◊ ODI 47.9 to 29.7 [14]
    - ◊ ODI 49 to 24, SRS(Total 48% to 75%, Pain 11 to 16, Self-image 11 to 19, Function 10 to 17, Satisfaction 8.7) [8]
    - ◊ SRS (Pain 2.4 to 3.5, Self Image 2.3 to 3.5, Function 2.6 to 3.2, Subscore 2.4 to 3.4)[15]
    - ◊ ODI 44 to 29.6, SRS 30 2.76 to 3.54, SF12 PCS 30.4 to 35.4[16]
- Difficulties with assessment of PSO results
  - * General predictors of poor surgical outcome [13]
    - ◊ Younger patients - depression/anxiety, smoking, narcotics, older age, BMI, and greater severity of pain
    - ◊ Older patients - depression/anxiety, narcotics, BMI, and greater severity of pain
    - ◊ Conclusion - baseline and perioperative factors distinguishing between patients with best and worst outcomes were predominantly patient factors (BMI, depression/anxiety, smoking and pain severity) not comorbidities, severity of deformity, operative parameters or complications
  - * Sagittal realignment failures [20]
    - ◊ Although 77% successful, 23% had failed realignment
    - ◊ Risk factors for failed realignment:
      - » ↑ preoperative SVA, PT, PI, and greater lumbar lordosis pelvic incidence mismatch
    - ◊ Conclusion
      - » Failed realignment patients received similar amounts of correction as those in the successfully aligned group
      - » Single PSO may not achieve optimal outcome in patients with high preop spinal pelvic malalignment, and these patients perhaps should receive larger osteotomies or additional corrective procedures beyond PSO
  - * Posterior malalignment after osteotomy for sagittal plane deformity [21]
    - ◊ 76 adult patients , PT > 20, LL-PI mismatch > 10 degrees, divided into SVA <50 or > 50 (anterior, posterior groups)
    - ◊ Patients with posterior alignment were younger, with lower preop PI and PT as well as SVA as well as cervical lordosis.
    - ◊ Conclusion - significantly lower PI and lack of restoration of thoracic kyphosis mainly to sagittal over-correction with a posterior alignment
  - * Different parameter inclusions lead to different analyses – Spine, Pelvis (static/dynamic), Unfused segments
    - ◊ LL ≥ TK + 20°[8]
    - ◊ PSO angle = atan (y/z)[22, 23]
    - ◊ LL + PI + TK ≤ 45°[24]
    - ◊ LL > PI - 10°[11]
    - ◊ Other [3, 25]
- Complications
  - * Three Column Osteotomies - [15]

- ◊ Major complications occurred in 35% (24.8% major surgical complications, 15% major medical complications)
- ◊ Risk factors for major complications - sagittal imbalance > 40 mm, age > 60, and three or more medical co-morbidities.
- ◊ A major complication did not affect the ultimate outcome at two years

* Revision Procedures - [26]
  - ◊ 34% of patients developed major complications
  - ◊ Risk factors for peri-op complications – age, 60, medical co-morbidities, obesity and pedicle subtraction osteotomy
  - ◊ Occurrence of a follow-up, but not peri-operative, major complication had negative impact on ultimate clinical outcome.
* Fusion to the Sacrum - [27]
  - ◊ Retrospective study of 103 consecutive patients fused long to pelvis 2003-2007
  - ◊ 4% mortality!
  - ◊ 12% had at least one major medical complication (4 MI, 4 PE, 4 ARDS, 4 pneumonia, 3 ARF, 3 CVA, 1 blindness)
  - ◊ 17% had a **documented new persistent neurological deficit** still present at final clinic visit
  - ◊ 35% underwent at least one unplanned return to the OR (infection, ASD, nonunion, etc)
* Neurologic Compromise with PSO - [28]
  - ◊ 11% (2.8% permanent) intraoperative and postoperative deficits (motor loss of 2 grades or more or loss of bowel/bladder control)
  - ◊ Intraoperative neurologic-monitoring did not detect the deficits which required revision with central enlargement and further decompression.
  - ◊ Deficits likely due to a combination of subluxation, residual dorsal impingement, and dural buckling
  - ◊ Intraoperative or postoperative neurologic deficits are relatively common following a PSO; however, in a majority of cases, deficits are not likely to be permanent
* Rod Fracture [29]
  - ◊ symptomatic rod fracture in 15.8% of PSO patients (stress at PSO level)
    - » 7% for cobalt chromium, 17% for stainless steel, and 25% for titanium.
  - ◊ Suggestions
    - » Place third rod spanning the PSO
    - » Plate benders (instead of French rod benders) may help reduce fractures.
* Elderly (> age 60)
    - » 18% major complications with PSO, but significant improvements in all 5 Scoliosis Research Society-22 domains and in ODI at final follow-up. [7]
    - » PSO can achieve significant restoration of sagittal and coronal balance and significant improvement in quality of life, but can lead to serious complications and should be selectively used
  - ◊ Improvements are similar in patients > 65 to those <55 in SRS subscores, SF-12 PCS, and MCS [4]
    - » Properly selected patients > 65 years of age with substantial sagittal imbalance can obtain as much clinical benefit as their younger counterparts 2 years following spinal deformity surgery that requires fusion from the thoracic spine to the sacrum

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Notes

Case Presentation: Anterior/Posterior Surgery vs. Posterior Based Surgery for Adult Sagittal Imbalance: Are Treatment Techniques Similar Globally?

Munish Chandra Gupta, MD
University of California – Davis
Sacramento, CA, USA

Case 1

A 64 year old male with a history of a fall a year ago, suffered a T11, L1 and L3 fractures. He had progression of his kyphotic deformity and pain and was referred to our clinic. He is a builder by trade and stated that his pain in his thoracolumbar junction was affecting his work and his personal life. His past medical history included osteopenia, T5 fracture, scapular fracture and clavicle fracture. His examination revealed a thorocolumbar kyphotic deformity which was tender to palpation. Patient had intact motor and sensory exam in both lower extremities. No hyperreflexia

The surgical options include:

- Anterior and Posterior Fusion
- Multiple PSO's
- PVCR

Case 2

Patient is a 70 year old female with a long history of chronic back pain and scoliosis. Patient stated that her pain has been ongoing since 1995. Patient had a lumbar laminectomy in 1998, anterior/posterior spinal fusion from L-1 – L4 in 2003 and then in November of 2007 she had a thorocotomy and anterior and posterior fusion from T5 – L4. She had severe pain in her back and was leaning forward. She had radiating bilateral leg pain down to the feet. Patient had a very difficult time walking and was taking heavy narcotics such as oxycodone, morphine and Fentanyl patches. Past medical history included Osteoarthritis, adult scoliosis, depression. Her exam revealed a flat back posture with kyphosis in the lumbar spine. Her motor exam showed 5 of 5 strength and hip flexion, and hip extension, knee extension, and flexion. Her EHL on the left was 3 out of 5. Ankle plantar flexion and dorsal flexion was 5 out of 5 bilaterally.

Surgical options include:

- Anterior reconstruction of the L4 vertebral body and then a posterior spinal fusion with possible pedicle subtraction osteotomy above .
- Pedicle subtraction osteotomy at L4 or above.
- Vertebral column resection

Case 3

68 year old male who had a past medical history of hypertension, hypothyroidism, and osteoporosis, no neurologic disease, muscle disease or a collagen disorder. His physical exam revealed a severe rigid thoracic kyphosis. Lower Extemity motor sensory and reflex exam was normal. Patient had multiple surgeries in the cervical spine presenting with severe kyphosis of the thoracic spine, unable to see in front of him.

Notes

Case Discussion & Educational Program

The Scoliosis Research Society gratefully acknowledges DePuy Synthes Spine for their support of the Post-Meeting Webcast, Pre-Meeting Course, Half-Day Courses and overall support of the 48th Annual Meeting & Course.

DePuy Synthes SPINE

COMPANIES OF Johnson & Johnson

Hibbs Society Meeting• Tuesday, September 17, 2013 • 1:00-5:00pm

14Th Hibbs Society Program

Chair: Robert W. Gaines, Jr., MD
Room: Forum 1, Forum Level

Experimental Studies

1. TPS Hooks vs. Screws at the Top of Long Constructs in Pigs
   Donita I. Bylski-Austrow, PhD
2. Screw Misplacement in Patients: Clinical Study
   Marinus De Kleuver, MD, PhD
3. Hook Fixation on the Ribs in Pediatric Patients: Biomech Study
   Richard H. Gross, MD

Case Reports

1. Two Case of PJK
   Martin Gehrchen, MD, PHD
2. One Case of PJK
   Benny Dahl, MD, PhD, DMSci
3. Two Cases of PJK/PJF
   Charles H. Crawford, III, MD
4. Osteoporosis and PJK/PJF
   Hossein Mehdian, MD, FRCS(Ed)
5. Update on PJK/ PJF Prevention
   Khaled Kebaish, MD

Invited Speakers & Experts

1. Special Invited Expert: Current Concepts of PJK/PJF
   Mitsuru Yagi, MD, PhD
2. Prevention Paradigm for PJK/PJF
   Steven D. Glassman, MD
   SRS President-Elect

Case Discussion Program • Wednesday, September 18, 2013 • 4:45-5:45pm

These sessions are open to all Annual Meeting delegates. Pre-registration is not required and no additional fee applies.

The case discussion sessions allow an opportunity to present unique and challenging clinical cases to the SRS with a panel of experts present to review and discuss each case and the clinical issues that are highlighted, as well as answer questions from audience participants. The panels will also prepare case studies for presentation and discussion, as time allows. All of the following case discussion presentations were selected from those submitted through the abstract submission and review process. The full abstract can be found on page 197.

1. Cervical

Moderator: Stephen J. Lewis, MD, MSc, FRCSC
Panelists: Kuniyoshi Abumi, MD; Steven M. Mardjetko, MD, FAAP
Room: Bellecour 1, Bellecour Level

Cases for Discussion:

1A. Cranial Nerve Injury Following Cervicothoracic Fusion in Klippel-Feil Syndrome
Elias Dakwar, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD

1B. The Four Fixation Points of the Axis: Technique and Case Report
Kris Siemionow, MD; Steven M. Mardjetko, MD, FAAP

1C. Metatropic Dysplasia as the Cause of Atlantoaxial Instability, Spinal Stenosis and Myelopathy: Case Report and Literature Review
Michal Barna, MD; Jan Stulik, PhD; Petr Nesnidal, MD; Tomas Vyskocil, MD; Jan Kryl, MD

1D. Treatment for Progressive Cervical Hyperlordosis After Multilevel Cervical Laminectomy in a Patient with Intramedullary Lipoma: A Case Report
Taichi Tsuji, MD; Noriaki Kawakami, MD, DMSc; Tetsuya Ohara, MD; Yoshitaka Suzuki, MD; Toshiki Saito, MD; Ayato Nohara, MD; Ryo Sugawara, MD; Kyotaro Ota, MD

2. Complications and Congenital Scoliosis

Moderator: John T. Smith, MD
Panelists: Francisco J. Sanchez Perez-Grueso, MD; Justin S. Smith, MD, PhD; Michael G. Vitale, MD, MPH
Room: Forum 1, Forum Level

Cases for Discussion:

2A. Early Recognition of Overcorrection After Anterior Vertebral Body Tethering
Amer F. Samdani, MD; Anuj Singla, MD; Robert J. Ames, BA; Joshua M. Pahys, MD; Randal R. Betz, MD

2B. Acute Renal Infarction After Lateral Lumbar Interbody Fusion for Kyphoscoliosis
Sanjeev Suratwala, MD; Vincent Leone, MD

2C. A Case of Spondylocostal Dysostosis (Jarcho Levin Syndrome) with Complaints of Costopelvic Impingement
Terry D. Amaral, MD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Vishal Sarwahi, MD

2D. Posterior Thoracic Vertebral Column Resection with Spinal Shortening Promote Syringomyelia Shrinkage in an Adolescent of Severe and Rigid Kyphoscoliosis and Chiari Malformation
Jingming Xie, PhD; Yingsong Wang, MD; Ying Zhang, MD; Tao Li, MD; Ni Bi, MD; Zhi Zhao, MD

2E. Treatment of Severe Spinal Deformity and Diastematomyelia with Vertebral Column Resection
Elias Dakwar, MD; James T. Bennett, MD; Amer F. Samdani, MD

Case Discussion Program • Wednesday, September 18, 2013 • 4:45-5:45pm

3. Kyphosis

Moderator: Baron S. Lonner, MD
Panelists: Ahmet Alanay, MD; Michael P. Grevitt, FRCS; Yong Qiu, MD
Room: Bellecour 2, Bellecour Level

Cases for Discussion:

3A. Combined Anterior and Posterior Fusion with Instrumentations for the Treatment of Tuberculosis on Lumbosacral Junction: Two Case Reports
Zhi Zhao, MD; Jingming Xie, PhD; Yingsong Wang, MD; Ying Zhang, MD; Tao Li, MD; Ni Bi, MD

3B. A Case of Progressive Kyphoscoliosis with Cord Ischemia
Terry D. Amaral, MD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Vishal Sarwahi, MD

3C. Two-Stage Combined Anterior and Posterior Spinal Fusion for Severe Cervico-Thoracic Kyphosis (Chin-on-Chest Deformity) in a Severely Osteoporotic Patient
Haruki Funao, MD; Floreana Naef, MD; Khaled Kebaish, MD

3D. Thoracolumbar Kyphosis and Osteomyelitis Requiring Complex Reconstruction Complicated by Proximal Junctional Failure Requiring Multiple Revisions
Sophia Strike, MD; Hamid Hassanzadeh, MD; Khaled Kebaish, MD

4. Neurologic Complications

Moderator: Hilali H. Noordeen, FRCS
Panelists: Hani Mhaidli, MD; Christopher I. Shaffrey, MD; Hee-Kit Wong, MD
Room: Bellecour 3, Bellecour Level

Cases for Discussion:

4A. Loss of Lower-Limb MEPs During Initial Exposure for Posterior Spinal Fusion in a Patient with Scoliosis and Myasthenia Gravis
Terry D. Amaral, MD; Alan D. Legatt, MD, PhD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Vishal Sarwahi, MD

4B. A Case of Syrinx with Severe Scoliosis Complicated with Disseminated Intravascular Coagulopathy (DIC)
Terry D. Amaral, MD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Aviva G. Dworkin, BS; Vishal Sarwahi, MD

4C. Intraoperative Neuromonitoring Prevented Postoperative Paralysis in a Case with Severe Congenital Kyphoscoliosis
Kazuhiro Hasegawa, MD, PhD; Haruka Shimoda, MD

4D. Loss of Motor Evoked Potentials and Quadriplegia During Unexpected Revision Posterior Spinal Fusion for a Chance Type Fracture in a Patient with Ankylosing Spondylitis
Haruki Funao, MD; Sophia Strike, MD; Khaled Kebaish, MD

Educational Program • Lunchtime Symposia

Wednesday, September 18, 2013

12:35 – 1:35 pm

Lifelong Radiology Exposure for Spine Surgery—Can we do Better?

Chair: Mark Weidenbaum, MD
Room: Forum 4, Forum Level

The Lunchtime Symposium entitled "Lifelong Radiation Exposure in Spinal Deformity- Can We Do Better?" will briefly explore the overall radiation experienced by patients with spinal deformity and by surgeons caring for these conditions. General definitions and concepts of radiation will be reviewed and some specifics of radiographs and imaging modalities (CT, Myelo-CT, bone scan, etc) will be discussed. We also will briefly look at technical aspects (shielding, technique, equipment) as well as differences between pediatric and adult populations, in addition to intraoperative radiation exposure for the surgeon and the patient. The purpose of this effort is to try to develop ways to reduce radiation while maintaining optimum care.

12:35 – 12:45pm **Introduction to Radiation**
Mark Weidenbaum, MD

12:45 – 12:55pm **X-rays and CT**
Kit M. Song, MD, MHA

12:55 – 1:05pm **Other Imaging**
Lawrence L. Haber, MD

1:05 – 1:15pm **Pediatric vs. Adult Differences**
Terry D. Amaral, MD

1:15 – 1:25pm **Lifelong Exposure of the Spine Surgeon**
Michael S. Chang, MD

1:25 – 1:35pm **Discussion**

Wednesday, September 18, 2013

12:35 – 1:35 pm

A Global Perspective on Neuromonitoring

Chairs: Ensor E. Transfeldt, MD & Norbert Passuti, MD
Room: Forum 5/6, Forum Level

Neuromonitoring remains an essential technique in preventing potential neurologic injury during spine surgery. Most spine surgeons serve as the final interpreter of these modalities during their intraoperative cases and therefore should have a thorough understanding of the basic science of how monitoring works and how to tailor the neuromonitoring techniques available to a specific surgery. The surgeon should be familiar with the correct type of anesthetic techniques necessary during surgery and have a basic knowledge of how to analyze and respond to abnormal neuromonitoring signals. Appreciating these key fundamentals of neuromonitoring will enable the surgeon to respond quickly to abnormal signals and take appropriate corrective measures.

12:35 – 12:37pm **Definition and Goals of Neuromonitoring During Spine Surgery**
Norbert Passuti, MD

12:37 – 12:42pm **Basic Science of Spinal Cord Monitoring**
Yann Péréon, MD, PhD

12:42 – 12:47pm **Neuromonitoring in Pediatric Patients**
John B. Emans, MD

12:47 – 12:52pm **Importance of Anesthesia and Medical and Physiologic Parameters Pre-Existing Neurologic Deficits During Neuromonitoring**
Amer F. Samdani, MD

12:52 – 12:57pm **Analysis and Response to Abnormal Neuromonitoring Signals**
John P. Dormans, MD

12:57 – 1:27pm **Case Presentations: Tailoring Neuromonitoring for Specific Surgery – What is the Ideal Paradigm? How Should a Surgeon Respond to Abnormal Signals?**
John B. Emans, MD; Norbert Passuti, MD; Amer F. Samdani, MD

1:27 – 1:35pm **Discussion**

Wednesday, September 18, 2013

12:35 – 1:35pm

Research Grant Outcomes

Chairs: Charles E. Johnston, MD
Room: Forum 1, Forum Level

The SRS Research Grant committee presents a lunchtime symposium giving recent grant recipients an opportunity to present and discuss the fruits of their labors. After presenting their preliminary or final results, each project will be discussed in detail. There will also be an opportunity to discuss the grant funding application process with the members of the SRS Research Grants Committee.

12:35 – 12:40 pm **Introduction**
Charles E. Johnston, MD

12:40 – 12:48 pm **Toward the Etiology of Idiopathic Scoliosis Using the Distribution Patterns of Quantitative MR Parameters Within the Intervertebral Discs as Predictive Factors of Progression**
Delphine Perie-Curnier, PhD

12:48 – 12:56 pm **A Novel Approach to Use Surface Topography Results for Assessing Scoliosis**
Eric Parent, PhD

12:56 – 1:04 pm **Molecular Analysis of the BMP-7 Action on Intervertebral Disc Cells**
Guang-Quin Zhou, MD, PhD

1:04 – 1:12 pm **Identification of a Locus for Idiopathic Scoliosis on Chromosome 12p**
Phillip F. Giampietro, MD, PhD

1:12 – 1:35 pm **Discussion**

Educational Program • Half-Day Courses

Thursday, September 19, 2013

1:30 – 4:30pm

Pre-Registration is required for all sessions and space is limited. There is an additional registration fee of $30 for the Half-Day Courses, which includes a ticket for lunch, which will be collected by ushers.

Spinal Deformity in Myelomeningocele

Co-Chairs: Peter G. Gabos, MD & Muharrem Yazici, MD
Room: Forum 1, Forum Level

1:30 – 1:40pm **Introduction: Etiology and the Developmental Embryology of Myelomeningocele**
Lawrence L. Haber, MD

1:40 – 1:50pm **How is the Incidence & Epidemiology of Myelomeningocele Different Globally?**
Robert H. Cho, MD

1:50 - 2:00pm **How do the Indications for Surgical Intervention Differ Globally?**
Muharrem Yazici, MD

2:00 – 2:15pm **Discussion**

2:15 – 2:30pm **Pre- and Post-Operative Techniques for Maximizing Soft Tissue Coverage After Spinal Deformity Correction**
Haemish A. Crawford, FRACS

2:30 – 2:45pm **Techniques for Handling the Abnormalities of the Neural Elements in Myelomeningocele**
Amer Samdani, MD

2:45 – 3:00pm **Surgical Treatment of Scoliosis: What Techniques are Available Worldwide?**
Peter G. Gabos, MD

3:00 – 3:15pm **Discussion**

3:15 – 3:30pm **Surgical Treatment of Kyphosis: What Techniques are Available Worldwide?**
Kit M. Song, MD, MHA

3:30 – 3:45pm **Management of Postoperative Complications, Infection and Wound Complications**
Patrick Cahill, MD

3:45 – 4:15pm **Case Presentations: Three Cases Including Kyphectomy, Scoliosis Correction, and a Major Complication**
Patrick Cahill, MD; Haemish A. Crawford, FRACS; Lawrence L. Haber, MD

4:15 – 4:30pm **Discussion**

Thursday, September 19, 2013

1:30 – 4:30pm

Pre-Registration is required for all sessions and space is limited. There is an additional registration fee of $30 for the Half-Day Courses, which includes a ticket for lunch, which will be collected by ushers.

This course is supported, in part by grants from DePuy Synthes Spine and Medtronic.

Sagittal Plane Deformity Corrective Techniques

Co-Chairs: Daniel H. Chopin, MD & Frank J. Schwab, MD
Room: Forum 5/6, Forum Level

1:30 – 1:45 pm **Overview of Sagittal Plane Corrective Techniques: Basic Theory, Operative Techniques and Effective Surgical Application**
John R. Dimar, III, MD

1:45 – 1:50 pm **Preoperative Clearance and Preparation to Prevent Perioperative Complications (Bleeding, Neuromonitoring, Infection)**
Tyler Koski, MD

Part I: Osteotomy Techniques

Moderator: Daniel H. Chopin, MD

1:50- 1:58 pm **What is a True Ponte Osteotomy (i.e. Why, Instead of When, is it Not a Smith-Petersen Osteotomy)**
Alberto Ponte, MD

1:58 – 2:06 pm **Pedicular Subtraction Osteotomy**
Stephen J. Lewis, MD, MSC, FRCSC

2:06 – 2:14pm **Vertebral Column Resection**
Lawrence G. Lenke

2:14 – 2:22pm **Vertebral Column Decancellation**
Yong Qiu, MD

2:22 – 2:30 pm **Indications for Anterior Based Surgery Techniques for Spinal Deformity**
Henry F.H. Halm, MD

2:30 - 2:50pm **Discussion**

2:50 – 3:10 pm **Techniques of Sagittal Deformity Correction in Severe Pediatric Kyphosis and Kyphoscoliosis**
Moderator: Peter O. Newton, MD
Panel: Daniel J. Sucato, MD, MS; Michael G. Vitale, MD, MPH; Charles E. Johnston, MD; Steven M. Mardjetko, MD, FAAP

Part II: Application of Osteotomies in Clinical Practice
Moderator: Frank J. Schwab, MD

3:10 – 3: 18 pm **Planification of Sagittal Plane Deformity**
Daniel H. Chopin, MD

3:18 – 3:26 pm **Technical Planning and Intraoperative Execution of Sagittal Plane Correction**
Frank J. Schwab, MD

3:26 – 3:34 pm **Combining Coronal and Sagittal Plane Deformity: Converting the Plan into an Appropriate Operative Technique**
Sigurd H. Berven, MD

3:34 – 3:42 pm **Complications of Osteotomies: How to Recognize and Institute Appropriate Treatment**
Pierre Guigui, MD

3:42– 3:50 pm **Corrective Techniques for the Treatment of Post Traumatic Kyphosis**
John C. France, MD

3:50 – 4:10 pm **Discussion**

4:10 – 4:30 pm **Case Presentation Adults Thoraco-Lumbar, Lumbar Sagittal Deformities**
Moderator: Stephen J. Lewis, MD, MSc, FRCSC
Panel: Serena S. Hu, MD; Dennis G. Crandall, MD; Christopher I. Shaffrey, MD; Khaled Kebaish, MD

Thursday, September 19, 2013

1:30 – 4:30pm
Pre-Registration is required for all sessions and space is limited. There is an additional registration fee of $30 for the Half-Day Courses, which includes a ticket for lunch, which will be collected by ushers.

Non-Operative Spinal Deformity Treatment Techniques
Co-Chairs: Theodoras B. Grivas, MD, PhD & Nigel Price, MD
Room: Forum 4, Forum Level

Session I

1:30 – 1:33pm **Introduction of SRS and SOSORT – Rationale for Combined Presentation**
Nigel J. Price, MD

1:33 – 1:40pm **Evidence Based Non-Operative Treatment**
Stefano Negrini, MD

1:40 – 1:47pm **Scoliosis Classifications Adopted for Non-Operative Approach**
Manuel Rigo, MD

1:47 – 1:54pm **Imaging Techniques and Patient Evaluation**
Patrick T. Knott, PhD, PA-C

1:54 – 2:05pm **Discussion**

2:05 – 2:12pm **Non-Operative Management Using the SOSORT Guidelines**
Tomasz Kotwicki, MD

2:12 – 2:19pm **European Brace Designs**
Theodoros B. Grivas, MD, PhD

2:19 – 2:26pm **North American Brace Designs**
Luke Stikeleather, CO

2:26 – 2:33pm **Brace Fabrication Techniques and Monitoring Devices**
James H. Wynne, CPO

2:33 – 2:40pm **Panel Case Presentation:What Specific Lenke Classification Deformities Have the Highest Success with Brace Treatment?**
Theodoros B. Grivas, MD, PhD; Nigel J. Price, MD

2:40 – 2:50pm **Discussion**

Session II

2:50 – 2:57pm **BrAIST Results**
Stuart L. Weinstein, MD

2:57 – 3:06pm **European Schools of Physical Therapy for Scoliosis**
Mónica Villagrasa-Escudero, PT, MSc, DO

3:06 – 3:13pm **Evidence Based Exercises for AIS-Cochrane Review**
Michele Romano, PT

3:13 – 3:20pm **North American Perspective on Exercises for Scoliosis**
Eric C. Parent, PhD, PT, MSc

3:20 – 3:30pm **Discussion**

3:30 – 3:37pm **Role of Education in Non-Operative Treatment**
Josette A. Bettany-Saltikov,PhD, MSc, MCSP

3:37 – 3:44pm **Psychological Support During Non-Operative Treatment**
Fabio Zaina, MD

3:44 – 3:51pm **Non-Operative Treatment: The Patient's Perspective**
Joseph P. O'Brien, MBA

3:51 – 3:58pm **SRS School Screening Task Force Report**
Hubert Labelle, MD

3:58 – 4:05pm **Non-Operative Treatment of Adult Deformity**
Jean Claude Demauroy, MD

4:05 – 4:20pm **Panel Discussion: Early Onset Scoliosis: Evidence Based Non-Operative Treatment vs. Operative Methods**
Moderator: James O. Sanders, MD
Faculty: Theodoros B. Grivas, MD, PhD; Nigel J. Price, MD

4:20 – 4:30pm **Discussion**

Educational Program • Lunchtime Symposia

Friday, September 20, 2013

12:00 – 1:00pm

Building a Culture of Safety in Your Operating Room: Quand La Merde Frappe Le Ventilateur

Chair: Kit M. Song, MD, MHA
Room: Forum 4, Forum Level

This symposium will highlight emergency situations that arise during spinal deformity cases and discuss the strategy around the development of emergency checklists for these scenarios. Background on the psychology of panic, creation of a culture of safety, and examples of crisis checklists for these situations that may guide O.R. teams through the management of these crises will be shown. Strategies for rehearsal and training used by the aviation industry will also be discussed.

12:00 – 12:05pm **Introduction**
Kit M. Song, MD, MHA

12:05 – 12:20pm **Psychology of Panic and Why Checklists**
Sam Chewning, Jr., MD

12:20 – 12:30pm **Building and Creating the Team Environment to Manage Crises**
Terry D. Amaral, MD

12:30 – 12:40pm **Irreversible Neurologic Monitoring Changes During Surgery**
James O. Sanders, MD; Suken A. Shah, MD

12:40 – 12:50pm **Case Presentation: Airway Loss and Cardiorespiratory Collapse**
Kit M. Song, MD, MHA

12:50 – 12:57pm **Discussion**

12:58 – 1:00pm **Closing Remarks**
Sam Chewning, Jr., MD

Friday, September 20, 2013

12:00 – 1:00pm

This course is supported, in part, by a grant from Medtronic.

Global Outreach Update

Co-Chairs: Youssry M.K. El-Hawary, MD & Kenneth J. Paonessa, MD
Room: Forum 1, Forum Level

Meet the members of the SRS Global Outreach Committee and representatives from the SRS Endorsed Sites at the Global Outreach Lunchtime Symposium, "Update on How to Start and Treat a Site." This symposium will be informative for anyone who has ever thought about volunteering skills and knowledge in another country or wants to learn about some of the current treatment of less common conditions such as Pott's disease or untreated severe scoliosis. During the symposium, representatives from SRS Endorsed Sites will report on the last year's activities at some of the sites where they have volunteered, including Western and Eastern Africa, South and Central America, India and Asia, and Eastern Europe. If you have already been involved in Global Outreach in spinal deformity care, this is an excellent opportunity to network with colleagues.

12:00 – 12:05pm **Introduction**
Youssry M.K. El-Hawary, MD

12:05 – 12:13pm **Global Outreach Needs/Current Programs and New Sites/ New Needs**
Kenneth J. Paonessa, MD

12:13 – 12:21pm **How to Start a Global Outreach Site: Pitfalls and Lessons Learned**
Oheneba Boachie-Adjei, MD

12:21 – 12:29pm **Treatment of Severe Neglected Scoliosis**
Ferran Pelliś Urquiza, MD, PhD

12:29 – 12:37pm **Treatment of Late TB Kyphosis**
Elias C. Papadopoulos, MD

12:37 – 12:45pm **Treatment of Early Onset Scoliosis in the Developing World**
Hazem B. El Sebaie, MD, FRCS

12:45 – 1:00pm **Discussion**

Friday, September 20, 2013

12:00 – 1:00pm

The Research Process: From Asking to Answering

Chair: Leah Y. Carreon, MD, MSc
Room: Forum 5/6, Forum Level

This lunchtime symposium will discuss the processes involved in answering a research question: from formulating the research question to getting a manuscript published. Topics include formulating the research question, criteria to consider before proceeding with a research project and study design considerations. Problems and pitfalls, as well as solutions, in performing research specifically on spine deformity will also be discussed, as well as characteristics of a manuscript that are acceptable for publication. The majority of the symposium will be devoted to an open discussion with the audience.

12:00 – 12:10pm **Formulating the Research Question**
· Criteria to initiate a study
· Designing the study
· The IRB: Friend or foe
Leah Y. Carreon MD, MSc

12:10 – 12:30pm **Pitfalls in Studies of Spinal Deformity**
· Bracing in Adolescent Idiopathic Scoliosis Trial (BrAIST)
· Minimize Implants Maximize Outcomes Trial (MIMO)
Lori A. Dolan, PhD and A. Noelle Larson, MD

12:30 – 12:40pm **Reviewing Manuscripts/Criteria for Publication**
John E. Lonstein, MD

12:40 – 1:00pm **Discussion**

Scientific Program

The Scoliosis Research Society gratefully acknowledges Orthofix for support of the Annual Meeting E-Poster Kiosks, Internet Kiosks and E-Newsletter.

Scientific Program • Thursday, September 19, 2013

**Hibbs Award Nominee for Best Clinical Paper*
┼ Hibbs Award Nominee for Best Basic Science Paper

The Russell A. Hibbs Awards are presented to both the best clinical and basic science papers presented at the 48th Annual Meeting and Course. The top podium presentations accepted in each category are invited to submit manuscripts for consideration. Winners are selected on the basis of manuscripts and podium presentations.

Session 1: Adolescent Idiopathic Scoliosis

Session Times: 7:55 – 9:49am
Moderators: Ronald A. Lehman, MD & Lawrence G. Lenke, MD
Room: Forum 5/6, Forum Level

7:55 – 8:00am **Welcome & Announcements**
Suken A. Shah, MD

8:00 – 8:04am **Paper #1: Recent Trends in Surgical Management of Adolescent Idiopathic Scoliosis: A Review of 17,412 Cases from the Scoliosis Research Society Database 2001-2008**
Samuel K. Cho, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Abigail Allen, MD; Yongjung J. Kim, MD

8:04 – 8:08am **Paper #2: Vertebral Column Derotation Provides Radiographic Spinal Derotation but No Additional Effect on Thoracic Rib Hump Correction as Compared with No Derotation in Adolescents Undergoing Surgery for Idiopathic Scoliosis with Total Pedicle Screw Instrumentation: A Prospective Follow-Up Study**
Mikko Mattila; Tuomas Jalanko; Ilkka Helenius, MD, PhD

8:08 – 8:12am **Paper #3: The Impact of Prolonged Surgical Wait Times on AIS: What Complications Can be Expected?**
Firoz Miyanji, MD, FRCS(C); Tracey Bastrom, MA; Amer F. Samdani, MD; Burt Yaszay, MD; David H. Clements, MD; Suken A. Shah, MD; Michelle C. Marks, PT, MA; Randal R. Betz, MD; Harry L. Shufflebarger, MD; Peter O. Newton, MD

8:12 – 8:21am **Discussion**

8:22 – 8:26am **Paper #4: What is Different About Surgically Treated AIS Patients Who Achieve a Minimal Clinically Important Difference (MCID) in Appearance at Five Years Post Surgery?**
Anuj Singla, MD; Amer F. Samdani, MD; John M. Flynn, MD; James T. Bennett, MD; Firoz Miyanji, MD, FRCS(C); Joshua M. Pahys, MD; Michelle C. Marks, PT, MA; Baron S. Lonner; Peter O. Newton, MD; Patrick J. Cahill, MD; Randal R. Betz, MD

8:26 – 8:30am **Paper #5: Surgery for Idiopathic Scoliosis in Adolescents Versus Young Adults: A Matched Cohort Analysis**
Ian G. Dorward, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Kathleen E. McCoy; Kevin R. O'Neill, MD, MS; Brian J. Neuman, MD; Terrence F. Holekamp, MD, PhD; Wilson Ray, MD; Brenda A. Sides, MA; Linda Koester, BS

8:30 – 8:34am **Paper #6: Does Operative Care of Adolescent Idiopathic Scoliosis Improve Outcomes Compared to Non-Operative Treatment?**
David H. Clements, MD; Randal R. Betz, MD; Peter O. Newton, MD; Firoz Miyanji, MD, FRCS(C); Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Harms Study Group

8:34 – 8:43am **Discussion**

8:44 – 8:48am **Paper #7: Distal Adding on in Lenke 1 and 2 Curves: What Happens at Five Years?**
Jahangir Asghar, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Harry L. Shufflebarger, MD; Burt Yaszay, MD

8:48 – 8:52am **Paper #8: Does Postoperative Shoulder Imbalance Lead to Adding on in Posterior Spinal Fusion for Lenke 1A and 1B Curves?**
Joshua M. Pahys, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Harms Study Group; Randal R. Betz, MD

8:52 – 8:56am **Paper #9: Intraoperative and Postoperative LIV-Tilt and Disk Angle in Patients with Idiopathic Scoliosis**
James Barsi, MD; Sumeet Garg, MD; David Baulesh; Brendan Caprio, BS; Mark A. Erickson, MD

8:56 – 9:05am **Discussion**

9:06 – 9:10am **Paper #10: An Analysis of Factors Leading to Reoperation in Adolescent Idiopathic Scoliosis**
Dennis R. Knapp, MD; Karl E. Rathjen, MD; John M. Wattenbarger, MD; W. F. Hess, MD; Terry R. Trammell, MD; Ross R. Moquin, MD; Francisco J. S. Pérez-Grueso, MD; Hilali H. Noordeen, FRCS; Mark D. Rahm, MD; Richard Hostin, MD; Marilyn L. Gates, MD; Matthew J. Geck, MD; Oheneba Boachie-Adjei, MD; Complex Spine Study Group

9:10 – 9:14am **Paper #11: Reoperation Risk After Surgery for Idiopathic Scoliosis: A Retrospective Study of 550 Scoliosis Operated Over 25 Years**
Guillaume Riouallon, MD; Benjamin Bouyer; Stephane Wolff

9:14 – 9:18am **Paper #12: The Effect of Time and Fusion Length on Motion of the Un-Fused Lumbar Segments in Adolescent Idiopathic Scoliosis**
Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Maty Petcharaporn, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Randal R. Betz, MD; Baron S. Lonner; Firoz Miyanji, MD, FRCS(C); Peter O. Newton, MD

9:18 – 9:27am **Discussion**

9:28 – 9:32am **Paper #13: What an AIS Patient Sees in the Mirror: Validation of the Truncal Anterior Asymmetry Scoliosis Questionnaire (TAASQ)**
Baron S. Lonner, MD; Courtney Toombs, BS; Suken A. Shah, MD; Tracey Bastrom, MA; Phedra Penn, MS; Kristin Bright, PhD; Carrie Scharf Stern, MD; Marjolaine Roy- Beaudry, MSc; Marie Beausejour; Stefan Parent, MD, PhD

9:32 – 9:36am **Paper #14: The Influence of Surgical Correction of Scoliosis on Sexual Function and Pregnancy in Young Women with Adolescent Idiopathic Scoliosis (AIS)**
Leon Kaplan, MD; Yair Barzilay, MD; Eyal Itshayek, MD; Joshua E. Schroeder, MD
*** This presentation is the result of a project funded, in part, by an SRS Research Grant***

9:36 – 9:40am **Paper #15: Predictors of Persistent Postoperative Pain After Surgery for Adolescent Idiopathic Scoliosis**
Christine Sieberg, PhD; Laura Simons, PhD; Mark R. Edelstein, BA; Maria R. DeAngelis; Melissa Pielech, MA; Navil F. Sethna, MD; Michael T. Hresko, MD

9:40 – 9:49am **Discussion**

9:49 – 10:06am Refreshment Break

Forum Level Foyer
This break is supported, in part, by a grand from Medtronic.

Session 2: Adult Spinal Deformity, Non-Operative Treatment Methods of AIS

Session Times: 10:06am – 12:30pm
Moderators: Sean Molloy, MBBS, MSc, FRCS & B. Stephens Richards, III, MD
Room: Forum 5/6, Forum Level

10:06 – 10:10am **Paper #16: Recent Trends in Surgical Treatment of Adult Scoliosis: A Review of 7,570 Cases from the Scoliosis Research Society Database 2001-2008**
Samuel K. Cho, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; John Caridi, MD; Yongjung J. Kim, MD

10:10 – 10:14am **Paper #17: Three Column Spine Reconstructions are Not Associated with Higher Rates of Complication or New Neurologic Deficit: A Retrospective Scoli-Risk 1 Study**
Michael P. Kelly, MD; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Steven D. Glassman, MD; Leah Y. Carreon, MD, MSc; Virginie Lafage, PhD; Frank J. Schwab, MD; Adam L. Shimer, MD

10:14 – 10:18am **Paper #18: Complications and Inter-Center Variability of Three Column Osteotomies for Spinal Deformity Surgery: A Retrospective Review of 423 Patients**
Kristina Bianco, BA; Frank J. Schwab, MD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Ibrahim Obeid; Gregory M. Mundis, MD; Khaled Kebaish, MD; Richard Hostin, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; International Spine Study Group

10:18 – 10:27am **Discussion**

10:28 – 10:32am **Paper #19: Proximal Junctional Failure in Adult Deformity Patients Results in Higher Rate of Revision but Limited Impact on Clinical Outcome**
Robert A. Hart, MD; Jayme R. Hiratzka, MD; D. Kojo Hamilton, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Praveen V. Mummaneni, MD; Eric Klineberg, MD; Ian McCarthy, PhD; Douglas C. Burton, MD; Richard Hostin, MD; International Spine Study Group

10:32 – 10:36am **Paper #20: Patients with Proximal Junctional Kyphosis Requiring Revision Surgery Have Higher Post-Op Lumbar Lordosis and Larger Sagittal Balance Corrections**
Han Jo Kim, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Moon Soo Park, PhD; Kwang-Sup Song, MD; Tapanut Chuntarapas; Chaiwat Piyaskulkaew, MD

10:36 – 10:40am **Paper #21: Characterization and Surgical Outcomes of Proximal Junctional Failure (PJF) in Surgically Treated Adult Spine Deformity Patients**
Mitsuru Yagi, MD, PhD; Mark D. Rahm, MD; Robert W. Gaines, MD; Ali M. Maziad, MD, MSc; Thomas Ross, MS, RN; Han Jo Kim, MD; Khaled Kebaish, MD; Oheneba Boachie-Adjei, MD; Complex Spine Study Group

10:40 – 10:49am **Discussion**

10:50 – 10:54am **Paper #22: The T1 Pelvic Angle (TPA), a Novel Radiographic Measure of Global Sagittal Deformity, Accounts for Both Pelvic Retroversion and Truncal Inclination and Correlates Strongly with HRQOL**
Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Nicolas Bronsard, MD, PhD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Thomas J. Errico; Virginie Lafage, PhD; International Spine Study Group

10:54 – 10:58am **Paper #23: Sacro-Pelvic Fixation Using the S2 Alar-Iliac (S2AI) Screws in Adult Deformity Surgery: A Prospective Study with Minimum Five-Year Follow-Up**
Sophia Strike; Hamid Hassanzadeh, MD; Floreana Naef, MD; Paul D. Sponseller, MD; Khaled Kebaish, MD

10:58 – 11:02am **Paper #24: Rod Fractures in Spinal Deformity Surgery Involving Pelvic Fixation: Does Stainless Steel Fracture Less Often?**
Michael Hellman, MD; Bryan Haughom, MD; Nathan Wetters; Mark F. Kurd, MD; Kasra Ahmadinia; Christopher DeWald, MD

11:02 – 11:11am **Discussion**

11:12 – 11:16am **Paper #25: Outcomes of Brace Treatment for Adolescent Idiopathic Scoliosis: Factors Affecting the Results of the Treatment**
Toru Maruyama, MD, PhD; Yusuke Nakao

11:16 – 11:20am **Paper #26: Incidence of Surgery After Brace Treatment in Patients with Adolescent Idiopathic Scoliosis**
Hideki Murakami; Ken Yamazaki, MD

11:20 – 11:24am **Paper #27: The Effect of Compliance Monitoring on Brace Use and Success in Patients with AIS**
Lori A. Karol, MD; Donald Virostek, BS; Kevin M. Felton, BS, MLA; Lesley Wheeler, BS

11:24 – 11:33am **Discussion**

11:34 – 11:39am **Bracing in Adolescent Idiopathic Scoliosis Trial: Primary Results**
Stuart L. Weinstein MD; Lori Dolan, PhD; James Wright, MD; Matthew B. Dobbs, MD; BrAIST Study Group

11:39 – 11:43am **Discussion**

11:44 – 11:49am **Harrington Lecture Introduction**
Kamal N. Ibrahim, MD, FRCS(C), MA

11:50am – 12:10pm **Harrington Lecture**

"The Pelvic Vertebrae: A French Obsesssion?"
Daniel H. Chopin, MD

12:10 – 12:30pm Presentation of Lifetime Achievement Awards

Ian A.F. Stokes, PhD
Presented By Steven D. Glassman, MD

George H. Thompson, MD
Presented By John P. Dormans, MD

12:30 – 1:30pm Networking Lunch

Open to all Half-Day Course participants. Tickets will be required.
Room: Lunches will be found in Forum Level Foyer

Member Information Session
Awards Meet-and-Greet
Room: Forum 1, Forum Level

1:30 – 4:30pm Half-Day Courses (see page 172)

Spinal Deformity in Myelomeningocele
Room: Forum 1, Forum Level

Non-Operative Spinal Deformity Treatment Techniques
Room: Forum 4, Forum Level

Sagittal Plane Deformity Corrective Techniques
Room: Forum 5/6, Forum Level

**Tickets are required for entrance. Tickets are available for purchase at the Registration Desk*

Session 3: Early Onset Scoliosis (Runs Concurrently with Session 4 from 7:55 – 9:49am)

Session Times: 7:55 – 9:49am
Moderators: James O. Sanders, MD & Muharrem Yazici, MD
Room: Forum 4, Forum Level

7:55 – 8:00am **Welcome & Announcements**

8:00 – 8:04am **Paper #28: Serial De-Rotational Casting in Idiopathic and Non-Idiopathic Progressive Early Onset Scoliosis**
Yazeed M. Gussous, MBBS; Safdar N. Khan, MD; Angela Caudill, MPT; Peter Sturm, MD; Kim Hammerberg, MD

8:04 – 8:08am **Paper #29: Results of Serial Casting in Idiopathic and Non-Idiopathic Cases of Early Onset Scoliosis**
Vishwas R. Talwalkar, MD; Josh Philbrick, MD; Pooya Hosseinzadeh, MD; Todd A. Milbrandt, MD, MS; Ryan D. Muchow, MD; Janet L. Walker, MD; Henry J. Iwinski, MD

8:08 – 8:12am **Paper #30: Pulmonary Function in Patients with Early Onset Idiopathic Scoliosis 24 Years After End of Brace Treatment**
Aina J. Danielsson, MD, PhD; Tero Laine, MD, PhD; Kerstin Löfdahl-Hällerman, MD, PhD

8:12 – 8:21am **Discussion**

8:22 – 8:26am **Paper #31: CT Lung Volume Improvement After Surgical Treatment for Early Onset Scoliosis (EOS)**
Charles E. Johnston, MD; Anna M. McClung, BSN, RN

8:26 – 8:30am **Paper #32: Magnetic Growth Rods Improve Pulmonary Function in Children with Early Onset Scoliosis**
Wai Weng Yoon, BSc(Hons), MBBS, MRCS, FRCS(Tr&Orth); Fady S. Sedra, MBBcH, MSc, MRCS; Nanjundappa S. Harshavardhana, MD, MS(Orth), Dip. SICOT; Suken A. Shah, MD; Francesco Muntoni, MD, FRCPCH, FMed Sci; Colin Wallis, MBChB, FRCPCH, MRCP, MD, DCH, FCP(SA); Hilali H. Noordeen, FRCS

8:30 – 8:34am **Paper #33: Pulmonary Outcomes of VEPTR Expansion Thoracoplasty in Early Onset Scoliosis: A Longitudinal Study**
Ozgur Dede, MD; Etsuro K. Motoyama, MD; Vincent F. Deeney, MD; Charles I. Yang, MD; Rebecca Mutich, BSRT; Austin Bowles, MS

8:34 – 8:43am **Discussion**

8:44 – 8:48am **Paper #34: 25 Years of Vertical Expandable Prosthetic Titanium Rib (VEPTR) Treatment for Spinal and Chest Wall Deformities: A Review of the Original Feasibility Cohort from Entry to Exit**
Megan K. Roth, PhD; Hope Trevino, AA; Lori Buegeler, RN, BC; Victor F. German, MD, PhD; John M. Shepherd, MD; John J. Doski, MD; Robert Thomas, MD; James W. Simmons, DO, PhD; Robert M. Campbell, MD; Ajeya P. Joshi, MD

8:48 – 8:52am **Paper #35: The Use of VEPTR for Treatment of Congenital Scoliosis without Fused Ribs**
Robert F. Murphy, MD; Alice A. Moisan, BSN; Derek M. Kelly, MD; William C. Warner, MD; Jeffrey R. Sawyer, MD

8:52 – 8:56am **Paper #36: Proximal Junctional Kyphosis (PJK) Following Posterior Hemivertebrectomy with Short Fusion in Children Younger Than 10 Years of Age**
Yiongsong Wang, MD; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Tetsuya Ohara; Yoshitaka Suzuki; Toshiki Saito; Ayato Nohara; Ryo Sugawara; Kyotaro Ota

8:56 – 9:05am **Discussion**

9:06 – 9:10am **Paper #37: Correction and Complications in the Treatment of EOS: Is There a Difference Between Spine Versus Rib-Based Proximal Anchors?**
Michael G. Vitale, MD, MPH; Howard Y. Park, BA; Hiroko Matsumoto, MA; Daren J. McCalla, BS; David P. Roye, MD; David L. Skaggs, MD, MMM; Behrooz A. Akbarnia, MD

9:10 – 9:14am **Paper #38: Risk Factors for Proximal Junctional Kyphosis Associated with Growing-Rod Surgery for Early Onset Scoliosis**
Kota Watanabe; Morio Matsumoto, MD; Koki Uno, MD, PhD; Teppei Suzuki; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Haruhisa Yanagida, MD; Manabu Ito, MD, PhD; Toru Hirano; Ken Yamazaki, MD; Shohei Minami; Hiroshi Taneichi, MD; Shiro Imagama, MD; Katsushi Takeshita, MD; Takuya Yamamoto

9:14 – 9:18am **Paper #39: Traditional Growing Rods Versus Magnetically Controlled Growing Rods in Early Onset Scoliosis: A Case-Matched Two Year Study**
Behrooz A. Akbarnia, MD; Kenneth M. Cheung, MBBS(UK), FRCS(England), FHKCOS, FHKAM(Orth); Gokhan H. Demirkiran; Hazem B. Elsebaie, FRCS, MD; John B. Emans, MD; Charles E. Johnston, MD; Gregory M. Mundis, MD; Hilali H. Noordeen, FRCS; Jeff Pawelek; M. Shaw, FRCS; David L. Skaggs, MD, MMM; Paul D. Sponseller, MD; George H. Thompson, MD; Muharrem Yazici, MD; Growing Spine Study Group

9:18 – 9:27am **Discussion**

9:28 – 9:32am **Paper #40: Implant Revisions with Shilla Patients at Five Year Follow Up: Lessons Learned**
Richard E. McCarthy, MD; Frances L. McCullough, MNSc

9:32 – 9:36am **Paper #41: Early Onset Scoliosis Treated with Growing Rods has a Greater Increase in T1-S1 Length, Better Cobb Correction, and More than Twice the Number of Surgeries Compared to Shilla**
Lindsay Andras, MD; Elizabeth Joiner, BS; Richard E. McCarthy; Scott J. Luhmann, MD; Paul D. Sponseller, MD; John B. Emans, MD; David L. Skaggs, MD, MMM; Growing Spine Study Group

9:36 – 9:40am **Paper #42: Risk Factors for Unsatisfactory Correction of Spinal Deformity Associated with Growing-Rod Surgery for Early Onset Scoliosis**
Kota Watanabe, MD; Morio Matsumoto, MD; Koki Uno, MD, PhD; Teppei Suzuki; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Haruhisa Yanagida, MD; Manabu Ito, MD, PhD; Toru Hirano; Ken Yamazaki, MD; Shohei Minami; Hiroshi Taneichi, MD; Shiro Imagama, MD; Katsushi Takeshita, MD; Takuya Yamamoto

9:40 – 9:49am **Discussion**

9:49 – 10:09am Refreshment Break

Forum Level Foyer

Session 4: Adult Spine Deformity and Tumors (Runs Concurrently with Session 3 from 7:55 – 9:49am)

Session Times: 7:55 – 9:49am
Moderators: Pierre Roussouly, MD & Frank J. Schwab, MD
Room: Forum 5/6, Forum Level

7:55 – 8:00am **Welcome & Announcements**

8:00 – 8:04am **Paper #43: Adult Deformity Surgery (ASD) Patients Recall Fewer than 50 Percent of the Risks Discussed in the Informed Consent Process Preoperatively and the Recall Rate Worsens Significantly in the Postoperative Period**
Rajiv Saigal, MD, PhD; Aaron J. Clark, MD, PhD; Justin K. Scheer, BS; Justin S. Smith, MD, PhD; Shay Bess, MD; Praveen V. Mummaneni, MD; Ian McCarthy, PhD; Robert A. Hart, MD; Khaled Kebaish, MD; Eric Klineberg, MD; Vedat Deviren, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

8:04 – 8:08am **Paper #44: How Patients Decide: Randomization Versus Surgery Versus Non-Surgical Treatment for Symptomatic Adult Lumbar Scoliosis**
Brian J. Neuman, MD; Keith H. Bridwell, MD; Christine Baldus, RN, MHS; Lukas P. Zebala, MD; Christopher I. Shaffrey, MD; Charles C. Edwards, MD; Tyler Koski, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Steven D. Glassman, MD; Stefan Parent, MD, PhD; Stephen J. Lewis, MD; Lawrence G. Lenke, MD; Jacob M. Buchowski, MD, MS; Charles H. Crawford, MD

8:08 – 8:12am **Paper #45: Pulmonary Function Following Adult Spinal Deformity Surgery: Minimum Two-Year Follow-Up**
Ronald A. Lehman, MD; Daniel G. Kang, MD; Lawrence G. Lenke, MD; Jeremy J. Stallbaumer, MD; Brenda A. Sides, MA

8:12 – 8:21am **Discussion**

8:22 – 8:26am **Paper #46: Variance in Complication Rate Reporting Among High Volume Spinal Deformity Centers: Analysis of a Multi-Center Prospective Database**
Eric Klineberg, MD; Jacob M. Buchowski, MD, MS; Kai-Ming Fu, MD, PhD; Justin S. Smith, MD, PhD; Oheneba Boachie-Adjei, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Shay Bess, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Richard Hostin, MD; Gregory M. Mundis, MD; Munish C. Gupta, MD; International Spine Study Group

8:26 – 8:30am **Paper #47: Comparing Prospective to Retrospective Acute Neurologic Complication Rates in Complex Adult Spinal Deformity Procedures: Is There a Difference?**
Michael P. Kelly, MD; Lawrence G. Lenke, MD; Adam L. Shimer, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Stephen J. Lewis, MD; Christopher P. Ames, MD; Leah Y. Carreon, MD, MSc; Steven D. Glassman, MD; Michael G. Fehlings, MD, PhD; Frank J. Schwab, MD; Virginie Lafage, PhD

8:30 – 8:34am **Paper #48: Administrative Databases Overestimate Hospital Readmission Rate Following Spinal Deformity Correction Surgery**
Beejal Y. Amin, MD; Paul D. Ackerman, MD; Sigurd H. Berven, MD; Shane Burch, MD; Vedat Deviren, MD; Serena S. Hu, MD; Bobby Tay, MD; Christopher P. Ames, MD; Dean Chou, MD; Praveen V. Mummaneni, MD

8:34 – 8:43am **Discussion**

8:44 – 8:48am **Paper #49: Upper Thoracic Versus Lower Thoracic Upper Instrumented Vertebrae Endpoints Have Similar Outcomes and Complications in Adult Scoliosis at Two-Year Follow-Up**
Han Jo Kim, MD; Oheneba Boachie-Adjei, MD; Justin K. Scheer, BS; Richard Hostin, MD; Khaled Kebaish, MD; Justin S. Smith, MD, PhD; Gregory M. Mundis, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Robert A. Hart, MD; Shay Bess, MD; Vedat Deviren, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

8:48 – 8:52am **Paper #50: Risk of Spinal Implants and the Development of Proximal Junctional Kyphosis for Adult Kyphoscoliosis**
Jamal McClendon, MD; Timothy R. Smith, MD, PhD, MPH; Patrick A. Sugrue, MD; Sara E. Thompson, BA; Brian A. O'Shaughnessy, MD; Tyler Koski, MD

8:52 – 8:56am **Paper #51: Proximal Junctional Kyphosis and Clinical Outcomes in Two Different Proximal Upper Instrumented Vertebral Levels (Proximal Thoracic Versus Distal Thoracic) After Adult Spinal Instrumented Fusion to Sacrum**
Yoon Ha, MD, PhD; Keishi Maruo, MD; Linda Racine; William Schairer; Serena S. Hu, MD; Vedat Deviren, MD; Shane Burch, MD; Bobby Tay, MD; Dean Chou, MD; Praveen V. Mummaneni, MD; Christopher P. Ames, MD; Sigurd H. Berven, MD

8:56 – 9:05am **Discussion**

9:06 – 9:10am **Paper #52: Age at Surgery Not BMP Exposure Predicts Cancer After BMP Exposure: Analysis of 127,087 Cases**
Michael P. Kelly, MD; Nicholas J. White, MPH; Wilson Ray, MD; Margaret A. Olsen, PhD, MPH

9:10 – 9:14am **Paper #53: Minimum Five-Year Comparison of Different Age Groups Who Underwent Primary Long Instrumented Fusions to the Sacrum for Adult Spinal Deformity**
Sang D. Kim, MD, MS; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Ian G. Dorward, MD; Brian J. Neuman, MD; Kevin R. O'Neill, MD, MS; Christine Baldus, RN, MHS; Linda Koester, BS; Azeem Ahmad, BA, BS

9:14 – 9:18am **Paper #54: Cost-Utility Analysis of Surgical Treatment for Adult Spinal Deformity**
Ian McCarthy, PhD; Michael F. Obrien, MD; Christopher P. Ames, MD; Thomas J. Errico; Han Jo Kim, MD; Gregory M. Mundis, MD; Frank J. Schwab, MD; Eric Klineberg, MD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; David W. Polly, MD; Richard Hostin, MD; International Spine Study Group

9:18 – 9:27am **Discussion**

9:28 – 9:32am **Paper #55: Multi-Segmental Primary Tumors and Solitary Metastasis of the Thoracolumbar Spine: 38 Patients Treated with Multilevel en bloc Spondylectomy and Reconstruction**
Alessandro Luzzati

9:32 – 9:36am **Paper #56: Sacrectomy and Adjuvant Radiotherapy for the Treatment of Sacral Chordomas: A Single-Centre Experience Over 27 Years**
Arjun A. Dhawale, MD; Joseph P. Gjolaj, MD; H Thomas Temple, MD; Frank J. Eismont, MD

9:36 – 9:40am **Paper #57: The Effect of Surgery on Health Related Quality of Life and Functional Outcome in Patients with Metastatic Epidural Spinal Cord Compression: The AOSpine North America Prospective Multi-Center Study**
Michael G. Fehlings, MD, PhD; Branko Kopjar; Charles G. Fisher, MD, MHSc; Alexander R. Vaccaro, MD, PhD; Paul Arnold; Laurence D. Rhines, MD; James Schuster, MD, PhD; Joel Finkelstein, MSc, MD, FRCS(C); Mark B. Dekutoski, MD; Ziya L. Gokaslan, MD; John C. France, MD

9:40 – 9:49am **Discussion**

9:49 – 10:09am Refreshment Break

Forum Level Foyer

Session 5: Etiology and Prognosis of AIS, Complications

Session Times: 10:09 – 11:50am
Moderators: Peter O. Newton, MD & Nobert Passuti, MD
Room: Forum 5/6, Forum Level

10:09 – 10:13am **Paper #58: Variations in Sagittal Spino-Pelvic Alignment Between Different Curve Patterns of Adolescent Idiopathic Scoliosis: Is the Evolution of Thoracic Scoliosis Different Than Lumbar?**
Tom P. Schlösser, MD; Suken A. Shah, MD; Samantha J. Reichard; Kenneth J. Rogers, PhD; Koen L. Vincken, PhD; Rene M. Castelein, MD, PhD

10:13 – 10:17am **Paper #59: An Independent Evaluation of the Validity of a DNA-Based Prognostic Test for Adolescent Idiopathic Scoliosis**
Benjamin D. Roye, MD, MPH; Margaret L. Wright, BS; Hiroko Matsumoto, MA; Petya Yorgova, MS; Geraldine I. Neiss, PhD; Daren J. McCalla, BS; Joshua E. Hyman, MD; David P. Roye, MD; Suken A. Shah, MD; Michael G. Vitale, MD, MPH
*** This presentation is the result of a project funded, in part, by an SRS Research Grant***

10:17 – 10:21am **Paper #60: The Simplified Skeletal Maturity Method and its Correlation with Curve Progression in Idiopathic Scoliosis**
Prakash Sitoula, MD; Kushagra Verma, MD, MS; James O. Sanders, MD; Petya Yorgova, MS; Geraldine I. Neiss, PhD; Kenneth J. Rogers, PhD; Laurens Holmes, PhD, DrPH; Peter G. Gabos, MD; Suken A. Shah, MD

10:21 – 10:30am **Discussion**

10:31 – 10:35am **Paper #61: Different Brace Treatment Outcomes: Making the Case for Biological Endophenotypes Classification in AIS Patients**
Frederique Desbiens-Blais, MS; Julie Joncas, BSc; Marie Beausejour; Alain Moreau, PhD; Ginette Larouche; Ginette Lacroix, RN; Jean-Marc Mac-Thiong, MD, PhD; Hubert Labelle, MD; Carl-Éric Aubin, PhD, PEng; Stefan Parent, MD, PhD

10:35 – 10:39am **Paper #62: Vitamin D Insufficiency and its Association with Low Bone Mass in Girls with Adolescent Idiopathic Scoliosis (AIS)**
Tsz Ping Lam, MBBS; Wing Sze Yu, MPhil; Queenie Wah Yan Mak, PGd(Ed), BSc(FNS); Franco Tsz Fung Cheung, MPhil; Kwong Man Lee, PhD; Bobby K. Ng, MD; Ling Qin; Jack C. Cheng, MD

10:39 – 10:43am **Paper #63: Quantitative Measurement of Abnormal Bone Quality and Strength with Bone Micro-Architecture and Rod-Plate Configuration in Osteopenic Adolescent Idiopathic Scoliosis (AIS)**
Wing Sze Yu, MPhil; Ka Yan Chan; Wai Ping Fiona Yu, MPH, BSc; Kwong Man Lee, PhD; Bobby K. Ng, MD; Ling Qin, PhD; Tsz Ping Lam, MBBS; Jack C. Cheng, MD

10:43 – 10:52am **Discussion**

10:53 – 10:57am **Paper #64: A Prospective Randomized Double-Blinded Study Comparing Postoperative Pain Control Modalities for Patients Undergoing Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis**
Mindy Cohen, MD; Jeannie Zuk, PhD; Jeffrey Galinkin, MD; Mark A. Erickson, MD

10:57 – 11:01am **Paper #65: Post-Operative DVT Rate After Spine Surgery**
William Schairer; Andrew C. Pedtke, MD; Serena S. Hu, MD

11:01 – 11:05am **Paper #66: Defining Rates and Causes of Mortality Associated with Spine Surgery Using a Scoliosis Research Society (SRS) Registry-Based System: Does Collection of Less Data Improve Compliance?**
Ellen C. Shaffrey; Justin S. Smith, MD, PhD; David M. Ibrahimi, MD; Manish Singh, MD; Lawrence G. Lenke, MD; David W. Polly, MD; Ching-Jen Chen, BA; Jeffrey D. Coe, MD; Paul A. Broadstone, MD; Steven D. Glassman, MD; Alexander R. Vaccaro, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD

11:05 – 11:14am **Discussion**

11:15 – 11:17am **21st IMAST (2014) Preview – Valencia, Spain**
Christopher I. Shaffrey, MD
IMAST Committee Chair

11:17 – 11:20am **49th Annual Meeting & Course (2014) Preview – Anchorage, Alaska**
James M. Eule, MD
Local Host

11:20 – 11:23am **Worldwide Conferences Preview**
Ahmet Alanay, MD
WWC Committee Chair

11:23 – 11:30am **Introduction of SRS President**
Steven D. Glassman, MD
President-Elect

11:30 – 11:50am **Presidential Address**
Kamal N. Ibrahim, MD, FRCS(C), MA

12:00 – 1:00pm Lunch Break

Lunchtime Symposia *(see page 175)*

Building a Culture of Safety in Your Operating Room
Room: Forum 4, Forum Level

Global Outreach Update
Room: Forum 1, Forum Level

The Research Process: From Asking to Answering
Room: Forum 5/6, Forum Level

1:00 – 1:15pm Walking Break

Session 6A: Hibbs Basic Science Award Nominees

Session Times: 1:15 – 1:57pm
Moderators: Kenneth M.C. Cheung, MD & Paul D. Sponseller, MD
Room: Forum 5/6, Forum Level

1:15 – 1:19pm ┼ **Paper #67: Induction of SHP2-Deficiency in Chondrocytes Causes Severe Scoliosis and Kyphosis in Mice**
Nobuhiro Kamiya; Daniel J. Sucato, MD, MS; B. Stephens Richards, MD; Harry Kim
*** This presentation is the result of a project funded, in part, by an SRS Research Grant***

1:19 – 1:23pm ┼ **Paper #68: The Relationship Between Serum Vitamin D Levels, Successful Fusion and Fusion Strength: A Quantitative Analysis**
Melodie F. Metzger, PhD; Linda E. Kanim, MA; Li Zhao; Samuel T. Robinson, BS; Rick B. Delamarter, MD
*** This presentation is the result of a project funded, in part, by an SRS Research Grant***

1:23 – 1:27pm ┼ **Paper #69: Intrawound Vancomycin Powder Eradicates Surgical Wound Contamination: An In Vivo Rabbit Study**
Lukas P. Zebala, MD; Tapanut Chuntarapas; Michael P. Kelly, MD; Michael Talcott, DVM; Suellen C. Greco, DVM; K. Daniel Riew, MD

1:27 – 1:36pm **Discussion**

1:36 – 1:40pm ┼ **Paper #70: Injectable Gelatin Utilized as Hemostatic Agent in Long Deformity Surgeries: Does it Embolize?**
Craig A. Kuhns, MD; Cristi R. Cook, DVM; John Dodam; Stacey B. Leach, DVM; Keiichi Kuroki, DVM, PhD; Tyler Jenkins, BS; Anne M. Tallmage, BS; Daniel G. Hoernschemeyer, MD

1:40 – 1:44pm ┼ **Paper #71: Medular Tolerance to Intraoperative Manipulation: Differences Between Acute and Slow Progressive Compression: Experimental Study**
Elena Montes; Jesús J F. Burgos, PhD; Gema De Blas, MD, PhD; Carlos Barrios, MD, PhD; Eduardo Hevia, MD; Luis Miguel Antón-Rodrigálvarez, PhD; Carlos Correa Gorospe

1:44 – 1:48pm ┼ **Paper #72: Critical Events Before Spinal Cord Injury in a Porcine Compression Model**
Vishal Sarwahi, MD; Etan P. Sugarman, MD; Aviva G. Dworkin, BS; Abhijit Pawar, MD; Marina Moguilevitch, MD; Terry D. Amaral, MD; Beverly Thornhill, MD; Adam L. Wollowick, MD; Alan D. Legatt, MD, PhD

1:48 – 1:57pm **Discussion**

Session 6B: Hibbs Clinical Award Nominees

Session Times: 1:58 – 3:03pm
Moderators: Sigurd H. Berven, MD & Daniel J. Sucato, MD, MS
Room: Forum 5/6, Forum Level

1:58 – 2:02pm ***Paper #73: Sagittal Parameters in Failed Paediatric Spinal Deformity Operations**
Julian J. Leong, FRCS, PhD; Nitin Shetty, FRCS; Tejas K. Yarashi, MBChB; Alexa J. Offen, BSc; Stewart Tucker, FRCS

2:02 – 2:06pm ***Paper #74: Lumbar Disc Degeneration on Unfused Segments in Adolescent Idiopathic Scoliosis: Long-Term Follow-Up Study Comparing Different Surgical Approaches**
Ayato Nohara; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Tetsuya Ohara; Yoshitaka Suzuki; Toshiki Saito; Ryo Sugawara; Kyotaro Ota; Kazuki Kawakami

2:06 – 2:10pm ***Paper #75: A New Predictive Model of Progression for Adolescent Idiopathic Scoliosis Based on 3D Spine Parameters at the First Visit: The Results of a Six-Year Prospective Observational Study**
Marie-Lyne Nault, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BSc; Hubert Labelle, MD; Jacques A. de Guise, PhD; Stefan Parent, MD, PhD
*** This presentation is the result of a project funded, in part, by an SRS Research Grant***

2:10 – 2:19pm **Discussion**

2:20 – 2:24pm ***Paper #76: Prospective, Multi-Center Assessment of Acute Neurologic Complications Following Complex Adult Spinal Deformity Surgery: The Scoli-Risk-1 Trial**
Lawrence G. Lenke, MD; Michael G. Fehlings, MD, PhD; Christopher I. Shaffrey, MD; Kenneth M. Cheung, MBBS(UK), FRCS(England), FHKCOS, FHKAM(Orth); Leah Y. Carreon, MD, MSc

2:24 – 2:28pm ***Paper #77: Incidence and the Risk Factors of Major Surgical Complication in Patients with Complex Spine Deformity: A Report from an SRS GOP Site**
Mitsuru Yagi, MD, PhD; Cristina Sacramento-Dominguez, MD, PhD; Han Jo Kim, MD; Oheneba Boachie-Adjei, MD; Focos Research Associates

2:28 – 2:32pm ***Paper #78: Recombinant Human Bone Morphogenetic Protein-2 (rhBMP-2) Use in Adult Spinal Deformity (ASD) Does Not Increase Major, Infectious or Neurological Complications and May Decrease Return to Surgery at One Year: A Prospective, Multi-Center Analysis**
Shay Bess, MD; Breton Line, BSME; Christopher I. Shaffrey, MD; Eric Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Douglas C. Burton, MD; Munish C. Gupta, MD; Robert A. Hart, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Justin S. Smith, MD, PhD; International Spine Study Group

2:32 – 2:41pm **Discussion**

2:42 – 2:46pm ***Paper #79: Comparative Analysis of Osteotomies During Adult and Pediatric Spinal Fusions: A Retrospective Review of >6,000 Cases from the Scoliosis Research Society Morbidity and Mortality Database**
Samuel K. Cho, MD; Natalia N. Egorova, PhD, MPH; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; John Caridi, MD; Yongjung J. Kim, MD

2:46 – 2:50pm ***Paper #80: Antifibrinolytics Reduce Blood Loss in Adult Spinal Deformity Surgery: A Prospective Randomized Controlled Trial**
Kseniya Slobodyanyuk; Thomas Cheriyan; Frank J. Schwab, MD; Kushagra Verma, MD, MS; Christian Hoelscher, BS; Austin Peters; Tessa Huncke, MD; Baron S. Lonner, MD; Thomas J. Errico, MD

2:50 – 2:54pm ***Paper #81: Two-Year Prospective, Multi-Center Analysis of Consecutive Adult Spinal Deformity (ASD) Patients Demonstrates Higher Fusion Grade, Lower Implant Failures and Greater Improvement in SRS-22r Scores for Patients Treated with Recombinant Human Bone Morphogenetic Protein-2 (BMP)**
Shay Bess, MD; Breton Line, BSME; Eric Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Douglas C. Burton, MD; Khaled Kebaish, MD; Robert A. Hart, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; International Spine Study Group

2:54 – 3:03pm **Discussion**

3:03 – 3:24pm Refreshment Break

Forum Level Foyer

Session 7: Health Resources, Complications, Neuromuscular Scoliosis and Neuromonitoring

Session Times: 3:24 – 5:11pm
Moderators: David W. Polly, MD & S. Rajasekaran, MD, FRCS, MCh, PhD
Room: Forum 5/6, Forum Level

3:24 – 3:28pm **Paper #82: Affordable Care Act (Obamacare) Versus Medicare Reimbursement for Spinal Surgeons: Analysis of Hourly Earnings for Four Degenerative and Three Scoliosis Surgeries**
Dennis Crandall, MD; Melissa Gebhardt, PA-C; Michael S. Chang, MD; Jason Datta, MD; Terrence Crowder, MD

3:28 – 3:32pm **Paper #83: Combined Orthopaedic and Neurosurgical Attending Surgeon Approach to Adult Spinal Deformity Surgery: A Multi-Center and Multi-Disciplinary Perspective**
Rajiv K. Sethi, MD; Erion Qamirani, MD, PhD; Alexander A. Theologis, MD; Jean- Christophe Leveque, MD; Christopher P. Ames, MD; Vedat Deviren, MD

3:32 – 3:36pm **Paper #84: Effect of Preoperative Indications Conference on Procedural Planning for Treatment of Scoliosis**
Charles M. Chan, MD; Howard Y. Park, BA; Joshua E. Hyman, MD; Michael G. Vitale, MD, MPH; David P. Roye, MD; Hiroko Matsumoto, MA; Benjamin D. Roye, MD, MPH

3:36 – 3:45pm **Discussion**

3:46 – 3:50pm **Paper #85: At What Levels are Free Hand Pedicle Screws Most Frequently Malpositioned in Children?**
Mark J. Heidenreich, BS; Yaser M. Baghdadi, MD; Anthony A. Stans, MD; Mark B. Dekutoski, MD; William J. Shaughnessy, MD; Amy L. McIntosh, MD; A. Noelle Larson, MD

3:50 – 3:54pm **Paper #86: Long-Term Effects of Thoracic Pedicle Screws with Intraoperative Undetected Invasion of the Spinal Canal at the Convexity in Scoliotic Patients**
Jesús J F. Burgos, PhD; Gema De Blas, MD, PhD; Carlos Barrios, MD, PhD; Eduardo Hevia, MD; Luis Miguel Antón-Rodrigálvarez, PhD; Ignacio Sanpera, MD, PhD

3:54 – 3:58pm **Paper #87: The Incidence of Neurologic Symptoms Using Free Hand Pedicle Screw Placement in Pediatric Deformity**
Ozgur Dede, MD; Austin Bowles, MS; James W. Roach, MD; W. Timothy Ward, MD; Patrick Bosch, MD

3:58 – 4:07pm **Discussion**

4:08 – 4:12pm **Paper #88: Tranexamic Acid and Intrathecal Morphine are Synergistic in Reducing Transfusion Requirements in Non-Idiopathic Scoliosis Patients Undergoing Posterior Spinal Fusion**
Gideon Blumstein, MS; Derek A. Seehausen, BA; Patrick Ross, MD; David L. Skaggs, MD, MMM

4:12 – 4:16pm **Paper #89: Scoliosis Surgery in Cerebral Palsy Spastic Quadriplegic Patients: Is Fusion to the Sacrum Always Necessary? A Minimum Four-Year Follow-Up**
Bruce F. Hodgson, FRACS; Nicholas deGiorgio-Miller, MBChB

4:16 – 4:20pm **Paper #90: Proximal Junctional Kyphosis in Cerebral Palsy: Risk Factors and Guidelines**
Paul D. Sponseller, MD; Suken A. Shah, MD; Burt Yaszay, MD; Peter O. Newton, MD; Mark F. Abel, MD; Tracey Bastrom, MA; Michelle C. Marks, PT, MA; Patrick J. Cahill, MD

4:20 – 4:29pm **Discussion**

4:30 – 4:34pm **Paper #91: A Prospective Multi-Center Study of Neuromonitoring for Cerebral Palsy Scoliosis: The Nature and Rate of Alerts and Recovery of Changes**
Suken A. Shah, MD; Paul D. Sponseller, MD; Mark F. Abel, MD; Peter O. Newton, MD; Burt Yaszay, MD; Firoz Miyanji, MD, FRCS(C); Amer F. Samdani, MD; Harms Study Group

4:34 – 4:38pm **Paper #92: Intraoperative Neuromonitoring for AIS: Multimodal Motor Evoked Potential Montitoring Utilizing Simultaneous Transcranial MEP and Neurogenic MEP**
Daniel J. Sucato, MD, MS; Anna M. McClung, BSN, RN; Steven Sparagana, MD; Patricia L. Rampy, MS, REPT, CNIM; Elizabeth M. Van Allen, MS

4:38 – 4:42pm **Paper #93: Failure of Intraoperative Monitoring to Detect Postoperative Neurologic Deficits: A 25-Year Experience in 12,375 Spinal Surgeries**
Barry L. Raynor, BS; Anne M. Padberg, MS; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; K. Daniel Riew, MD; Jacob M. Buchowski, MD, MS; Scott J. Luhmann, MD

4:42 – 4:49pm **Discussion**

4:50 – 4:54pm **Paper #94: The Recognition, Incidence and Management of Spinal Cord Monitoring Alerts in Early Onset Scoliosis**
Jonathan H. Phillips, MD; Denise Lopez, MSN, ARNP; Dennis R. Knapp, MD; Jose A. Herrera-Soto, MD

4:54 – 4:58pm **Paper #95: The Cutoff Amplitude of Transcranial Motor Evoked Potentials for Predicting Postoperative Motor Deficis in Thoracic Spine Surgery**
Akio Muramoto, MD; Shiro Imagama, MD; Zenya Ito; Kei Ando, PhD; Ryoji Tauchi, MD; Hiroki Matsui; Tomohiro Matsumoto, MD, PhD; Naoki Ishiguro

4:58 – 5:02pm **Paper #96: Neurophysiologic Protocol for Intraoperative Identification of the Injury Level After Spinal Cord Damage During Spine Surgery: A New Method Experimentally Tested in Pigs**
Javier Cervera; Jesús J F. Burgos, PhD; Gema De Blas, MD, PhD; Lidia Cabanes; Eduardo Hevia, MD; Carlos Barrios, MD, PhD; Carlos Correa Gorospe; Gabriel Piza Vallespir, MD, PhD; Ignacio Sanpera, MD, PhD

5:02 – 5:11pm **Discussion**

Session 8: Kyphosis, Osteotomies and Cervical Deformity

Session Times: 7:55 – 10:30am
Moderators: Marinus De Kleuver, MD, PhD & Burt Yaszay, MD
Room: Forum 5/6, Forum Level

7:55 – 8:00am **Welcome & Announcements**

8:00 – 8:04am **Paper #97: Pulmonary Function Changes Maintained Following Surgery for Scheuermann's Kyphosis**
Baron S. Lonner, MD; Courtney Toombs, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD

8:04 – 8:08am **Paper #98: The Clinical Implications of Radiological Changes in Sagittal Parameters of the Cervical and Lumbar Spine Following Correction of Scheuermann's Kyphosis**
Hossein Mehdian, MD, MS(Orth), FRCS(Ed); Georgios Arealis, PhD; Sherief Elsayed, FRCS(Tr&Orth)

8:08 – 8:12am **Paper #99: Quality of Life Improvement Following Surgery for Scheuermann's Kyphosis Compared to Adolescent Idiopathic Scoliosis**
Baron S. Lonner, MD; Courtney Toombs, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Harry L. Shufflebarger, MD; Burt Yaszay, MD; Paul D. Sponseller, MD; Peter O. Newton, MD

8:12 – 8:21am **Discussion**

8:22 – 8:26am **Paper #100: The Routine Use of MRI Prior to Surgical Treatment for Scheuermann's Kyphosis is Not Indicated**
Daniel J. Sucato, MD, MS; Anna M. McClung, BSN, RN

8:26 – 8:30am **Paper #101: Vertebral Column Decancellation (VCD) for the Management of Severe Spinal Deformity**
Yan Wang, MD; Yonggang Zhang, PhD; Guoquan Zheng, MD

8:30 – 8:34am **Paper #102: Preoperative Skull-Femoral Traction with Posterior Vertebral Column Resection (PVCR) to Treat Severe Rigid Spinal Deformity with Angular Curves >150°**
Jingming Xie; Zhi Zhao; Tao Li; Yingsong Wang, M.D; Ying Zhang; Ni Bi

8:34 – 8:42am **Discussion**

8:43 – 8:47am **Paper #103: Posterior Vertebral Column Resection (PVCR) in Congenital Thoracic Lordoscoliosis**
Meric Enercan; Cagatay Ozturk, MD; Sinan Kahraman; Bekir Y. Uçar, MD; Gurkan Gumussuyu, MD; Ahmet Alanay, MD; Azmi Hamzaoglu, MD

8:47 – 8:51am **Paper #104: Three Column Spinal Osteotomies for Adult Spinal Deformity: Inter-Center Analysis of Variability in Technique and Alignment Impact**
Pierre Devos, MS; Jamie S. Terran, BS; Richard Hostin, MD; Robert A. Hart, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Ibrahim Obeid; Gregory M. Mundis, MD; Khaled Kebaish, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

8:51 – 8:55am **Paper #105: Pedicle Subtraction Osteotomy (PSO) in the Revision Versus Primary Adult Spinal Deformity (ASD) Patient: Is There a Difference in Correction and Complications?**
Munish C. Gupta, MD; Jamie S. Terran, BS; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Oheneba Boachie-Adjei, MD; Virginie Lafage, PhD; Shay Bess, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Khaled Kebaish, MD; Eric Klineberg, MD; International Spine Study Group

8:55 – 9:04am **Discussion**

Moderators: Todd J. Albert, MD & Christopher P. Ames, MD

9:05 – 9:09am **Paper #106: Revision Surgery After Three Column Osteotomy (3CO) in 335 Adult Spinal Deformity (ASD) Patients: Inter-Center Variability and Risk Factors**
Stephen P. Maier, BA; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Ibrahim Obeid; Gregory M. Mundis, MD; Eric Klineberg, MD; Khaled Kebaish, MD; Richard Hostin, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Oheneba Boachie-Adjei, MD; Christopher P. Ames, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; International Spine Study Group

9:09 – 9:13am **Paper #107: Morbidity of Pedicle Subtraction Osteotomy (PSO), Retrospective Multi-Centre Study: 267 Cases with Two Years Minimum Follow-Up in Nine Centers**
Ibrahim Obeid, MD; Didier Fort; Guillaume Riouallon, MD; Jean M. Vital, MD, PhD; Stephane Wolff; Ges Ges

9:13 – 9:17am **Paper #108: Routine Use of Intraoperative Spinal Cord Monitoring is Necessary During Spinal Osteotomy for Adult Spinal Deformity**
Sho Kobayashi, PhD; Tomohiko Hasegawa; Yu Yamato; Daisuke Togawa; Tatsuya Yasuda; Hideyuki Arima; Yukihiro Matsuyama, MD

9:17 – 9:26am **Discussion**

9:27 – 9:31am **Paper #109: Analysis of Cervical Spine Alignment According to Roussouly Sagittal Global Spine Classification in Cervical Spondylosis Patients**
Miao Yu, MD; WenKui Zhao, MD

9:31 – 9:35am **Paper #110: How the Neck Affects the Back: Changes in Regional Cervical Sagittal Alignment Correlate to HRQL Improvement in Adult Thoracolumbar Deformity Patients at Two-Year Follow-Up**
Themistocles S. Protopsaltis, MD; Justin K. Scheer, BS; Jamie S. Terran, BS; Justin S. Smith, MD, PhD; Han Jo Kim, MD; Gregory M. Mundis, MD; Robert A. Hart, MD; Ian McCarthy, PhD; Eric Klineberg, MD; Virginie Lafage, PhD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

9:35 – 9:39am **Paper #111: Prevalence and Type of Cervical Deformity Among 470 Adults with Thoracolumbar Deformity**
Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Themistocles S. Protopsaltis, MD; Eric Klineberg, MD; Justin K. Scheer, BS; Kai-Ming Fu, MD, PhD; Richard Hostin, MD; Vedat Deviren, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group

9:39 – 9:48am **Discussion**

9:49 – 9:53am **Paper #112: T1 Slope Minus Cervical Lordosis (T1S-CL), the Cervical Analog of PI-LL, Defines Cervical Sagittal Deformity in Patients Undergoing Thoracolumbar Osteotomy**
Themistocles S. Protopsaltis, MD; Jamie S. Terran, BS; Nicolas Bronsard, MD, PhD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Gregory M. Mundis, MD; Han Jo Kim, MD; Richard Hostin, MD; Robert A. Hart, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

9:53 – 9:57am **Paper #113: Comparison of Smith Peterson (SPO) Versus Pedicle Subtraction (PSO) Versus Anterior Osteotomy (AO) Types for the Correction of Cervical Spine Deformities**
Han Jo Kim, MD; Chaiwat Piyaskulkaew, MD; Lawrence G. Lenke, MD; K. Daniel Riew, MD

9:57 – 10:01am **Paper #114: Cervical Scoliosis: Clinical and Radiographic Outcomes**
Addisu Mesfin, MD; Wajeeh R. Bakhsh, BA; Samuel Romero-Vargas, MD; Han Jo Kim, MD; K. Daniel Riew, MD

10:01 – 10:10am **Discussion**

10:11 – 10:20am Transfer of the Presidency

Kamal N. Ibrahim, MD, FRCS (C), MA & Steven D. Glassman, MD

10:20 – 10:30am Awards Presentation

Russell A. Hibbs Awards
Louis A. Goldstein Awards
John H. Moe Award

Suken A. Shah, MD
Program Committee Chair

10:30 – 10:50am Refreshment Break

Forum Level Foyer

Session 9:	Innovative Methods, Spondylolisthesis, Non-Idiopathic Scoliosis and Outcomes
Session Times:	10:50am – 12:39pm
Moderators:	Hubert Labelle, MD & David S. Marks, FRCS
Room:	Forum 5/6, Forum Level

10:50 – 10:54am **Paper #115: Spinal Hemiepiphysiodesis for Fusionless Scoliosis Treatment Using Titanium Implant Alters Biomechanical Properties**
Matthew T. Coombs, MSc; David Glos, BSE; Eric Wall, MD; Donita Bylski-Austrow, PhD

10:54 – 10:58am **Paper #116: Effect of Screw Across Vertebral Neurocentral Synchondrosis on Spinal Canal Development in an Immature Spine**
Xuhui Zhou, MD; Hong Zhang, MD; Daniel J. Sucato, MD, MS; Charles E. Johnston, MD

10:58 – 11:02am **Paper #117: Fusion After Vertebral Body Stapling**
Elias Dakwar, MD; Amer F. Samdani, MD; Michael Auriemma; Joshua M. Pahys, MD; Randal R. Betz, MD; Patrick J. Cahill, MD

11:02 – 11:11am **Discussion**

11:12 – 11:16am **Paper #118: Patient Outcomes in the Operative and Non-Operative Management of High-Grade Spondylolisthesis in Children**
Kristopher Lundine, MD, MSc, FRCS(C); Stephen J. Lewis, MD; Zaid T. Al-Aubaidi, MD; Benjamin Alman, MD; Andrew Howard, MD, MSc, FRCS(C)

11:16 – 11:20am **Paper #119: Radiographic Healing of Spondylolysis Does Not Influence Pain or Return to Sports Eight Years Later**
Kent T. Yamaguchi, BA; Jerald D. Borgella; Christopher Lee, MD; Lindsay Andras, MD; Karen S. Myung, MD, PhD; Pierre A. D'Hemecourt, MD; John M. Flynn, MD; Jeffrey R. Sawyer, MD; David L. Skaggs, MD, MMM

11:20 – 11:24am **Paper #120: Risks and Outcomes of Corrective Spine Surgery in Chiari Malformation with Syringomyelia Versus Idiopathic Spine Deformity**
Jakub Godzik; David Limbrick, MD, PhD; Lawrence G. Lenke, MD; Terrence F. Holekamp, MD, PhD; Wilson Ray, MD; Michael P. Kelly, MD

11:24 – 11:33am **Discussion**

11:34 – 11:38am **Paper #121: Scoliosis Surgery with Hybrid System in Osteogenesis Imperfecta (OI): Results of 12 Patients: Are Pedicle Screws Applicable to Weak, Tiny and Fragile Vertebrae in OI?**
Masaaki Ito; Koki Uno, MD, PhD; Teppei Suzuki; Yoshihiro Inui

11:38 – 11:42am **Paper #122: Results of Surgical Correction of Scoliosis in 17 Patients with Osteogenesis Imperfecta**
Zeeshan Sardar, MD, CM; Abhishek Kumar; Vincent Arlet; Neil Saran, MD, MHSc, FRCS(C); Jean A. Ouellet, MD

11:42 – 11:46am **Paper #123: Scoliosis Surgery in Children with Congenital Heart Disease**
Muayad Kadhim, MD; William G. Mackenzie, MD; Ellen Spurrier; Deepika Thacker; Christian Pizarro, MD; Suken A. Shah, MD

11:46 – 11:55am **Discussion**

11:56am – 12:00pm **Paper #124: Adjunctive Vancomycin Powder in Pediatric Spine Surgery is Safe**
Itai Gans, BS; John P. Dormans, MD; David A. Spiegel, MD; John M. Flynn, MD; Wudbhav Sankar, MD; Robert M. Campbell, MD; Keith D. Baldwin, MD, MSPT, MPH

12:00 – 12:04pm **Paper #125: Cost Savings Analysis of Intra-Wound Vancomycin Powder in Posterior Spinal Surgery**
Osa Emohare, MBBS, PhD; Brian W. Hill, MD; Charles Gerald T. Ledonio, MD; Bowei Song; Eva Enns, PhD; Rick A. Davis, MD; Robert A. Morgan, MD; David W. Polly, MD; Matthew Kang, MD

12:04 – 12:08pm **Paper #126: Does a Kaolin Impregnated Hemostatic Dressing Reduce Intraoperative Blood Loss and the Blood Transfusions in Pediatric Spinal Deformity Surgery?**
Emily Abbott, BS; Richard M. Schwend, MD; Sreeharsha V. Nandyala, BA

12:08 – 12:17pm **Discussion**

12:18 – 12:22pm **Paper #127: Before Diagnosis the SRS-22 Questionnaire Discriminates Populations but Does Not Correlate with Deformity: A Cross-Sectional Study of 1354 Adolescent Idiopathic Scoliosis (AIS) Patients**
Laura Rainoldi; Francesco Negrini; Fabio Zaina; Stefano Negrini, MD

12:22 – 12:26pm **Paper #128: Impact of BMI and Depression on Scoliosis Research Society (SRS- 22) Questionnaire After Major Spine Surgery**
Sara E. Thompson, BA; Jamal McClendon, MD; Frank L. Acosta, MD; Tyler Koski, MD

12:26 – 12:30pm **Paper #129: The SRS-7: An Unidimensional Rasch-Developed Short Form of the SRS-22 Questionnaire for Measuring Health-Related Quality of Life in Adolescent Idiopathic Scoliosis**
Antonio Caronni, MD, PhD; Fabio Zaina; Stefano Negrini, MD

12:30 – 12:39pm **Discussion**

12:40pm Adjourn

Podium & Case Discussion Abstracts

Podium & Case Discussion Abstracts

The Scoliosis Research Society gratefully acknowledges the following companies for their overall support of the Annual Meeting & Course:

OrthoPediatrics

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Case Discussion 1 - Cervical

1A. Cranial Nerve Injuries Following Cervicothoracic Fusion in Klippel-Feil Syndrome

Elias Dakwar, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD

USA

Summary: Most cases of neurologic deficits after undergoing posterior cervicothoracic fusion are vascular in nature. We report a 6-year-old boy who developed traction facial and hypoglossal nerve injuries after undergoing a cervicothoracic fusion with halo-vest application for torticollis secondary to Klippel-Feil Syndrome.

Introduction: Torticollis is a clinical symptom and sign characterized by a lateral head tilt and chin rotation. A common non-muscular cause of torticollis is Klippel-Feil Syndrome (KFS). We present a case of cranial nerve deficits after cervicothoracic fusion for KFS and cervical torticollis.

Methods: A 6-year-old boy with KFS and congenital scoliosis presented with progressive cervical torticollis. His past medical history is significant for arthrogryposis, club foot, cervical syrinx, and recent tethered cord release. He was taken to surgery for a posterior cervicothoracic fusion. He was placed in a Mayfield head clamp in a neutral position. A C2-T3 posterior spinal fusion was performed. A halo vest was then placed to maintain his head and cervical spine in neutral position. The positioning involved tilting through the (unfused) upper cervical spine. There were no neuromonitoring changes.

Results: Postoperatively, he remained neurologically intact. Approximately 48 hours postoperatively, he developed facial droop and slurring of his speech. He was diagnosed with unilateral peripheral cranial nerve 7 (facial) and 12 (hypoglossal) nerve deficits. A CT scan of his head and neck showed no abnormalities. An MRI and magnetic resonance angiogram of his head and neck were performed to rule out stroke, bleed, or dissection. His halo vest was removed and he began to show some improvement. At his 6-week post-op visit, the patient has continued to show improvement but still has some residual deficit.

Conclusion: We report a rare case of a 6-year- old patient with torticollis secondary to KFS who developed facial and hypoglossal nerve deficits after undergoing a cervicothoracic fusion with halo-vest application. There was no evidence of stroke or dissection. The most likely etiology is traction injury to the cranial nerves secondary to the halo-vest.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

1B. The Four Fixation Points of the Axis, Technique and Case Report

Kris Siemionow, MD; Steven M. Mardjetko, MD, FAAP

USA

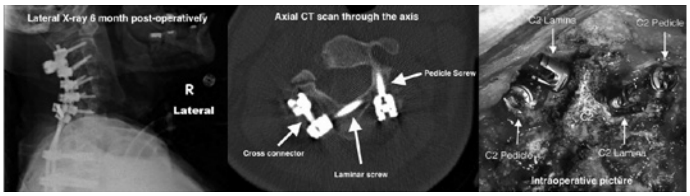
Summary: A novel 4 screw technique has proven effective for management of patients with cervical deformity. The technique increases the number of anchor points in C2, potentially increasing the pullout strength of the construct.

Introduction: Instrumentation of the axis can be accomplished through a variety of techniques. In order to maximize the potential of the axis as a fixation point we report on the evolution of our 4-screw technique consisting of two C2 translaminar screws and two C2 pedicle screws connected to a long construct.

Methods: Retrospective case review. Surgical technique- After exposure of posterior spinal elements, the medial and superior walls of the C2 pedicle were identified from within the spinal canal. Using anatomic landmarks, a starting point was made with a burr. A high-speed drill was then advanced under lateral fluoroscopy, which guided cranio-caudal angulation. Medial angulation was based on pre-operative CT scan and averaged 30 degrees. This was followed by placement of translaminar screws according to the technique described by Wright. When extending the construct into the subaxial spine or the occiput, lateral connectors are placed in translaminar screws, which are usually more offset. The rod is directly connected to the pedicle screws, which are usually more in alignment with the subaxial/ occipital instrumentation

Results: Two male patients ages 56 and 58 underwent posterior instrumentation of the axis employing a combination of pedicle and laminar polyaxial screws (Figure 1). Indications

included multilevel spinal cord compression and deformity in a patient with Downs Syndrome(DS) and cervical meningioma, respectively. Follow up was 6 months and 4 years, respectively. Medical complications(N=2) occurred in the DS patient resulting in prolonged intubation with tracheostomy placement. Reduction was maintained in both patients at last followup. There were no neurologic, vascular, or instrumentation related complications.
Conclusion: The axis serves as a versatile anchor point. Lateral connectors play a crucial role and allow for incorporation of the C2 screws with the rest of the construct. Local anatomy will dictate the ability to place instrumentation and detailed preoperative planning is critical



Lateral x-ray, axial CT, and intraoperative images of a 56 year old male with Down's Syndrome, cervical deformity, and spinal cord compression. Patient underwent a C2 toT2 posterior spinal fusion with 4 points of fixation obtained in the axis via 2 pedicle and 2 translaminar screws.

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1C. Metatropic Dysplasia as the Cause of Atlantoaxial Instability, Spinal Stenosis and Myelopathy: Case Report and Literature Review

Michal Barna; Jan Stulik; Petr Nesnidal, MD; Tomas Vyskocil; Jan Kryl

Czech Republic

Summary: We present the case of a patient, aged 4 years and 10 months, with metatropic dysplasia. The baby had repeated apnoeic episodes, bradycardia and cardiac arrests and was diagnosed with foramen magnum stenosis and atlantodental dislocation. The episodes were markedly associated with neck movements. Considering this clinical presentation, we performed laminectomy of the atlas, foramen magnum enlargement and decompression followed by dorsal C0-C2 stabilisation with allogeneic bone chips. After the operation, apnoeic episodes did not recur.
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Methods: The baby had repeated apnoeic episodes, bradycardia and cardiac arrests and was diagnosed with foramen magnum stenosis and atlantodental dislocation. The episodes were markedly associated with neck movements.
Results: Considering this clinical presentation, we performed laminectomy of the atlas, foramen magnum enlargement and decompression followed by dorsal C0-C2 stabilisation with allogeneic bone chips.
Conclusion: After the operation, apnoeic episodes did not recur.

1D. Treatment for Progressive Cervical Hyperlordosis After Multilevel Cervical Laminectomy in a Patient with Intramedullary Lipoma: A Case Report

Taichi Tsuji, MD; Noriaki Kawakami, MD, DMSc; Tetsuya Ohara; Yoshitaka Suzuki; Toshiki Saito; Ayato Nohara; Ryo Sugawara; Kyotaro Ota

Japan

Summary: A 10-year-old boy complaining of cervical hyperlordosis and dyspnea was referred to this department. He underwent cervical and thoracic laminectomy to remove a lipoma at the age of 3 years and 6 months. His lordosis of cervical spine gradually progressed. The cervical lordosis reached 112° with 62° thoracic scoliosis at the age of 10. We corrected both the cervical and thoracic deformities by a two staged operation. SPO was the key to the correction.
Introduction: Post-laminectomy deformity, particularly kyphosis, in the cervical spine is a common complication that often shows progressive deformity with neck pain in adult patients. One pediatric patient showed progressive post-laminectomy hyperlordosis, which was very rare, and was treated surgically and achieved a good outcome.
Methods: Case presentation
Results: A 10-year-old boy complaining of cervical hyperlordosis and dyspnea was referred to this department. Muscle weakness of his bilateral upper extremities was recognized at the age of 2 months followed by a diagnosis of intramedullary lipoma. He underwent cervical and thoracic laminectomy to remove a lipoma at the age of 3 months. However, lordosis of the cervical spine gradually progressed without influencing any independent activity of daily life (ADL). The cervical lordosis reached 112° with 62° thoracic scoliosis at the age of 10; causing severe dyspnea and abnormal posture with his lumbar spinal curvature bending forward to almost 90° in a sitting position. Three dimensional-computed tomography (3D-CT) showed spontaneous fusion in almost the entire cervical spine and MRI exhibited a intramedullary cyst at the brainstem. Two-stage surgical decompression and correction/fusion of hyperlordosis were planned because that both the cervical hyperlordosis and a brainstem cyst were causing the dyspnea. The spontaneous fusion were first released with Smith-Peterson osteotomy (SPO) from C2 to T2 followed by temporary fusion. A neurosurgeon then resected the brainstem cyst via a posterior approach after realignment of the cervical spine. Although his sitting position improved dramatically after the first combined operation, the thoracic scoliosis progressed to 84° over several months F/U period. Anterior release and

posterior corrective fusion was performed for scoliosis by extending the fusion down to L3. Cervical hyperlordosis and thoracic scoliosis were well corrected and maintained by two operations; his ADL improved, allowing independent self-control of his wheel chair.
Conclusion: This report presented a rare case of post-laminectomy hyperlordosis with scoliosis with adequate correction of both the cervical and thoracic deformities by a two staged operation. SPO was the key to the correction.

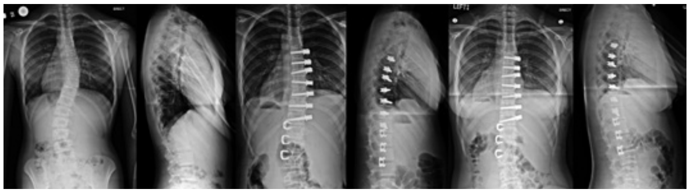
Case Discussion 2 - Complications and Congenital Scoliosis

2A. Early Recognition of Overcorrection After Anterior Vertebral Body Tethering

Amer F. Samdani, MD; Anuj Singla, MD; Robert J. Ames, BA; Joshua M. Pahys, MD; Randal R. Betz, MD

USA

Summary: Anterior vertebral body tethering offers a fusionless option for the treatment of scoliosis in the growing spine. It is a strong growth modulation device, and potential overcorrection needs vigilant surveillance. We present a patient who underwent thoracic anterior vertebral body tethering with anticipated subsequent overcorrection requiring adjustment of the tether.
Introduction: Anterior vertebral body tethering is a promising fusionless option for the treatment of the growing spine. One peer-reviewed case report documents the potential effectiveness of this technique (Crawford, Lenke, JBJS 2010). Having known that overcorrection is a potential risk of the procedure, careful surveillance and timely intervention were discussed with the family before the procedure was performed. We present a patient treated at our institution with anterior vertebral body tethering who subsequently developed mild overcorrection requiring adjustment of the tether.
Methods: A 12-year-old girl with a 38° right thoracic curve (bend=12°) and a 34° left lumbar curve (bend=8°, Lenke 1B) was treated with right sided anterior vertebral body tethering from T6-T12 and left sided vertebral body stapling from T12-L3. At the time of the surgery, the patient was Risser stage 1 and Sanders stage 3.
Results: The thoracic curve corrected to 13° immediately, with subsequent gradual overcorrection to minus 13° over a period of 19 months. At this time, a decision to surgically loosen the tether was made, since the patient was still skeletally immature. The patient underwent thoracoscopic loosening of the tether device from T9 to T12 (maintaining the same cable) with straightening of the overcorrection. The original cable was left 2 cm long beyond the screws, anticipating possible need to lengthen the construct. The current Cobb angle is being maintained at 0°.
Conclusion: Anterior vertebral body tethering is a strong growth modulation device with potential for overcorrection. As this technology gains acceptance, surgeons should be aware of the potential for overcorrection. Patients should be followed at regular intervals, and surgeons should anticipate possibly having to lengthen the tether by leaving excess cable during the index procedure.



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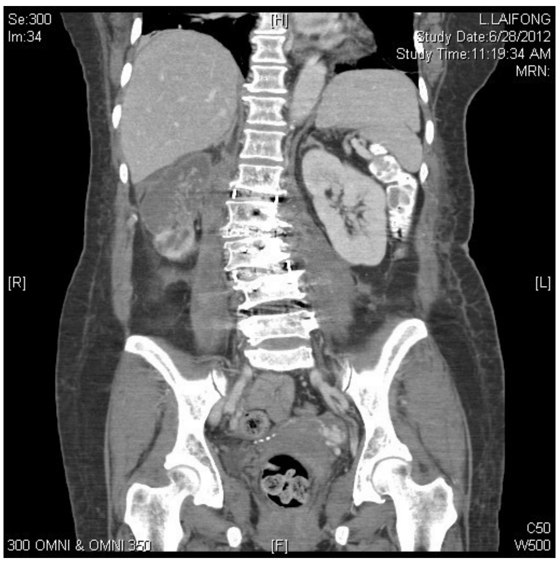
2B. Acute Renal Infarction After Lateral Lumbar Interbody Fusion for Kyphoscoliosis

Sanjeev Suratwala, MD; Vincent Leone, MD

USA

Summary: The lateral approach to the lumbar spine is an exciting new tool to access the spine. However, this procedure can have significant potential complications. We report a case of acute renal infarct following multilevel lateral interbody fusion with posterior instrumentation from L1-L5 for adult kyphoscoliosis. No obvious complication noted intra-operatively. Patient reported vague abdominal pain 7 days post-op. CT abdomen revealed right renal infarct. Caution should be used when performing lateral interbody fusion in patients with atherosclerosis.
Introduction: The lateral approach to the spine appeals to both surgeons and patients. However, this approach is not without risk. Commonly reported complications are transient hip flexor weakness, peripheral nerve injuries, as well as incisional hernia. We report a case of contralateral to the approach renal infarct following lateral interbody fusion & percutaneous posterior spinal instrumentation from L1-5 for kyphoscoliosis. Elevated LDH with normal aminotransferases is suggestive of renal infarction
Renal infarction is rare. Patients present with abdominal pain or flank pain that mimics other conditions like nephrolithiasis. Major etiologies are thromboemboli & thrombosis of a renal artery. Risk factors include atherosclerosis & hypercoagulability. Kidneys do not tolerate prolonged warm ischemia, so reperfusion has a limited role. The main treatment is anticoagulation. Antihypertensive therapy may be required.
Methods: A 72 yr old Asian woman (BMI 25.8) with lumbar kyphoscoliosis had a 3 yr history of worsening low back pain & symptomatic spinal stenosis. Left lateral interbody fusion & posterior percutaneous fixation from L1-5 was performed. No intraoperative hemodynamic abnormalities noted.
She was hypotensive on day of surgery requiring fluid bolus

& anemic on POD#2 requiring transfusion. She reported abdominal pain on POD#7. Abdominal CT revealed right renal artery occlusion & right renal infarct. BUN/Cr, urine output was normal.
TEE revealed diffuse plaque in the descending aorta. No reperfusion was performed. She was anticoagulated.
Results: Correction of kyphoscoliosis in the lumbar spine through lateral approach may precipitate thromboembolism & renal infarct. Postoperative hypotension can contribute to an ischemic renal infarct.
Conclusion: Minimally invasive spinal surgery techniques appeal to both surgeons and patients. With widespread use of these techniques, potential risks of the procedure can become apparent. We report a case of renal infarction following lumbar reconstruction for kyphoscoliosis. Diagnosis requires a high index of suspicion since the primary complaint may be vague abdominal pain. Caution should be used when performing lateral lumbar spine approaches around the renal artery origin in patients with atherosclerosis.



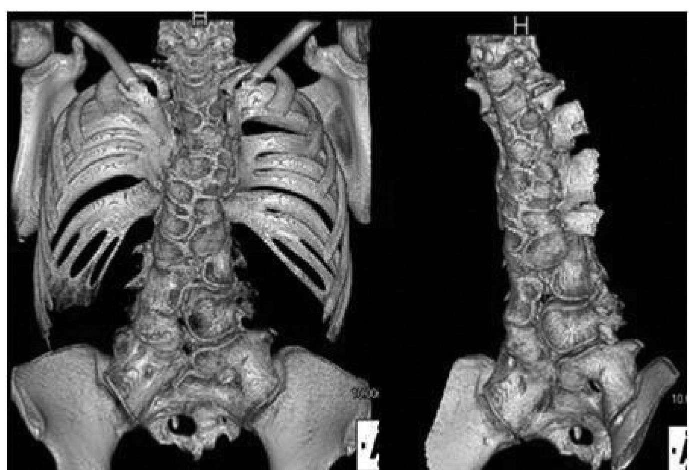
CT demonstrating right acute renal Infarct

2C. A Case of Spondylocostal Dysostosis (Jarcho Levin Syndrome) with Complaints of Costopelvic Impingement

Terry D. Amaral, MD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Vishal Sarwahi, MD

USA

Summary: 16 year old female child with spondylocostal dysostosis (Jarcho Levin Syndrome) with costopelvic impingement underwent spinal distraction, posterior vertebral column resection, to increase the anterior length of the thoraco-abdominal region for pain relief and improvement in quality of life.
Introduction: A 16 year old female child with spondylocostal dysostosis (Jarcho Levin Syndrome) presents with some pulmonary limitations (PFT"s with moderative restrictive and mild obstructive lung disease, VC 41% and TLC 60%) but most importantly, she complains of flank pain at the costopelvic junction. She had been able to participate in all activities with mild limitation but her biggest issue was her ribs rubbing on the top of her pelvis. She had no back pain or neurological findings. Our initial plan was to attempt distraction of the spine to improve her symptoms which was achieved. Subsequently, she was indicated for vertebral column resection, increasing spine length and improving spinal position. This was planed as to increase her height and give good posture.
Methods: Initial Posterior Spinal Instrumentation (PSI) was performed with distraction, providing some improvement to her symptoms. The screws were placed using the freehand technique described by Lenke et al. She underwent second distraction maneuver with further improvement. A year later, she underwent manipulation of previous PSI. A posterior vertebral column recession, hyperextension of the osteotomy site and placement of anterior bone graft was performed. This increased the anterior height, thus increasing the costopelvic distance.
Results: She has improvement in her symptoms and also some increase in height with radiographic improvement in the space between her 12th rib and her pelvis. This procedure also improved the costopelvic impingement and improved her breathing by increasing the space for intra-thoracoabdominal organs.
Conclusion: Management of a complex spine deformity with posteriorly performed circumferential osteotomies have significant risk for neurological sequel. This procedure of circumferential osteotomies allowed for improved height and costopelvic distance, which reduced her pain and improved pulmonary symptoms with no neurologic sequel.



2D. Posterior Thoracic Vertebral Column Resection with Spinal Shortening Promote Huge Syringomyelia Shrinkage in an Adolescent of Severe and Rigid Kyphoscoliosis and Chiari Malformation

Jingming Xie; Yingsong Wang, MD; Ying Zhang; Tao Li; Ni Bi; Zhi Zhao

China

Summary: We reported a severe rigid kyphoscoliosis with huge Syringomyelia, who underwent one-stage thoracic posterior vertebral column resection (PVCR). Syrinx shrinkage and neurological improvement had been detected postoperatively.

Introduction: Although the etiological relationship between syrinx and spinal deformity is unclear, most surgeons prefer to suboccipital decompression before deformity correction, in order to improve neurological safety. We previously reported a series satisfied cases undergone PVCR and without neurosurgical intervention, and their hydrodynamic changes of cerebrospinal fluid (CSF) flow on the craniocervical junction were also investigated.

Methods: A 17-year-old boy with severe and rigid kyphoscoliosis was noticed as asymmetric tendon hyperreflexia and hypermyotonia of lower extremities. The huge syringomyelia was on the cervical and extended to the thoracic portion of the spinal cord. Treatment strategy focused on safe and effective deformity correction, and PVCR with long fusion was selected. After apical vertebral resection, the correction forces are mainly applied as repeated compression though the spinal column and in situ rod bending, while the vertebral column was shortened and to avoid the over tethering or unexpected displacement of the spinal cord.

Results: Postoperatively, he has not encountered any major complication. Although there was no differences in the range of syrinx involved, the maximal anterior-posterior diameter of the syrinx was significantly reduced when 3-months follow-up. His motor function had a return to normal at 6 months follow-up. At 24 months after operation, he showed continuously resolution of the syrinx with negative neurological examination.

Conclusion: The spinal cord tension could be decreased following PVCR correction and spinal shortening, and the abnormal CSF flow at the craniocervical junction was indirectly improved, then contributed to syrinx resolution. In addition, recovery of the previous neural dysfunction might be related to reduction of the cord tension and syrinx resolution. The correlation between spinal deformity progression, high tension of the spinal cord and syringomyelia formation needed to further exploration.

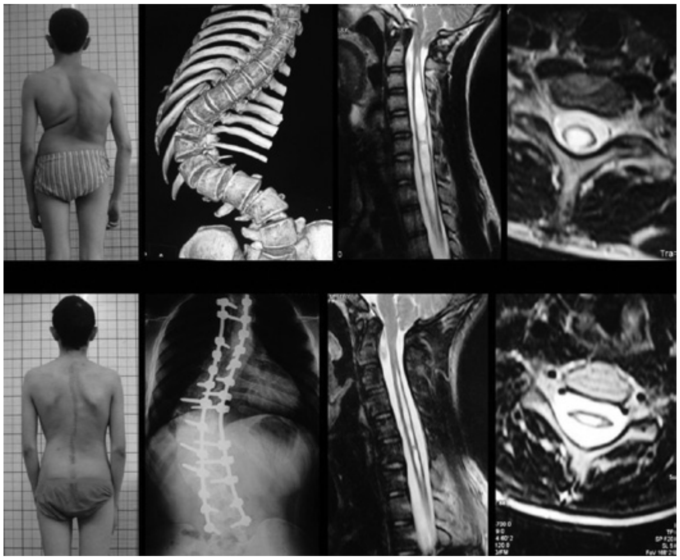


Fig: The clinical feature and radiograph of the patient, and several contiguous wedge shape vertebrae around T11 apical region could be noticed. Following PVCR, the coronal and sagittal alignments were recovered with fine trunk balance. Syrinx shrinkage was confirmed during postoperative follow-up.

2E. Treatment of Severe Spinal Deformity and Diastematomyelia with Vertebral Column Resection

Elias Dakwar, MD; James T. Bennett, MD; Amer F. Samdani, MD

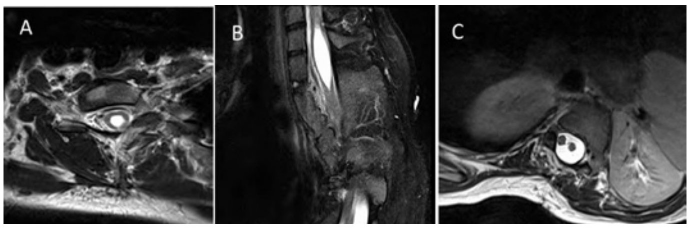
USA

Summary: A 19-year-old girl with congenital scoliosis, diastematomyelia, and cervical syringomyelia presented to our institution with a progressive spinal deformity. A posterior approach vertebral column resection (VCR) for successful correction of her spinal deformity and indirect untethering of her spinal cord was performed without resection of her diastematomyelia.

Introduction: Congenital scoliosis associated with a split cord malformation and syrinx raises the question as to how to best achieve satisfactory deformity correction while avoiding neurologic injury. Surgery has a significantly higher risk in patients with neurologic etiologies than in those with idiopathic scoliosis. Many surgeons advocate neurosurgical treatment of the intraspinal anomalies prior to any deformity correction. We present a case of congenital scoliosis, diastematomyelia, and a cervical syrinx that was treated with a VCR for successful correction of the spinal deformity.

Methods: A 19-year-old girl with congenital scoliosis, diastematomyelia, and a cervical syrinx presented with a progressive spinal deformity. On physical examination, she had left trunk shift, left shoulder elevation, and slight pelvic tilt to the left. On Adam's forward bending test, the inclinometer measured 25 degrees of rotation. She had a left-sided thoracic

curve with a major coronal Cobb angle of 63 degrees. The patient underwent a two-staged posterior spinal fusion from T2 to L4, with VCR at T7 and Ponte osteotomies from T7 to T10. No attempts to resect the diastematomyelia were made.
Results: Postoperatively, she had correction of her spinal deformity with excellent correction of trunk shift and shoulder balance. Radiographs demonstrate a T2-L4 posterior spinal fusion and T7 VCR, with a major coronal Cobb angle of 20 degrees. There were no complications.
Conclusion: We present a 19-year-old girl with congenital scoliosis, diastematomyelia, and a cervical syrinx who underwent a corrective spinal deformity procedure. We performed a posterior only approach VCR with posterior pedicle screw fixation to successfully correct her spinal deformity and indirectly untether her spinal cord.



Case Discussion 3 - Kyphosis

3A. Combined Anterior and Posterior Fusion with Instrumentations for the Treatment of Tuberculosis on Lumbosacral Junction: Two Cases Report

Zhi Zhao; Jingming Xie; Yingsong Wang, MD; Ying Zhang; Tao Li; Ni Bi

China

Summary: We reported two cases with lumbosacral tuberculosis, performed anterior debridement and structured bone autograft, with anterior and posterior instrumentations.
Introduction: The increased prevalence of spinal tuberculosis has been recently noticeable. In case of infrequent lumbosacral tuberculosis, eradicating focal infection, reliable stability reconstruction and neurological safety were primary challenges to surgeons. One-stage posterior spondylectomy has been reported as an effective method for lumbosacral region. However, difficult technique, possible injury of the nerve roots and residual of the paravertebral abscess still restricted its extensive application.
Methods: Two patients, one of 26-years-old and one 34-years old female, were admitted for progressed low back pain. Both of them were detected radiating pain on lower limb. Radiograph showed osseous lesions associated with osteosclerosis across L5/S1 intervertebral space. Large paravertebral abscess extended to the lower sacrum were noticed by MRI scan. After regularly chemical therapy for 4 to 8 weeks for erythrocyte sedimentation rate improvement, operative intervention has been chosen due to the aggravated symptoms. We performed anterior para-peritoneum approach, for debridement, and elimination the abscess under direct observation, then structured bone autograft with a slim and bended plate fixation. Next, a posterior approach using pedicle instrumentation for lumbosacral arthrodesis and fusion has been performed.
Results: Both of them have no complications after operation, and pain released completely. Chemical therapy has continued to 9 months after operation. Rigid fusion has been confirmed by 24 months radiograph, and there was no sign of local tuberculosis recurrent or implant failure.
Conclusion: Compared to posterior only approach, the advantages of anterior debridement included complete eradicating the anterior inflammation tissue, especially when large abscess descended lower sacrum portion, and avoiding potential infection spreading from anterior to the posterior elements. Moreover, for spinal tuberculosis, reliable stability based on instrumentations was benefit to control infection and achieve bone fusion.

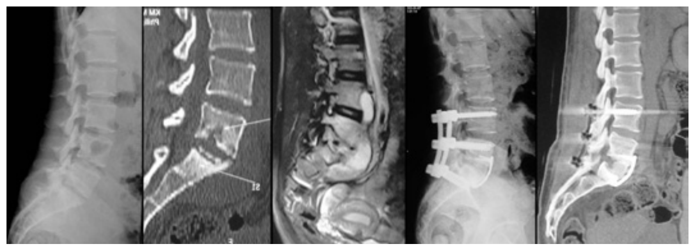


Fig Preoperative radiograph and MRI showed the osseous lesions and anterior abscess. At 24 months after operation, rigid bone fusion has been detected by CT scan.

3B. A Case of Progressive Kyphoscoliosis with Cord Ischemia

Terry D. Amaral, MD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Vishal Sarwahi, MD

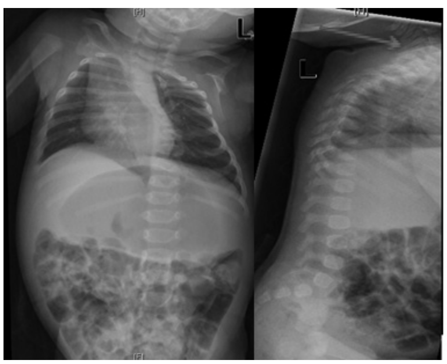
USA

Summary: A patient with progressive Kyphoscoliosis underwent Posterior Spinal Instrumentation (PSF) with loss of SSEP's and MEP's due to spinal cord ischemia.
Introduction: A 3 yr old female child with severe kyphoscoliosis of 90 degrees, at T5-T6. Deformity was progressive with failed bracing and casting. MRI revealed a significant stenosis at the apex of kyphosis with available space of less than 5mm for the cord. Hence, indicated for halo traction to allow some correction of the deformity and eventual surgical management. Two months post halo traction, she was scheduled for laminectomy, vertebral column resection at the kyphotic region and instrumentation with growing rod construct to gain gradual correction, and Risser cast placement.
Methods: Growing rod instrumentation, decompression, laminectomy at T5, T6, and T7 with vertebral column resection and local fusion was planned. Baseline neuromonitoring found undetectable MEPs in the left lower extremity and significantly

diminished in right lower extremity. A complete loss of MEPs of right lower extremity observed during the approach. Wake-up test confirmed the loss of signal. Decompression, to improve the space available for the cord was planned. Blood pressure and room temperature elevated to improve spinal cord perfusion. Warm saline was irrigated to improve core temperature. Multiple rounds of MEPs in the lower extremities, showed no return of signal. Steroid protocol started to protect the spine cord. Instrumentation aborted and the patient placed in a Risser cast, was taken for an MRI. MRI showed no changes, compared to the preoperative MRI.

Results: Two months after surgery, patient still in Risser cast, done to prevent her from going into kyphosis. There is no return of MEPs and SSPEPs in bilateral lower extremities. The patient still awaits PSF and instrumentation.

Conclusion: Severe kyphosis poses a significant neurological risk. A minimal manipulation in already severely compromised cord led to the motor signal loss in the lower extremity. Improved position to account for loss of stabilization afforded by the soft tissue dissection may have prevented the loss.



3C. Two-Stage Combined Anterior and Posterior Spinal Fusion for Severe Cervico-Thoracic Kyphosis (Chin-on-Chest Deformity) in a Severely Osteoporotic Patient

Haruki Funao, MD; Floreana Naef, MD; Khaled Kebaish, MD

USA

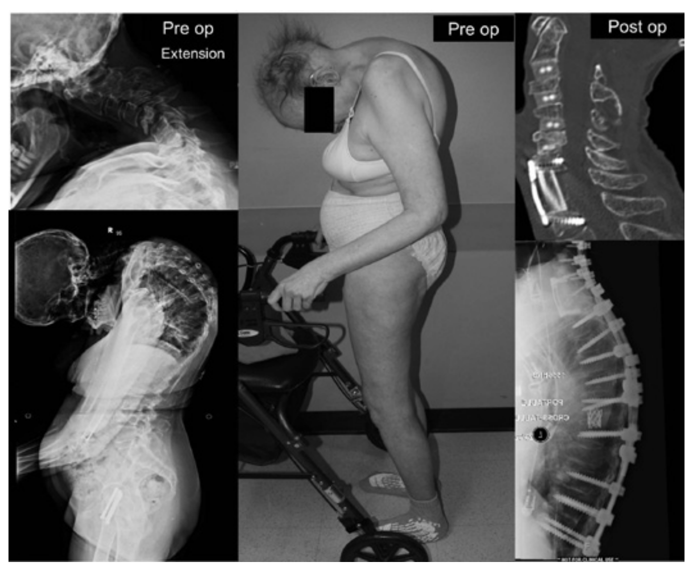
Summary: We present a case of challenging chin-on-chest deformity in a severely osteoporotic patient where significant curve correction was achieved by a two-stage combined anterior and posterior approach. Patient also had a history of external radiation for a brain and cervical spine medulla blastoma. The procedures were staged and had to be delayed by several months secondary to several medical and surgical complications, which highlights the many challenges that can be encountered while treating patient with this problem.

Introduction: Chin-on-chest deformity has many different etiologies including post-traumatic, post-laminectomy, ankylosing spondylitis, and dropped head syndrome. It is not only a cosmetic problem but often causes significant difficulties for forward gaze, ambulation and even swallowing.

Methods: 52-year-old woman presented with a chin-on-chest deformity that developed over many years. She had undergone resection of a medulla blastoma as a teen ager and had high-dose postoperative radiation to her head and cervical spine. Her deformity has progressed over the past two years, especially she fell and suffered multiple compression fractures in the cervical spine. Her skin and soft tissues were compromised from prior radiation. She has developed progressive difficulty with walking and swallowing because of the restriction of neck extension. Radiographs showed multiple compression fractures with severe chin-on-chest deformity (C4-T12; 152°). Her chin-brow vertical angle was 92°. When lying supine, her head did not correct passively.

Results: A two-stage anterior and posterior spinal fusion was planned. Initially she was placed in a halo traction which helped improve her alignment before surgery. However, she developed aspiration pneumonia, then her 1st procedure was delayed for a few weeks to treat her pneumonia. She had difficuly swallowing and her nutrition was also impaired, so a PEG tube was placed to optimize her nutrition. After her respiratory status improved, anterior cervical discectomy and fusion from C2 to T1 with a corpectomy of C7 was performed. There was no intraoperative complications, however the second stage was delayed because of her compromised medical condition, including recurrent aspiration pneumonia and decubitus under the halo. 8 months after the 1st surgery, posterior spinal fusion from C2 to T12 with a vertebral column resection of T7 was performed. Excellent correction was achieved (C4-T12; 41°), and her corrected cervical alignment was maintained. She remained neurologically intact.

Conclusion: Two-stage combined anterior and posterior spinal fusion can be very challenging and may be associated with many complications, some of them can be life threatening, especially in a patient with a sub-optimal medical condition.



3D. Severe Thoracolumbar Kyphosis and Osteomyelitis, Requiring Complex Reconstruction Complicated by Proximal Junctional Failure Requiring Multiple Revisions

Sophia Strike; Hamid Hassanzadeh, MD; Khaled Kebaish, MD

USA

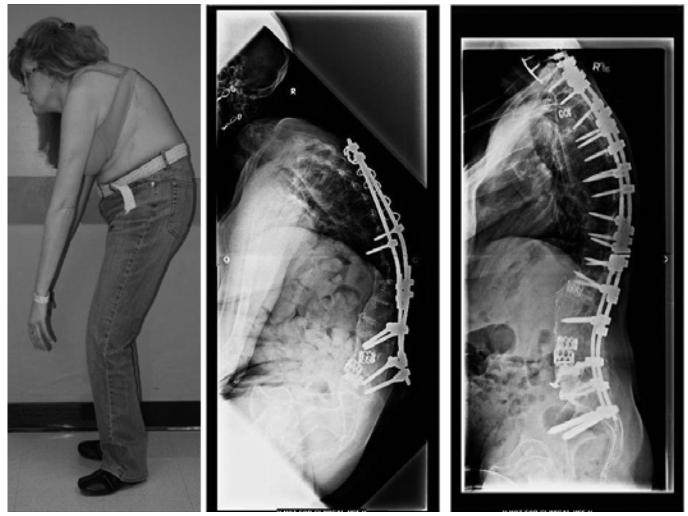
Summary: We present a 52 year old female with a severe kyphotic deformity, osteoporosis (hip T scores of -4.5 and -2.8) and inability to achieve horizontal gaze after multiple prior spine surgeries. She was found to have osteomyelitis and underwent removal of posterior instrumentation followed by staged revision spinal fusion. Her course was complicated by an L1 fracture, antibiotic-related renal failure and proximal junctional kyphosis requiring extension of posterior fusion. At 12 months follow-up she had excellent alignment with good function.

Introduction: A 52 year old female with a history of a progressive kyphotic deformity and severe back pain following multiple prior surgeries. Her kyphotic deformity was predominantly at the thoracolumbar junction and measured 86°.Prior surgeries included staged T4 to L5 fusion, L4-L5 and L5-S1 interbody fusion and an L2 pedicle subtraction osteotomy. She was noted to have prominent instrumentation as well as loosening at the proximal and distal ends of her construct.

Methods: A two-stage revision procedure was planned. Upon initial surgical exposure gross purulence was noted suggesting chronic osteomyelitis. Removal of instrumentation, irrigation and debridement was performed. After a course of antibiotics complicated by vancomycin-induced acute renal failure, the patient underwent posterior spinal fusion from T3 to the sacrum with L1 vertebral column resection, L4 pedicle subtraction osteotomy. There was an intra-operative decrease in motor signals bilaterally however the patient maintained full strength post-operatively. Six weeks later, after recovery from hospital-acquired pneumonia, patient developed symptomatic PJK, requiring her posterior spinal fusion to be extended to C5 with a T3 VCR. Anterior cervical discectomy and fusion from C5 to C7 was also performed.

Results: At follow-up after her intial revision procedure, the patient was noted to have recovered lower extremity strength, regained good global spinal alignment and had no evidence of instrumentation failure or junctional problems.

Conclusion: Patients with complex deformities can be challenging and they may require multiple revision procedures, with the potential for adverse medical and surgical complications. However significantly improved function and defornity correction can be achieved in spite of these serious complications.



Case Discussion 4 - Neurologic Complications

4A. Loss of Lower-Limb MEPs During Initial Exposure for Posterior Spinal Fusion in a Patient with Scoliosis and Myasthenia Gravis

Terry D. Amaral, MD; Alan D. Legatt, MD, PhD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Vishal Sarwahi, MD

USA

Summary: A 13 y/o female with myasthenia gravis developed complete loss of motor evoked potentials on intra-op monitoring following soft tissue dissection. No instrumentation or correction of the deformity was performed. The case was aborted and spinal cord ischemia was found on MRI. The patient has had partial recovery of motor function and remains ambulatory. A vascular insult to the cord is suspected due to a "steal" phenomenon.

Introduction: A 13-year-old girl with myasthenia gravis and progressive scoliosis was indicated for surgical deformity correction. The patient had good baseline SSEP's and tc MEP's on intra-operative neurological monitoring prior to incision. Neuromuscular blockade was administered for the initial exposure. There was profuse bleeding during the soft-tissue dissection. The estimated blood loss during the exposure was 500cc. The patient received 2 units of PRBC's. The MAP remained around 80 mmHg throughout the procedure.

Methods: Once the paralytic agents wore off, SSEPs were intact in both the upper and lower extremities. MEPs remained present in the arms but none were detected in the legs. No instrumentation or deformity correction was performed. A wake-up test was performed, and the patient was found to be paraplegic. The surgery was aborted. The patient was emergently brought to MRI, which showed a lesion at T4-T6, indicative of possible spinal cord ischemia.

Results: Post-operatively, the patient had a myasthenic crisis requiring respiratory support. She was given steroids and her myasthenia medications by the Neurology service for her myasthenic crisis. She had some recovery of lower extremity motor function. Repeat MRI showed a new central spinal cord abnormality at the T4-T7 levels consistent with a watershed infarct. The leg weakness improved further with physical therapy. She is now able to ambulate, but has residual spasticity of both lower extremities.

Conclusion: The blood supply to the thoracic spinal cord is typically poorly collateralized and is dependent on one or a small number of segmental arteries. Profuse soft tissue bleeding during the dissection may have lowered the blood pressure in these vessels enough to cause spinal cord infarction via a "steal" phenomenon, despite maintenance of systemic blood pressure. To determine if any spinal cord compromise has occurred, MEPs should be assessed following the exposure, but prior to spinal instrumentation and deformity correction.

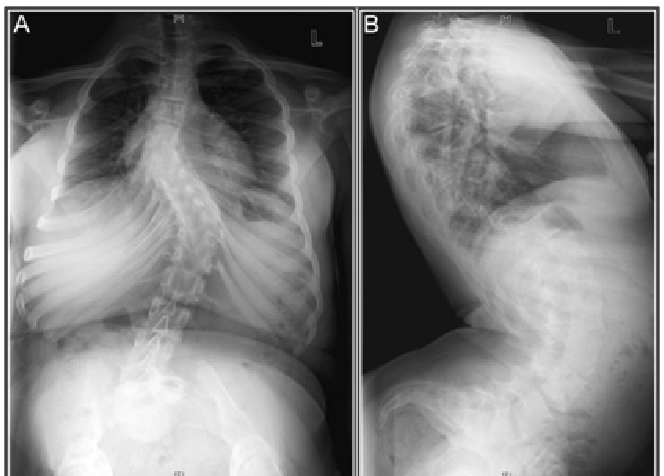


Fig. 1: Preoperative A-P (**A**) and lateral (**B**) radiographs, showing the severe lordoscoliosis in this patient.

4B. A Case of Syrinx with Severe Scoliosis Complicated with Disseminated Intravascular Coagulopathy (DIC)

Terry D. Amaral, MD; Preethi M. Kulkarni, MD; Adam L. Wollowick, MD; Aviva G. Dworkin, BS; Vishal Sarwahi, MD

USA

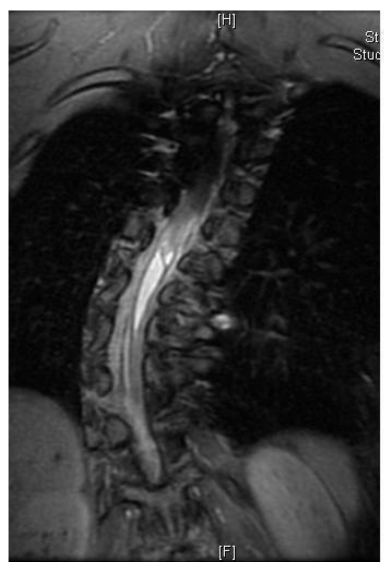
Summary: A 13 year old male with scoliosis and syrinx admitted for elective Posterior Spinal Fusion (PSF). Operative course was complicated by sever coagulopathy and loss of signals.

Introduction: A 13 year old male patient presented with a history of syrinx from T6-T9 and progressive scoliosis with no neurological findings. PSF and instrumentation from T2-L2 with syrinx decompression was planned.

Methods: PSF with instrumentation from T2- L2 and decompression of the syrinx was indicated. A Freehand technique was used to place pedicle screws (PS) from T2-L2. No spinal cord monitoring changes were noted during pedicle screw placement. During the approach and instrumentation, there was continuous oozing that was not controlled with specialized anesthesia protocol and with standard hemostasis techniques. After the Dura was opened the patient was found to be in consumptive coagulopathy. Syrinx decompression was stopped because of disseminated intravascular coagulation (DIC), bleeding and hypotension. The procedure was abandoned. The Dura was closed and short holding rod was placed over the site of the laminectomy. The patient was in burst suppression, which returned to baseline once the anesthesia was decreased. Adequate hemostasis was achieved after transfusing coagulation factors and platelets. Six days later the patient was indicated for placement of two full rods to stabilize the spine until his coagulopathy is fully investigated before syrinx decompression. During rod placement 30-40% signal drop was observed, which returned to baseline after the rod were placed. No corrective maneuvers were used. During application the set screws, there was loss of signal of 30- 70% respectively. After some time, the signals returned to baseline. Fluoroscopic imaging showed proper location of the implants and no iatrogenic injury.

Results: His DIC improved and the spine was instrumented with no neurological deficit.

Conclusion: Corrective maneuvers of the spine in the setting of a syrinx can potentially result in neurological compromise. A staged approach to synrinx decompression and definitive scoliosis surgery in the face of a coagulopathy may prevent intraspinal cord bleeding and the potential of permanent neurologic sequel.



4C. Intraoperative Neuromonitoring Prevented Postoperative Paralysis in a Case with a Severe Congenital Kyphoscoliosis

Kazuhiro Hasegawa, MD, PhD; Haruka Shimoda, MD

Japan

Summary: A case report of an 11-year-old congenital kyphoscoliosis. NASCIS-II protocol and immediate fixation with instrumentation following an alarm of intraoperative neuromonitoring during VCR could prevent postoperative paralysis.

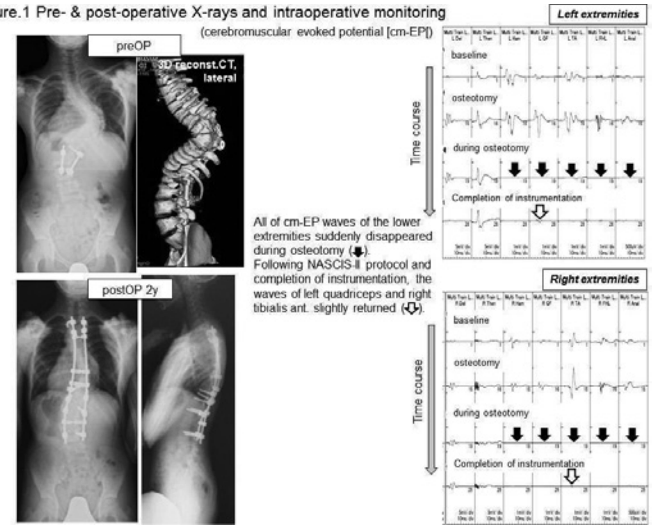
Introduction: The greater the complexity of scoliosis surgery is, the superior the attention should be paid to the complication. One of the countermeasures to prevent neurologic complication is an intraoperative neuromonitoring, especially multimodal intraoperative monitoring (MIOM). We present a case of an 11-year-old congenital kyphoscoliosis in whom MIOM could prevent postoperative paralysis.

Methods: We have routinely been using MIOM with 2 channels for neurocerebral evoked-potential (nc-EP) as a sensory tract monitoring, and 14 channels for cerebromuscular evoked-potential (cm-EP) as a motor tract monitoring. Using an alarm point of ≥30% drop in amplitude and ≥10% elongation of latency of the corresponding cm-EPs, the sensitivity and the specificity of our MIOM are 100% and 95.7%, respectively.

Results: We scheduled VCR, correction and fusion with instrumentation under MIOM for an 11-year-old boy who had undergone L1-L3 posterior fusion at the age of 3 years and T8-10 right hemiepiphyseodesis at 5 years, suffered from progressive thoracic kyphoscoliosis. Following placing all the anchors with pedicle screws, hooks, and sublaminar wires, we underwent VCR of the anomalous T8-9 vertebrae. As usual, total laminectomy and bilateral pediculectomies were done with normal waves of cm-EP. Then, we went forward to VCR. Although cm-EPs remain normal when the right T8 nerve root was ligated and severed, the cm-EPs from bilateral lower extremities suddenly disappeared when VCR was almost done. We considered some instability at VCR site induced spinal cord impairment, and thus we immediately administered NASCIS-II protocol. At the same time, concave side rod was fixed and VCR was accomplished. The cm-EPs slightly emerged one hour after finalizing the instrumentation. Following recovery from anesthesia, we confirmed that there was no neurologic deficit of the lower extremities. The postoperative course was uneventful, and he is enjoying his school life 2 years after surgery (Fig.1).

Conclusion: Using the alarm point of ≥30% drop in amplitude and ≥10% elongation of latency of the corresponding cm-EPs, we could prevent postoperative paralysis following VCR in the case with severe congenital kyphoscoliosis.

Figure.1 Pre- & post-operative X-rays and intraoperative monitoring (cerebromuscular evoked potential [cm-EP])



4D. Loss of Motor Evoked Potentials and Quadriplegia During Unexpected Revision Posterior Spinal Fusion for a Chance Type Fracture in a Patient with Ankylosing Spondylitis

Haruki Funao, MD; Sophia Strike; Khaled Kebaish, MD

USA

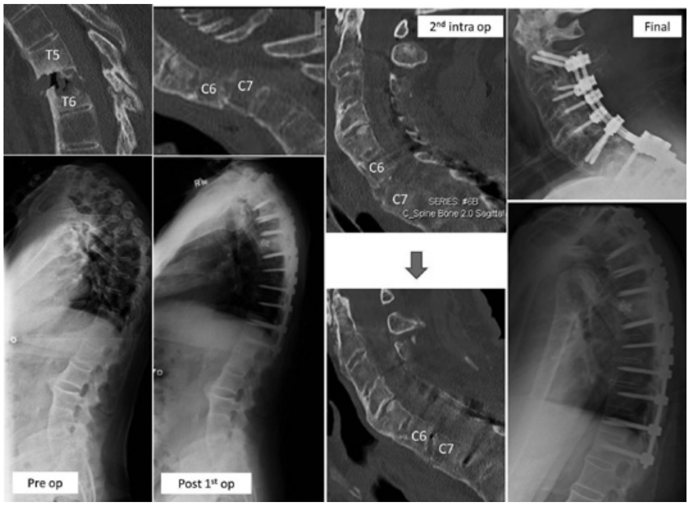
Summary: Chance type fractures in ankylosing spondylitis (AS) are known to be unstable fractures due to involvement of all three columns of the spine, and can occur even after minor traumas. We present a patient with AS who developed loss of motor evoked potentials (MEPs) and quadriplegia following posterior stabilization of the cervico-thoracic spine. Careful neurological monitoring with MEPs and early intervention is essential for early diagnosis and treatment of spinal cord injury during complex spinal surgery.

Introduction: Chance type fractures in AS are known to be unstable fractures due to involvement of all three columns of the spine, and can occur even after minor traumas. Nonsurgical treatment is often inadequate, thus surgical treatment is usually necessary. Neurological monitorings may reduce the incidence of spinal cord injury in these patients. MEPs are widely used because of their high-sensitivity.

Methods: We present a 70-year-old male with a long history of back pain and a kyphotic posture secondary to AS. His upper back pain was progressively worsened after he suffered a fall six months prior. He had nonsurgical treatment with conservative management, but his pain progressed and he had complained of numbness radiating down his trunk with difficulty ambulating. Radiographs showed a Chance type fracture at T5/6 with a 36° focal kyphosis and a 94°overall thoracic kyphosis.

Results: An extended pedicle subtraction osteotomy of T6 followed with posterior spinal fusion from T2 to T10 was performed. Kyphotic correction (focal 34°, overall 44°) was achieved with a good sagittal alignment. At his 6 weeks follow-up, the instrumentation was intact with no change in his spine alignment from post-op. The patient, however, experienced another fall and at follow-up, computed tomography (CT) showed a Chance type fracture at C6/7, and his posterior spinal fusion was extended to C2. There was no abnormality in neurological monitorings detected during positioning, screws insertion, or rod connections. MEPs were lost suddenly during wound closure, thus a wake up test was performed. He was found to have C6 quadriplegia. Emergent CT demonstrated posterior displacement of C6/7 fracture, and he was taken back for exploration, a laminectomy, and correction of the alignment to neurtral. He was placed in a halo vest for additional external stabilization because of his unstable fracture and poor bone quality. Neurological recovery occurred gradually after the procedures.

Conclusion: Careful neurological monitoring using MEPs and early intervention is essential for early diagnosis and treatment of spinal cord injury during complex spinal surgery.



Podium Presentation Abstracts

**Hibbs Award Nominee for Best Clinical Presentation*
┼ Hibbs Award Nominee for Best Basic Science Presentation

The Russell A. Hibbs Awards are presented to both the best Clinical and Basic Science papers presented at the SRS Annual Meeting. The top podium presentations accepted in each category are invited to submit manuscripts for consideration. Winners are selected on the basis of manuscripts and podium presentations.

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1. Recent Trends in Surgical Management of Adolescent Idiopathic Scoliosis: A Review of 17,412 Cases from the Scoliosis Research Society Database 2001-2008

Samuel K. Cho, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Abigail Allen, MD; Yongjung J. Kim, MD

USA

Summary: Surgical management of adolescent idiopathic scoliosis (AIS) has evolved over the past decade. We demonstrate that there has been a steady increase in posterior spinal fusion with pedicle screw-based segmental instrumentation to treat AIS. Overall complication rates were lower with posterior surgery when compared to anterior-posterior surgery.

Introduction: Surgical treatment of AIS has evolved over the past decade with the development of new techniques and technologies. We hypothesized more posterior spinal fusions (P) with pedicle screw-based instrumentation were performed compared to anterior (A) and anterior-posterior spinal fusions (AP) in recent years and this has led to less complications.

Methods: The Scoliosis Research Society morbidity and mortality database was queried for patients aged 10-18 years who underwent spinal fusion for AIS from 2001-2008. Patient demographics, surgical characteristics, and complications were analyzed based. Two-tailed t test and chi-square test were performed.

Results: Of 17,412 patients (mean age 14.3 years), 1,360 had AP, 2,352 A, and 13,695 P. Distribution of curve types was: cervicothoracic 0.1%, triple major 1.2%, unknown 1.8%, lumbar 3.7%, double thoracic 5.7%, thoracolumbar 16.4%, double major 21.1%, and thoracic 50.0%. Distribution of curve magnitude was: 0-20o 0.2%, 21-30o 0.3%, 31-40o 2.1%, 41-50o 22.1%, 51-60o 36.4%, 61-70o 19.1%, 71-80o 7.7%, 81-90o 3.7%, 91-100o 2.0%, >100o 2.3%, and unknown 4.1%. American Society of Anesthesiologists scores were: I 84.6%, II 9.3%, III 2.7%, VI 0.1%, and unknown 3.3%. P increased from 68.4% in 2001 to 89.2% in 2007, while A decreased from 16.8% to 8.1% and AP from 14.8% to 3.5%. Pedicle screw-only instrumentation increased from 9.5% in 2001 to 50.8% in 2007, while hook-only instrumentation decreased from 31.3% to 1.4% and wire-only instrumentation from 2.5% to 0%. The use of hybrid constructs remained steady at 57.6%. Overall complication rates were 12.1% for AP, 5.0% for A, and 5.5% for P with significant difference ($p<0.0001$) when A or P was compared to AP. There was no difference between A and P ($p=0.41$).

Conclusion: There was a steady increase in P and the use of pedicle screw-only constructs to treat AIS over the past decade. The overall complication rate was significantly lower with P when compared to AP.

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2. Vertebral Column Derotation Provides Radiographic Spinal Derotation but No Additional Effect on Thoracic Rib Hump Correction as Compared with No Derotation in Adolescents Undergoing Surgery for Idiopathic Scoliosis with Total Pedicle Screw Instrumentation: A Prospective Follow-Up Study

Mikko Mattila; Tuomas Jalanko; Ilkka Helenius, MD, PhD

Finland

Summary: Seventy-two patients with structural thoracic idiopathic scoliosis operated using total pedicle screw instrumention (PSI) with en bloc vertebral column derotation (DVR, n=48) or without it (N-DVR, n=24) were prospectively followed-up for a minimum of two years. Rib hump and main thoracic (MT) curve correction were similar in both groups during follow-up, but radiographic correction of spinal derotation was significantly better in the DVR group and thoracic kyphosis was also better preserved in this group.

Introduction: Vertebral column derotation (DVR) may allow correction of rib hump. DVR can be performed using segmental or en bloc techniques. No data exist comparing PSI with and without DVR on thoracic rib hump correction and radiographic outcomes.

Methods: We followed 72 consecutive children and adolescents (14 males, mean age 14.7 years; 6 juvenile, 66 adolescent) operated for idiopathic scoliosis (Lenke 1-4, or 6) using all PSI in a prospective manner for a minimum 2 years. 24 had PSI with apical monoaxial screws without derotation (N-DVR) and 48 with DVR using a device (VCM) with the ability to lift up concave MT area. Ponte procedure was performed in 14 (58%) in N-DVR and in 34 (71%) of DVR patients ($p=0.29$). None of the patients received thoracoplasty or were lost during FU.

Results: Preoperatively, mean (SD) MT curve was 56° (±9°) and 57° (±11°) and was corrected to 16° (±6°) in both groups at two-year follow-up ($p=0.67$). Thoracic rib hump averaged 12.3°(±3.6°) in N-DVR vs. 14.2° (±5.0°) in DVR ($p=0.075$) preoperatively and 7.2° (±3.8°) vs. 8.3° (±3.7°) at 2-year FU ($p=0.30$). Correction of thoracic rib hump was 40% (31%) in N-DVR and 44% (26%) in DVR groups at 2-year FU ($p=0.62$). Radiographic correction of spinal rotation (Upsani score) was significantly better in DVR (1.00±0.74) than in N-DVR group (1.38±0.58) at 2-year FU ($p=0.032$). Thoracic kyphosis (T5-T12) flattened from a mean of 23° (±18°) to 20° (±9°) in N-DVR group, but remained unchanged in DVR group (24° pre and at 2-yr FU; $p=0.11$). SRS-24 total score averaged 100 (±5.7) in the N-DVR and 99 (±9.0) points at 2-year FU ($p=0.56$).

Conclusion: PSI provides excellent radiographic coronal Cobb angle correction. En bloc DVR has a significant effect on radiographic spinal column derotation and may help to prevent flattening of thoracic kyphosis, but this derotation is not reflected by better thoracic rib hump correction at 2-year FU.

3. The Impact of Prolonged Surgical Wait Times on AIS: What Complications Can be Expected?

Firoz Miyanji, MD, FRCS(C); Tracey Bastrom, MA; Amer F. Samdani, MD; Burt Yaszay, MD; David H. Clements, MD; Suken A. Shah, MD; Michelle C. Marks, PT, MA; Randal R. Betz, MD; Harry L. Shufflebarger, MD; Peter O. Newton, MD

Canada

Summary: Lengthy surgical waitlists for Adolescent Idiopathic Scoliosis (AIS) often results in significant increases in curve magnitude and stiffness. Curve progression has been suggested to increase the predicted complexity of surgery and potential complication rates. We found curves >=65° to be 1.74 times more likely to experience a complication compared to smaller curves. In particular, larger curves have a significantly higher risk of intra-operative neurophysiologic monitoring (IONM) events, excessive blood loss, and allogenic blood transfusion rates compared to curves between 50°-65°.

Introduction: Timely access to surgery is a challenge in publicly funded healthcare systems. Prolonged delays can lead to increasing spinal deformity, often by 10°-15° or more. Limited data exists focusing on complication rates in patients subjected to lengthy surgical waitlists for AIS. The aim of our study was therefore to quantify the relationship between curve magnitude and the rate of complications in AIS surgery, and to identify potential predictors associated with an increased complication rate in the surgical care of AIS.

Methods: A prospective, longitudinal multi-center study evaluating operative outcomes of AIS identified a homogeneous population of Lenke 1 curves. Univariate analysis explored the association between curve severity and complication rate by dividing patients into curves >=65° and those between 50°-65°. Multivariate regression was used to identify potential predictors influencing the complication rate in these patients.

Results: 686 subjects with a mean age of 14.7 +/- 2.2 years were included. Mean thoracic cobb was 58.1° +/- 8° (range 50°-110°). There were 123 complications (17.9%). The type and frequency of reported complications is summarized (Table). Curve magnitude was associated with the overall complication rate with curves >=65° having a significantly higher complication rate (24.8%) compared to curves <65° (16.5%) (p=0.034). Patients with curves >= 65° had a significantly higher rate of an IONM event (17.5%) compared to those < 65° (3.3%) (p=0.002). Excessive blood loss (> 100% blood volume) with resultant significantly higher transfusion rates was also noted in the larger curve group (p=0.007, p=0.026, respectively). Multivariate regression found curves >=65° to have a 1.74 fold increase in the overall complication rate (OR 1.74, CI 1.08-2.81).

Conclusion: We found larger curve magnitude to be associated with significantly higher complication rates, with curves >=65° to be 1.74 times more likely to experience a complication. Significantly higher rates of IONM events, excessive blood loss and allogenic blood transfusions were noted in patients with larger curve magnitude. These findings are suggestive that prolonged surgical waitlists for AIS negatively influence the surgical care of these patients.

4. What is Different About Surgically Treated AIS Patients Who Achieve a Minimal Clinically Important Difference (MCID) in Appearance at Five Years Post Surgery?

Anuj Singla, MD; Amer F. Samdani, MD; John M. Flynn, MD; James T. Bennett, MD; Firoz Miyanji, MD, FRCS(C); Joshua M. Pahys, MD; Michelle C. Marks, PT, MA; Baron S. Lonner, MD; Peter O. Newton, MD; Patrick J. Cahill, MD; Randal R. Betz, MD

USA

Summary: A series of 291 patients with AIS and 5 years of follow-up post spinal fusion were studied to identify factors which differentiate those patients who experience an MCID from those who do not. Patients most likely to experience a clinically significant improvement are those with larger preoperative Cobb angles and for which surgical strategies to maximize coronal and axial correction while maintaining shoulder balance were employed. Patients with Lenke 5 curves are least likely to attain the MCID.

Introduction: The outcome for scoliosis surgery is usually measured with changes in the SRS scores without an appreciation of what constitutes a significant change. Previous work has determined the MCID for the appearance domain of the SRS-22 questionnaire to be an increase of ≥ 1.0 in surgically treated AIS patients. However, no study has sought to determine factors which may predict those patients who achieve the MCID 5 years post-op.

Methods: A prospectively collected multicenter database was retrospectively reviewed to identify surgically treated AIS patients with minimum 5 year follow-up. 291 patients were divided into two cohorts: "I"= improved after surgery (Δ Appearance ≥ 1.0) and "NI"= not improved after surgery (Δ Appearance < 1.0). The two cohorts were compared using clinical and radiographic measures. Univariate regression was used to find a significant difference between the cohorts for individual measures. Multivariate logistic regression was used to find continuous predictors.

Results: Overall, 169 patients (58%) were improved and 122 (42%) not improved. Patients experiencing improvement were those with a larger preoperative major Cobb angle (I=55±11.5°,NI=52±11.5°, P=0.03). Preoperatively, they had a larger rib prominence (I=14.0±6.0, NI=12.6±6.0, p=0.07) with greater postoperative coronal correction (I= 64±14%, NI=60±16%, p=0.06). In addition, we observed trends toward less postoperative shoulder height difference (I=0.85, NI=0.97, p=0.3) and greater reduction of rib prominence (I=48%, NI=43%, p=0.3). Multivariate regression analysis revealed that patients with Lenke 5 (P=0.03) curves were 2.3 times less likely to have a clinically significant improvement in appearance above the MCID.

Conclusion: Our results imply that the patients most likely to demonstrate a clinically significant improvement in the SRS Appearance domain are those with greatest coronal and axial preoperative deformity. In addition, surgical strategies to maximize coronal and axial correction while maintaining shoulder balance appear to enhance the chances of attaining the MCID at 5 year follow-up. Patients with Lenke 5 curves are the least likely to attain the MCID.

5. Surgery for Idiopathic Scoliosis in Adolescents Versus Young Adults: A Matched Cohort Analysis

Ian G. Dorward, MD; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; Kathleen E. McCoy; Kevin R. O'Neill, MD, MS; Brian J. Neuman, MD; Terrence F. Holekamp, MD, PhD; Wilson Ray, MD; Brenda A. Sides, MA; Linda Koester, BS

USA

Summary: We compared 59 adolescents (age 10-18) and 59 young adults (19-39) matched 1:1 undergoing posterior surgery for idiopathic scoliosis, excluding fusions to the sacrum. Adults had inferior radiographic improvements, but no statistical difference in surgical variables, complications, or change in SRS scores.

Introduction: It is unknown if outcomes differ between adolescents and young adults with idiopathic scoliosis (IS) when the extent of surgery (i.e. instrumented levels) is similar. We compared adolescents versus young adults matched for instrumented/fused levels, excluding fusions to the sacrum.

Methods: Two groups of 59 patients with IS [adolescents 10-18 ("AIS") vs young adults 19-39 ("YAdIS")] were matched from a prospectively-enrolled database 1:1 on the basis of gender (76% females in each group) and instrumented levels (mean 10.9 levels in each). Only posterior-only, pedicle screw constructs ending at or above L5 were included. Operative data, radiographs, complications, and SRS-30 scores were compared at preop, 2-yr postop, and final f/u (mean 3.67 yrs AIS, 3.61 yrs YAdIS).

Results: OR time (mean 274 min for AIS vs 280 min for YAdIS, P=.92) and EBL (534mL AIS vs 605mL YAdIS, P=.63) did not differ. AIS pts. had greater reduction than YAdIS pts. in Cobb angles for MT curves (56° to 18° for AIS vs 50° to 29° in YAdIS, P=.002), TL/L curves (38° to 10° for AIS vs 38° to 22° for YAdIS, P=.04), and coronal balance (20mm to 7mm for AIS vs 14mm to 17mm for YAdIS, P=.0002) at final f/u. Changes in sagittal radiographic data were similar for both groups. Complications occurred in over twice as many YAdIS pts. [11 (19%)] as AIS pts. [5 (8%)], though the difference was not significant (P=.11). YAdIS pts. began with worse SRS scores in all domains except mental health, but there were no significant differences in postop change between groups (Subscores: AIS mean 3.98 improved to 4.44 postop; YAdIS mean 3.64 improved to 4.15 postop; P=.0002 preop and P=.69 for difference between groups in final postop change)(see Figure 1).

Conclusion: AIS pts. gained more correction of MT and TL/L curves and coronal balance than YAdIS pts. SRS scores for YAdIS were lower preop but not different in postop improvement. YAdIS had more complications, though this difference was not statistically significant. These results are important for discussion when AIS pts consider delaying surgery until their young adult (YAdIS) life.

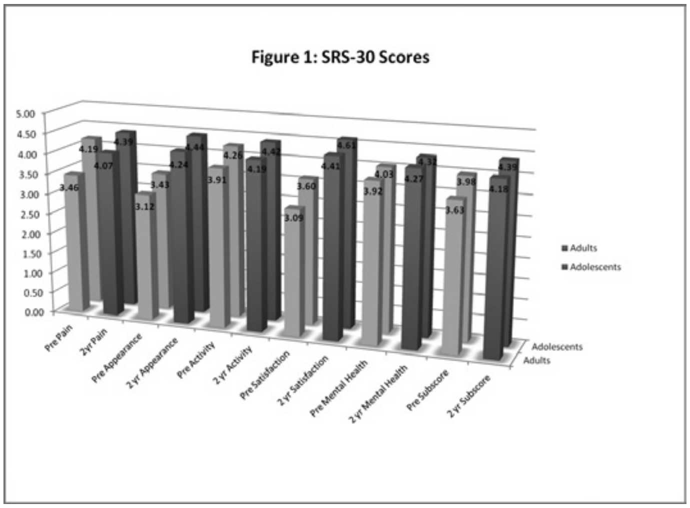


Figure 1: SRS-30 Scores

6. Does Operative Care of Adolescent Idiopathic Scoliosis Improve Outcomes Compared to Non-Operative Treatment?

David H. Clements, MD; Randal R. Betz, MD; Peter O. Newton, MD; Firoz Miyanji, MD, FRCS(C); Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Harms Study Group

USA

Summary: A prospective multicenter study was done to evaluate subjective patient reported outcomes of operative compared to nonoperative treatment of adolescent idiopathic scoliosis in patients with similar initial curves and ages. We defined outcomes as patient scoring of the SRS-22 on initiation and after two years of nonoperative care or two years postoperatively. We found that the lower initial self image and treatment satisfaction scores in the operative group increased significantly and were significantly better than those of the nonoperative group at two years follow-up.

Introduction: While surgical correction of Adolescent Idiopathic Scoliosis (AIS) typically results in improvement in radiographic deformity, trunk balance and patient reported outcomes, it is unclear how these improvements in outcome compare to patients with similar deformity who select nonoperative treatment. The purpose of this study was to compare subjective outcome scores at 2 years in operative versus nonoperative patients.

Methods: Prospectively collected data from a multicenter AIS database including operative and nonoperative patients was queried. 22 nonoperative patients were matched to 44 operative patients using criteria of upper thoracic, main thoracic, and lumbar Cobb magnitude within 5 degrees. Ages ranged from 14-19 years in both groups (16 +/- 2 non-op; 15+/-2 op), all female. Erect radiographs and SRS-22 results were recorded for each group on presentation and at 2 years after initiation of treatment.

Results: Initial coronal curves were similar (table). At two years the Cobb magnitudes were significantly less in the operative group (p<0.001). SRS-22 scores were similar at baseline for both groups except for Self-Image and Treatment Satisfaction, which were significantly higher in the nonoperative group (p<0.05). At two years after initiating treatment, the reverse was true with Self-Image and Treatment Satisfaction scores significantly higher in the operative group (p=0.007). The operative group also had a significantly higher Total score at two years (p=0.009). After two years of treatment there was a significant improvement in Self-Image, Treatment Satisfaction and Total scores in the operative group (p<0.001); the nonoperative group had no significant change. There was no cross-over between groups.

Conclusion: Our data suggest that patients with AIS who have elected surgical treatment report significant improvements in SRS-22 Self-Image and Treatment Satisfaction scores as well as Total scores compared to those treated non-surgically. The significantly lower initial Self-Image scores of the operative group increased dramatically at the two year mark. Operative care of AIS results in improved outcomes as defined by a significant increase in reported SRS-22 Total, Self-Image, and Treatment Satisfaction scores.

		Operative	Non-Operative	p
Upper Thoracic Cobb	Pre	21°	21°	0.837
	2yr	13°	21°	<0.001
Thoracic Cobb	Pre	43°	43°	0.958
	2yr	18°	44°	<0.001
Lumbar Cobb	Pre	33°	33°	0.988
	2yr	14°	35°	<0.001
Pain	Pre	4.2	4.4	0.329
	2yr	4.3	4.1	0.212
Image	Pre	3.4	3.9	**<0.001**
	2yr	4.4	3.9	**0.007**
Function	Pre	4.4	4.6	0.966
	2yr	4.6	4.4	0.173
Mental Health	Pre	4.1	4.1	0.573
	2yr	4.2	4	0.128
Satisfaction with treatment	2yr	4.5	3.9	**0.005**
Total	Pre	3.9	4.2	0.084
	2yr	4.4	4.1	**0.009**

7. Distal Adding on in Lenke 1 and 2 Curves: What Happens at Five Years?

Jahangir Asghar, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Harry L. Shufflebarger, MD; Burt Yaszay, MD

USA

Summary: Adding on (AO) tends to occur within one year after posterior spinal fusion (PSF). Patients with AO had a significantly higher rate of distal junctional kyphosis. However, this did not affect SRS scores or complication rates. These observations imply that there is a significant sagittal component to distal adding-on.

Introduction: Distal adding on is a poorly understood phenomenon with respect to risk factors, rate of occurrence, and temporal changes. Our study queried a prospective multi-center dataset, to determine the incidence of adding on over a period of five years, and its effect on clinical and radiographic outcomes.

Methods: A prospectively collected multicenter database was reviewed to identify all AIS patients with primary thoracic (Lenke 1 & 2) curves and A or B lumbar modifiers. All patients underwent a PSF and had a minimum of 5-year followup (n=172). As described by Cho et al (Spine 2012), Adding-On (AO) was strictly defined as: an increase in Cobb angle of at least 5° with distalization of the lowest end vertebra (LEV), or a change in the disc angulation below the lowest instrumented vertebra (LIV) of >5° between the first erect and follow up radiograph.

Results: The incidence of adding on at 1, 2, and 5-year followup was 18.7 %, 22.8%, and 24.4%, respectively. A significant majority, 76.2% (32/42, p>0.05), were observed to have added-on at the 1-year followup visit, and 90% (38/42) at the 2-year followup. The incidence of distal junctional kyphosis (Δ of >10° from 1st erect) was significantly higher in patients with adding-on (AO-7/42 vs. NonAO-7/130; p=0.044). Similar to AO, the majority of patients, 71%, developed distal junctional kyphosis by the 2 years postop. Similar to AO group, 71% of patients had distal junctional kyphosis by the 2-year followup. SRS scores and complication/reoperation rates were similar for both groups at 1, 2, and 5 years.

Conclusion: The incidence of adding on at 5 years was 24.4% and predominately (76.2%; p>0.05) occurred within 12 months of posterior spinal fusion. Furthermore, patients with AO had a higher incidence of distal junctional kyphosis. These observations imply that there is a significant sagittal component to distal adding-on.

8. Does Postoperative Shoulder Imbalance Lead to Adding on in Posterior Spinal Fusion for Lenke 1A and 1B Curves?

Joshua M. Pahys, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Harms Study Group; Randal R. Betz, MD

USA

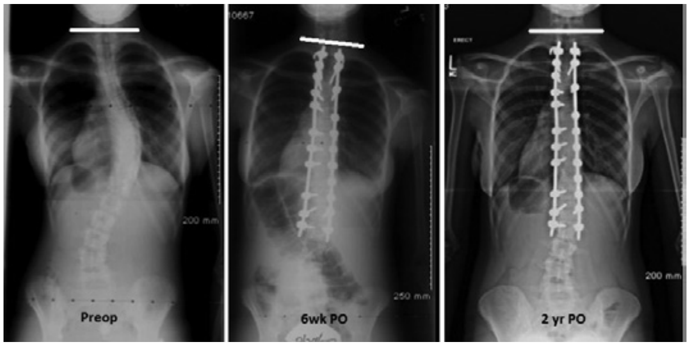
Summary: Adding on was identified in 56/194 (28.9%) of Lenke 1A/B curves 2 years after fusion. The adding-on group (AO) had significantly higher T1 rib angle (T1RA) compared to the non-adding-on (Non AO) group on first erect x-ray. 75% of AO patients had T1RA >5° on first erect x-ray with the left shoulder higher in 92.9%. Thus, immediate post-op shoulder imbalance may increase the risk of the curve subsequently adding-on in the unfused lumbar spine as the patient subconsciously tries to balance the shoulders.

Introduction: Adding on has been described as an increase in the spinal deformity below a fusion postoperatively. This study seeks to evaluate whether early post-op shoulder imbalance after posterior spinal fusion (PSF) for Lenke 1A/B curves leads to adding-on in the unfused lumbar spine.

Methods: A prospectively collected multicenter database was reviewed to identify all AIS patients with Lenke 1A and 1B curves who underwent PSF with >80% pedicle screws and a minimum 2 year follow-up (n=194). Adding on was strictly defined as an increase in Cobb angle of at least 5° with distalization of the lowest end vertebra (LEV) or a change in the disc angulation below the lowest instrumented vertebra (LIV) of >5° between the first erect and two years post-op.

Results: 56/194 patients (28.9%) added on (AO) between the first erect and 2 year post-op x-rays. In the AO group, 75% of patients had a T1RA >5° on first erect x-ray compared to 52% of Non AO patients (p=0.006). The left shoulder was high in AO vs. Non AO (92.9% vs. 81.1%, respectively; p=0.05). The mean T1RA, as well as distribution of shoulder balance (left/right shoulder high, neutral shoulder balance) became equal at 2 years post-op for both groups as the lumbar curve added on. There were no significant differences between the AO and Non AO groups with regards to the pre-op stable vertebra as well as the upper and lower instrumented vertebrae. SRS scores and complication/reoperation rates were similar for both groups at 2 years.

Conclusion: In this dataset, there was a higher prevalence (75%) of adding-on for Lenke 1A/B curves at 2 years post-op if the shoulders were imbalanced on the first erect x-ray, specifically the left shoulder higher than the right. Thus, the authors propose that in some cases the unfused lumbar deformity increases (adding on) to compensate as the patient attempts to level his/her unbalanced shoulders.



Radiographs demonstrating shoulder imbalance (left shoulder higher than right) at 6 weeks post-op, with evidence of level shoulders and adding-on in the lumbar spine at 2 years post-op.

9. Intraoperative and Postoperative LIV-Tilt and Disk Angle in Patients with Idiopathic Scoliosis

James Barsi, MD; Sumeet Garg, MD; David Baulesh; Brendan Caprio, BS; Mark A. Erickson, MD

USA

Summary: Our purpose was to determine if LIV-tilt and disc wedging measured intra-operatively are correlated to their respective values on standing radiographs at intermediate follow-up. From 2004-2007, 17 patients with AIS had fusion of structural lumbar curves with adequate imaging and minimum two year follow-up. Intraoperative supine fluoroscopy provided reliable measurement of disc wedging below LIV on post-operative radiographs and was maintained on standing radiographs two years after surgery, but LIV-tilt improvement was not maintained at two years after surgery.

Introduction: Selection of an appropriate lowest instrumented vertebra (LIV) in patients with adolescent idiopathic scoliosis (AIS) who have structural lumbar curves undergoing posterior spinal fusion (PSF) is important. The purpose of this study was to determine if LIV-tilt and disc wedging measured intra-operatively are correlated to their respective values on standing radiographs at intermediate follow-up.

Methods: After IRB approval, a consecutive series of patients with AIS and structural lumbar curves treated with PSF at a single institution between 2007 and 2010 was identified. 166 patients with AIS underwent PSF during this time period, of which 17 had fusion of structural lumbar curves with adequate imaging and minimum two year follow-up. The LIV-tilt and disc angle below the LIV was measured on the pre-operative standing, intra-operative supine fluoroscopy, and postoperative standing radiographs, and coronal balance was measured on the preoperative and post-operative standing radiographs using a standardized method separately by two authors.

Results: The curve distribution was as follows: Lenke 3 (29%), Lenke 5 (47%) and Lenke 6 (24%). End vertebra (EV)+0 (70.6%), EV-1 (23.5%) and EV+1 (5.9%) were selected as the LIV. There was agreement on radiographic measurements

between the two authors with a correlation coefficient of 0.99 for coronal balance, 0.91 for LIV-tilt and 0.75 for disc angle. LIV-tilt improved from 21° preoperatively to 4° intra-operatively. At minimum two year follow-up LIV had on average progressed to 9°. The disc angle improved from 6° preoperatively to 3° intra-operatively. This improvement was maintained at two years (3°). Coronal balance also improved during the post-operative period from 18 mm immediately following surgery to 11 mm at the last follow up.
Conclusion: Disc wedging below LIV remains stable at two years post-surgery in patients with AIS undergoing PSF including structural lumbar curves, while LIV-tilt improvement is not maintained. Intraoperative fluoroscopy provides a reliable prediction of disc wedging below LIV two years after surgery on standing radiographs.

10. An Analysis of Factors Leading to Re-Operation in Adolescent Idiopathic Scoliosis

<u>Dennis R. Knapp, MD</u>; Karl E. Rathjen, MD; John M. Wattenbarger, MD; W. F. Hess, MD; Terry R. Trammell, MD; Ross R. Moquin, MD; Francisco J. S. Pérez-Grueso, MD; Hilali H. Noordeen, FRCS; Mark D. Rahm, MD; Richard Hostin, MD; Marilyn L. Gates, MD; Matthew J. Geck, MD; Oheneba Boachie-Adjei, MD; Complex Spine Study Group

USA

Summary: A retrospective analysis from a prospective multi-center database was done to analyze factors that may be associated with an increased likelihood to return to the operating room after the index operation in adolescent idiopathic scoliosis.
Introduction: A retrospective analysis from a prospective multi-center database was performed on 601 patients with adolescent idiopathic scoliosis (AIS) who have undergone spinal fusion. A detailed comparison was done between the group of patients requiring reoperation and the ones that did not have any subsequent surgery after the index operation.
Methods: Characteristics analyzed included gender, ethnicity, age, BMI, Lenke class, levels fused, blood loss, operative time, length of hospital stay, curve magnitude and correction in the coronal and sagittal plane and surgical approach. Follow-up averaged 34.8 months in the reoperated group and 42.7 months in the index procedure only group. Implant, surgical and non-surgical related complications were analyzed. P-values are from two sample t-test for continuous measures with pooled variance or Satterthwaite approximation as appropriate and Fisher's exact test for discrete measures.
Results: There were 492 female and 109 male AIS patients. 72 were done exclusively anteriorly and 512 posterior only. There was no statistically significant difference in gender, ethnicity, age, BMI, Lenke class, number of levels fused, blood loss, operative time, hospital length of stay, curve magnitude or correction between the two groups. There were statistically significant more surgical (17.1%) and non-surgical complications (17.1%) associated with anterior only approach than the posterior only approach (6.6%) and (2.6%) respectively. Return to the OR rate was 3.5% for the posterior approach and 6.9% for the anterior approach with an overall rate of 3.8%.
Conclusion: There were more surgical and non-surgical complications associated with the anterior than the posterior approach. Demographics, Lenke class, operative data, curve magnitude and correction did not seem to correlate with return to the OR after the initial procedure. Our return to the OR rates can serve as a reference for surgeons.

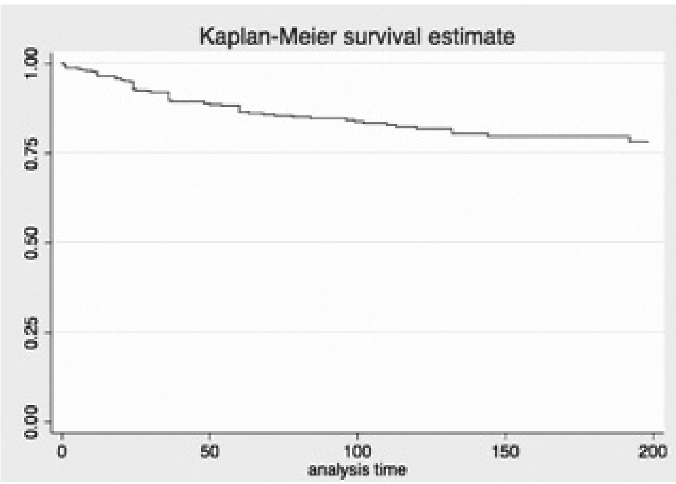
11. Reoperation Risk After Surgery for Idiopathic Scoliosis: A Retrospective Study of 550 Scoliosis Operated Over 25 Years

<u>Guillaume Riouallon, MD</u>; Benjamin Bouyer; Stephane Wolff

France

Summary: A retrospective review was performed of 550 operated idiopathic scoliosis. The aim was to determine the reoperation risk using the Kaplan-Meier method and the risk factors of reoperation. The mean follow-up was 8.2 years and overall survival was 82.2% at 10 years. In multivariate regression model, gender, number of vertebrae and fusion to the sacrum were significant predictors of reoperation. This series gives crucial information in the decision-making for surgery.
Introduction: Risk factors of early morbidity of adult spine deformity surgery are now well described, but the long-term state of these patients is still little known. The aim of this study is to describe long-term follow-up of a cohort of adult operated idiopathic scoliosis.
Methods: The reoperation risk was studied in a retrospective monocentric continuous series of patients operated as from 1983 until 2011. Operating data were collected [type of deformation (Lenke classification), date, number of vertebrae involved in the fusion, need for an anterior discal release and association with a laminectomy]. Any new intervention was registered as an event and date, cause and procedure performed were collected. Overall survival and follow-up was estimated using the Kaplan-Meier method. Univariate analysis was performed using log-rank test. Multivariate analysis was performed using the proportional hazard regression model.
Results: The series included 550 patients [477 women (86.6%) for 74 males(13.4%)], reviewed with a mean follow-up of 8.2 years (range 0-28). Mean age at the operation was 44.2 years. The mean number of vertebrae included in the fusion was 10 (range: 3-16), and for 110 patients (20%) it included sacro-lumbar fusion. In addition, 69 patients (12.5%) needed an anterior release before spinal correction.
Overall survival (without reoperation) was 90% at 3 years (CI: 86-92), 85% at 6 years (CI: 82-89) and 82% at 10 years (CI: 77-86).

There were strong association with gender, age, need for an anterior release, number of vertebrae fused and inclusion of sacro-lumbar hinge. In multivariate regression model, gender (HR: 2.7 CI: 0,9-8,9), number of vertebrae (HR: 1.13 per vertebrae fused, CI: 1.03-1.23) and fusion to the sacrum (HR: 3.9, CI: 2.4-6.2) were significant predictors of reoperation.
Conclusion: This series allows us to address the issue of the risk of performing a new surgery following a spinal fusion for idiopathic scoliosis: it seems to increase linearly with a rate of nearly 20% after 10 years. It clearly represents crucial information in the decision-making for surgery and must be given to patients during preoperative discussion with the surgeon, especially for women and when a large fusion including sacro-lumbar fusion is planed.



12. The Effect of Time and Fusion Length on Motion of the Un-Fused Lumbar Segments in Adolescent Idiopathic Scoliosis

Michelle C. Marks, PT, MA; Tracey Bastrom, MA; Maty Petcharaporn, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Randal R. Betz, MD; Baron S. Lonner; Firoz Miyanji, MD, FRCS(C); Peter O. Newton, MD

USA

Summary: This prospective study assessed inter-vertebral motion of the un-fused distal segments following fusion in 259 patients with Adolescent Idiopathic Scoliosis (AIS) to determine the effect of length of follow-up: early (<5), midterm (5-10) and long-term (>10) on residual motion. The motion of a subset of patients was evaluated with respect to fusion length. Length of follow-up does not have any effect on residual motion however, longer fusion results in significantly increased motion from L4 to S1 compared to selective fusion.
Introduction: Two questions confront the surgeon and patient with regards to motion in the un-fused lumbar segments prior to fusion for AIS: what will happen in the long term and what effect will the fusion length have? The purpose of this study was to assess L4-S1 coronal motion of the spine in AIS following instrumented fusion with regards to post-operative time and fusion length, independently.
Methods: Patients were offered inclusion into this IRB approved prospective study at their routine 2-16 year post-operative visits at one of 5 centers. Coronal motion was assessed by standardized radiographs acquired in maximum right and left bending positions. The intervertebral angles were measured via digital radiographic measuring software and the motion from the levels of L4 to S1 was summed. The entire cohort was included to evaluate the effect of follow-up time on residual motion. Patients were grouped into early (<5 years), midterm (5-10 years) and long (>10 years) follow-up groups. A subset of patients (n=35) with a primary thoracic curve and a non-structural modifier type 'C' lumbar curve were grouped as either selective fusion (LIV of L1 and above) or longer fusion (LIV of L2 and below) and effect on motion was evaluated.
Results: The data for 259 patients are included. The distal residual un-fused motion (from L4 to S1) remained unchanged across early, midterm, to long term follow-up. In the subset of patients, a significant increase in motion from L4-S1 was seen in the patients who are fused long versus the selectively fused patients, irrespective of length of follow-up time (Figure 1).
Conclusion: Motion in the un-fused distal lumbar segments did not change within the >10-year follow-up period. However, in patients with a primary thoracic curve and a nonstructural lumbar curve, the choice to fuse longer versus shorter is met with significant consequences. The summed motion from L4-S1 is 50% greater in patients fused longer compared to those patients with a selective fusion, in which post-operative motion is shared by more un-fused segments. The implications of this focal increased motion are unknown but can be surmised.

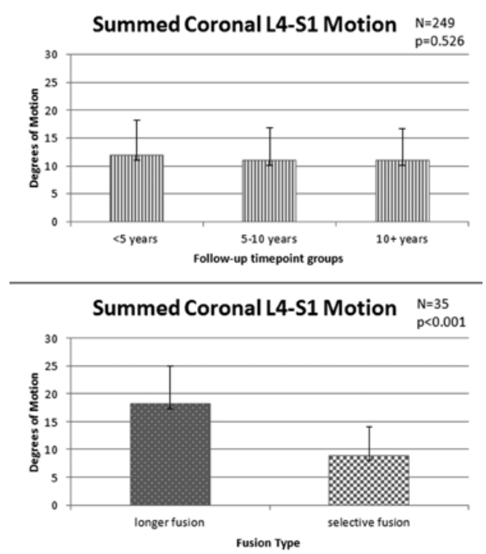


Figure 1. Coronal L4-S1 summed motion at each of the post-operative time periods (top graph) and motion in the longer versus selective fusions (bottom graph).

13. What an AIS Patient Sees in the Mirror: Validation of the Truncal Anterior Asymmetry Scoliosis Questionnaire (TAASQ)

Baron S. Lonner, MD; Courtney Toombs, BS; Suken A. Shah, MD; Tracey Bastrom, MA; Phedra Penn, MS; Kristin Bright, PhD; Carrie Scharf Stern, MD; Marjolaine Roy-Beaudry, MSc; Marie Beausejour; Stefan Parent, MD, PhD

USA

Summary: In response the clinical lack of knowledge about the significant self image and anterior body shape concerns that adolescent females with AIS have, the TAASQ has been developed to assess concerns related to anterior truncal appearance, and mental preoccupation and behavioral modification. This study demonstrates reliability and concurrent validity of the questionnaire.

Introduction: Self image and body shape concerns are of paramount importance to the adolescent with scoliosis (AIS). The impact of scoliosis on anterior trunk shape including waistline, rib, and breast asymmetry have been incompletely studied. The Truncal Anterior Asymmetry Questionnaire (TAASQ) has been developed to assess concerns related to anterior truncal appearance, and mental preoccupation and behavioral modification related to those concerns. The purpose of this study is to validate TAASQ in AIS.

Methods: TAASQ was developed with the assistance of breast cancer researchers. Preliminary questions were piloted in 13 perioperative adolescent and adult idiopathic scoliosis patients, and modified based on patient feedback. The questionnaire contains 14 questions: a combination of response scale and free response questions. Questions fall into 3 domains: Breast, Appearance, and Clothing. To view the TAASQ: https://docs.google.com/file/d/0BzOWcJHISIAVZE9YMEZkenJtdDA/edit?usp=sharing

105 consecutive female, surgical AIS patients, average age 14.9 years, completed TAASQ, SAQ and SRS-22 questionnaires. Mean curve magnitude was 51.6°. To validate the questionnaire, we statistically determined internal consistency/reliability (Chronbach's alpha) and concurrent validity.

Results: Internal consistency for the domains was 0.86, 0.77, and 0.84 for clothing, appearance and breast, respectively (good to excellent). The domains and sub-domains of the TAASQ correlate well with most of the domains of the other questionnaires: specifically self-image, pain and total score in the SRS, and total score, general, curve, trunk shift, shoulders and expectations for the SAQ. The clothing and overall appearance domains of the TAASQ correlated best with the SRS and overall appearance and breast shape correlated best with the SAQ domains. This establishes concurrent validity of the questionnaire.

Conclusion: The TAASQ is a reliable and valid measure of the significant concerns and behavioral modifications related to anterior truncal appearance in female AIS patients. Further study with this new instrument will help clinicians counsel patients on the impact of surgery on anterior truncal deformity and its related psychosocial impact.

14. The Influence of Surgical Correction of Scoliosis on Sexual Function and Pregnancy in Young Women with Adolescent Idiopathic Scoliosis (AIS)

Leon Kaplan; Yair Barzilay, MD; Eyal Itshayek, MD; Joshua E. Schroeder, MD

Israel

Summary: The affect of surgical correction of scoliosis has yet to be studied. This study compared the sexual function of AIS patients with the general population. who underwent surgical correction of scoliosis due to AIS, have an increased distress sexual function score, and decreased sexual arousal, orgasm and satisfaction, when compared to the general population.

Introduction: Idiopathic Scoliosis is common in young females. The influence of surgical correction of scoliosis on sexual function has yet to be assessed. We compared the sexual function of women surgically treated for scoliosis correction to healthy pears.

Methods: Women 18-40, who underwent surgical correction of scoliosis deformity for AIS , and healthy women, were assessed for sexual function via the validated Female Sexual distress scale- revised (FSDS) questioner and a depression questioner. Scoliosis patients were assessed via the Female Sexual Function Index (FSFI) as well. The scores retained were compared to the general population data in the following five categories: Desire, sexual arousal, lubrication, orgasm, satisfaction and pain

Results: 40 women after the surgical correction of scoliosis and 40 controls responded to the questioner. Average age was 24 (range18-35). Time from surgery was 8.2 years (range 3-12 years). The Cobb angle correction in the surgery was 55 degrees (range 40-70). Average FSDS score was 7.05 (STD=3.02) in the scoliosis group and 4.6 (STD=2.79) in the healthy group (P<0.001). 25% of the women in the scoliosis group scored pathologically vs. four in the healthy population . Patients scored within normal range in sexual desire, pain during intercourse and lubrication. A decreased score was noted in sexual arousal, orgasms and satisfaction. Depression rates were similar in both groups.

Conclusion: Female patients, who underwent surgical correction of scoliosis due to AIS, have an increased distress sexual function score, and decreased sexual arousal, orgasm and satisfaction, when compared to the general population.

15. Predictors of Persistent Postoperative Pain After Surgery for Adolescent Idiopathic Scoliosis

Christine Sieberg, PhD; Laura Simons, PhD; Mark R. Edelstein, BA; Maria R. DeAngelis; Melissa Pielech, MA; Navil F. Sethna, MD; Michael T. Hresko, MD

USA

Summary: 219 AIS patients were analyzed for pain trajectories for 2 yrs post surgery and 77 patients for 5 years. 5 distinct pain trajectories were identified with self image, mental health and age being significant different amongst the groups.

Introduction: Factors contributing to persistent postsurgical pain are poorly defined and previous research largely focused on adults. The present study characterizes pain in patients with adolescent idiopathic scoliosis undergoing spinal fusion surgery who have been enrolled in a prospective, multi-centered trial examining post-surgical outcomes.

Methods: The SRS - Version 30, which includes pain, activity, mental health, and self-image subscales, was administered to 219 patients prior to surgery and at 1 and 2 years post-surgery: the ages at the time of surgery were between 8 and 21 years (M=14.28; SD=2.28), female (79%) and Caucasian (83%). . A subset (n=77) completed 5-year post-surgery data. Pain across time points of the past 6-months, past month, and at rest was examined. Longitudinal pain trajectories were empirically grouped based on potential predictors of baseline pre-operative characteristics. The ages at the time of surgery were between 8 and 21 years (M=14.28; SD=2.28). The sample was predominantly female (79%) and Caucasian (83%). ics of age, gender, self-image and mental health functioning that could potentially distinguish trajectory groups were examined through ANOVAs and post-hoc Sheffe analyses

Results: 36%of patients reported pain in the moderate-severe range prior to surgery. Postoperatively, the moderate-to severe pain persisted in 13% at one-year, 17% at two-years and in 20% at 5-year follow-up. The results indicate significant differences on self-image ($p<.01$), mental health ($p<.01$), and age ($p<.01$) among these groups. 5 distinct pain trajectories were identified - no pain, pain improvement, short term pain, delayed pain, and high pain

Conclusion: This is the largest pediatric study to date to examine longitudinal time course of post-surgical pain to identify predictors of poor long-term outcomes of postsurgical pain that might contribute to reduced quality of life and transition of acute to chronic pain

16. Recent Trends in Surgical Treatment of Adult Scoliosis: A Review of 7,570 Cases from the Scoliosis Research Society Database 2001-2008

Samuel K. Cho, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; John Caridi, MD; Yongjung J. Kim, MD

USA

Summary: Using a large cohort of adult patients who underwent spinal fusion for scoliosis, we found steady use of anterior, posterior, and circumferential surgical approaches with increasingly more pedicle screw-only constructs. Circumferential fusions had the highest complication rate.

Introduction: Surgical treatment of adult scoliosis continues to evolve with improvement in surgical techniques and technologies. We performed a retrospective cohort analysis using a multi-institutional database to assess recent trends in spinal fusion for adult scoliosis in the past decade.

Methods: The Scoliosis Research Society morbidity and mortality dataset was queried for adult patients (>18 years) who underwent spinal fusion for idiopathic or degenerative scoliosis from 2001-2008. Patient and surgical characteristics, as well as reported complications were analyzed. Two-tailed Fisher's exact test was performed.

Results: We identified 7,570 patients (mean age 51.4 years) who underwent spinal fusion for idiopathic (62.4%) or degenerative scoliosis (37.6%): 981 (13.0%) were anterior spinal fusions (A), 1,606 (21.2%) anterior-posterior spinal fusions (AP), and 4,983 (65.8%) posterior spinal fusions (P). Curve types were: cervicothoracic 0.1%, triple major 0.4%, double thoracic 1.7%, lumbosacral 2.8%, unknown 4.2%, double major 10.9%, thoracic 14.3%, thoracolumbar 25.9%, and lumbar 39.7%. Distribution of curve magnitude was: 0-20o 5.5%, 21-30o 10.8%, 31-40o 12.9%, 41-50o 17.5%, 51-60o 18.7%, 61-70o 10.2%, 71-80o 6.1%, 81-90o 2.9%, 91-100o 0.9%, >100o 1.2%, and unknown 13.2%. American Society of Anesthesiologists scores were: I 39.9%, II 38.1%, III 12.0%, IV 0.5%, and unknown 9.4%. 978 (17.8%) were revisions, 1,193 (21.7%) staged, and 1,363 (21.4%) underwent osteotomies. Pedicle screw-only instrumentation increased from 19.8% in 2001 to 80.5% in 2008, whereas hook-only instrumentation decreased from 11.6% to 0.4% and hybrid constructs from 67.7% to 16.0%. Wire-only instrumentation was rare (0.03%). Overall complication rates differed based on surgical approach with statistical significance ($p<0.0001$): A 9.0%, AP 22.5%, and P 15.3%. Mortality rate was 0.2% (n=17).

Conclusion: All surgical approaches continue to be used to treat adult scoliosis, with the highest complication rate in AP (22.5%) approaches. Unlike adolescent idiopathic scoliosis, the predominant curve type was lumbar. There has been a steady increase in the use of pedicle screw-only constructs over time.

17. Three Column Spine Reconstructions are not Associated with Higher Rates of Complication or New Neurologic Deficit: A Retrospective Scoli-Risk 1 Study

Michael P. Kelly, MD; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Steven D. Glassman, MD; Leah Y. Carreon, MD, MSc; Virginie Lafage, PhD; Frank J. Schwab, MD; Adam L. Shimer, MD

USA

Summary: A retrospective analysis of complex spinal deformity pts revealed similar rates of complications and neurologic deficits between PSF and 3-CO groups. Careful prospective data collection is needed to define risk factors for perioperative complications and deficits.

Introduction: With technique advancements, three column osteotomies for spine realignment may be safer than previously believed. Complex spinal deformity patients are at particular risk for perioperative complications, both medical and neurological.

Methods: 207 pts (5 centers) were retrospectively identified according to Scoli-Risk 1 inclusion criteria: 1. Primary deformity with > 80-deg Cobb angle; 2. Revision deformity having any type of osteotomy; 3. Any type of 3-column osteotomy (3CO). Patients undergoing a 3CO were compared to those not(PSF). Rates of neurologic complications and medical complications were compared.

Results: 75 PSF and 132 3CO pts were identified. 3CO patients were older (58.9 vs 49.4, p<0.0001), had higher BMI (29.0 vs 25.8, p=0.034), had smaller preoperative coronal Cobb measurements (33.8 vs 56.3, p<0.001), had more preoperative sagittal malalignment (116.6 vs 54.5mm, p<0.001), and had similar sagittal Cobb measurements (45.8 vs 57.7, p=0.113). Operative times were similar (393 vs 423min, p=0.112), though 3CO sustained higher EBL (2120 vs 1700mL, p=0.013). Rates of new neurologic deficits were similar (PSF:6.7% vs 3-CO:9.8%, p=0.435) and rates of any perioperative medical complication were similar (PSF:45.3% vs 3-CO:34.8%, p=0.136). VCR patients were more likely to sustain medical complications than PSO (73.7% vs 46.9%, p=0.031), though new neurologic deficits were similar (15.8% vs 8.8%, p=0.348). Regression analysis did not reveal significant predictors of neurologic injury nor complication from collected data.

Conclusion: Despite higher EBL, rates of complication (49.3%) and neurologic injury (8.7%) did not vary for complex reconstruction patients, whether a 3-CO is performed or not. VCR patients sustained more medical complications without an increase in new neurologic deficits. Prospective study of patient and provider factors is needed to define and optimize risk factors for complication and neurologic deficits.

18. Complications and Inter-Center Variability of Three Column Osteotomies for Spinal Deformity Surgery: A Retrospective Review of 423 Patients

Kristina Bianco, BA; Frank J. Schwab, MD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Ibrahim Obeid; Gregory M. Mundis, MD; Khaled Kebaish, MD; Richard Hostin, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; International Spine Study Group

USA

Summary: High rates of complications have been reported for three column osteotomies (3CO). The incidence of overall major complications was 58% following 3CO at eight different sites with 28% intraoperative and 45% postoperative. Major intra-operative blood loss over 4 liters was 24%. Two osteotomies, thoracic osteotomies, and having surgery at a low volume center were risk factors for more complications.

Introduction: Three column osteotomy (3CO) are commonly performed for sagittal deformity, but have high rates of reported complications. This study examined the incidence and inter-center variability of major intra-operative complications (IOC), post-operative complications (POC) and overall complications (both IOC and POC) up to six weeks post-operation.

Methods: The incidence of IOC, POC, and overall complications were determined for the study population. The analysis compared patients with one and two 3CO, as well as patients with one thoracic 3CO (ThO) and those with one lumbosacral 3CO (LSO). Subsequent analysis compared sites with small (<50) and large (>50) osteotomy volumes.

Results: The incidence of major IOC, POC, and overall complications was 28%, 45%, and 58%, respectively (Table 1). The most common major complication was major intra-operative blood loss over 4 liters (MBL, 24%). When MBL was not included in the analysis, the incidence of IOC and overall complications reduced significantly (7%, 48%, p<0.01 respectively). Other common major complications were spinal cord deficit (3%), unplanned return to the operating room (19%), motor deficit paralysis (12%), and death (0.2%). Patients with two 3CO had more POC (p<0.01) and overall complications (p=0.04) than those with one 3CO. Patients with ThO had more POC and overall complications than patients with LSO (p<0.01). Low volume sites had more MBL (p<0.01) and higher IOC (p<0.01) than large volume sites. Patients with MBL had a significantly longer operating time (p<0.01) and a higher risk of developing other IOC, POC, and overall complications (RR=2.04, 1.24, and 1.27 respectively).

Conclusion: The overall incidence of complications was 58%; however, it was reduced when MBL was not included in the analysis. There was significant variation in complications depending on the number of 3CO, location of 3CO in the spine, and volume of 3CO performed at the site. Risks for developing complications included having MBL, two osteotomies, thoracic osteotomies, and having surgery at a low volume center.

19. Proximal Junctional Failure in Adult Deformity Patients Results in Higher Rate of Revision but Limited Impact on Clinical Outcome

Robert A. Hart, MD; Jayme R. Hiratzka, MD; D. Kojo Hamilton, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Praveen V. Mummaneni, MD; Eric Klineberg, MD; Ian McCarthy, PhD; Douglas C. Burton, MD; Richard Hostin, MD; International Spine Study Group

USA

Summary: Proximal Junctional Failure (PJF) represents a more severe form of Proximal Junctional Kyphosis (PJK), as it includes evidence of mechanical failure. A prospective multi-center cohort of 172 patients undergoing surgery for adult spinal deformity demonstrates an incidence of PJF of 13.3%. Although PJF patients more frequently underwent proximal extension of their fusion than did patients with PJK, clinical outcomes were equal at minimum 2 year follow up.

Introduction: Proximal Junctional Failure (PJF), a more severe form of Proximal Junctional Kyphosis (PJK) that includes evidence of mechanical failure, has been recognized as an important concern in adult deformity patients. Prospective evaluation of incidence and clinical impact of PJF have not been reported. We performed a prospective evaluation of PJF in patients undergoing adult deformity surgery.

Methods: 172 adult deformity surgical patients from 10 centers were followed prospectively with minimum 2 year follow-up. PJF was defined as increased proximal kyphosis of > 10 degrees plus fracture of UIV or UIV+1 or instrumentation failure. Proximal Junctional Kyphosis (PJK) was defined as increased kyphosis of > 10 degrees without evidence of mechanical failure. Patients were grouped as PJF, PJK, or neither. One and two year HRQoL scores, rate of revision surgery, and development of neurological deficit were compared among the 3 groups.

Results: There were 23 PJF patients, 36 PJK patients, and 113 with neither (NoPJF) over 2 year followup, for a PJF incidence of 13.3% and a PJK incidence of 20.5% . There was no worsening among PJF or PJK patients in 1-year, 2-year, or change from baseline scores for ODI, SF-36 PCS, or SRS-22 scores compared to NoPJF patients. There was a significant increase in rate of proximal extension of fusion among PJF versus PJK patients (14.6% vs. 1.9%; p=0.018). No PJF or PFK patients experienced neurological motor deficits due to their junctional compromise in this patient cohort.

Conclusion: PJF represents a more substantial complication than PJK, as shown by the increased rate of fusion extension among patients with PJF. However, negative impact on HRQoL measures were not found at 1 or 2 year follow up between patients with PJF or PJK compared to NoPJF patients. There were no neurological deficits due to PJF in this cohort. The reported incidence of 13.3% represents the highest level of medical evidence to date for occurrence of PJF among adult deformity surgical patients.

20. Patients with Proximal Junctional Kyphosis Requiring Revision Surgery Have Higher Post-Op Lumbar Lordosis and Larger Sagittal Balance Corrections

Han Jo Kim, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Moon Soo Park, PhD; Kwang-Sup Song, MD; Tapanut Chuntarapas; Chaiwat Piyaskulkaew, MD

USA

Summary: Patients with PJK requiring revision (RR) surgery were older, have adult degenerative scoliosis (DS), UIV instrumentation with bilateral pedicle screws and larger post-operative lumbar lordosis (LL) and sagittal balance corrections.

Introduction: Some patients maintain stable PJK angles, while others progress and develop severe PJK RR surgery. We aimed to evaluate risk factors in patients in 3 groups, those without PJK (N), those with PJK but not requiring revision (P) and those with PJK requiring revision surgery (RR).

Methods: 206 pts at a single institution from 2002-2007 with adult idiopathic (IS) or DS with 2 yr min f/u (avg. 3.5 yrs) were analyzed. Inclusion criteria were age > 18, primary fusions >5 levels from any thoracic UIV to any LIV. Revisions were excluded. Radiographic assessment included Cobb angles in the AP/lateral plane and PJK angle measurements at post-op time points: 1-2 mo, 2 yrs and final f/u. PJK was defined as an angle >10°.

Results: The prevalence of PJK was 34% (70/206). The average age was 49.9 vs. 51.3 and 60.1 in N, P and RR respectively (p=.03, N vs RR). The diagnosis was DS in 40%, 44% and 75% in N, P and RR (p=.03, N vs RR). Gender, BMI and smoking status were not significantly different between groups. Fusions extending to the pelvis were 74%, 85% and 91% of the cases in Groups N, P and RR. (p=.02, N vs RR)

Instrumentation type was different between groups N and RR (p=<0.01), with a higher use of UIV hooks in N. (Table 1) Radiographic parameters showed higher postop LL (38.7 vs 54.4;p<.01) and a larger sagittal balance (SVA) change with surgery (4.1cm vs 8.8cm, p=.02) in those in RR. Surgical approach and crosslink use were not significantly different. SRS post-op pain scores were inferior in group N vs. P and RR (4.0 vs 3.7, 4.0 vs 3.5, p=.04;p=.03) and inferior ODIs were seen for group N vs P (22.6 vs 29.1;p=.04)

Conclusion: PJK patients requiring revisions were older, had higher postop LL and larger SVA corrections than patients w/o PJK. In addition, there were a higher proportion of patients with DS than IS. Based on this data, older patients with adult DS should have moderate corrections in their LL and SVA as opposed to large corrections in order to minimize the risk for developing PJK.

21. Characterization and Surgical Outcomes of Proximal Junctional Failure (PJF) in Surgically Treated Adult Spine Deformity Patients

Mitsuru Yagi, MD, PhD; Mark D. Rahm, MD; Robert W. Gaines, MD; Ali M. Maziad, MD, MSc; Thomas Ross, MS, RN; Han Jo Kim, MD; Khaled Kebaish, MD; Oheneba Boachie-Adjei, MD; Complex Spine Study Group

Japan

Summary: Although recent reports have shown the catastrophic results of PJF, very few reports have shown the character and clinical outcomes of revision surgery of PJF in Adult Spinal Deformity (ASD). Patients with PJF entered into a multicenter database were retrospectively reviewed. Bone failure was the most common type of PJF, and neurologic deficit was not uncommon. Older age, previous surgery, and UIV at thoracolumbar junction were identified as a risk factor of PJF.

Introduction: Although recent reports have shown the catastrophic results of proximal junctional failure (PJF), very few reports have shown the character and clinical outcomes of revision surgery of PJF in adult spine deformity (ASD). The purpose of this study is to characterize PJF in ASD patients undergoing long instrumented spinal fusion and to evaluate the revision surgery of PJF. A new proximal junctional kyphosis (PJK)/PJF classification is also proposed.

Methods: A retrospective analysis of data entered prospectively into a multi-center database was reviewed. Surgically treated ASD patients with minimum 1 year F/U were included. PJF was defined as any type of symptomatic PJK requiring surgery. Demographic and radiographic data were reviewed, as well as clinical and radiographic outcomes. Based on our previous classification (Table 1), modified PJK classification was established as follows: Grade A: Proximal Junctional Increase of 10°-19°, Grade B: Proximal Junctional Increase of 20°-29°, Grade C: Proximal Junctional Increase of 30° or more. 3 types of PJK were also defined: PJK from disc and ligamentous failure was Type 1, bone failure was Type 2, and implant/bone interface failure was Type 3. Additional criterion was added for PJF with Spondylolisthesis above the UIV.

Results: 23 patients developed PJF (M 6: F 17). Mean age was 62.3±7.9 yrs. 17 of these patients had had prior surgery, and all patients underwent multilevel fusion from the thoracic spine to L5 or S1 for their ASD. Symptoms of PJF consisted of 16 with intolerable pain, 6 with neurological deficit and 1 with head ptosis. 6 patients had UIV above T8 and 17 had UIV below T9. Mean PJ angle was 26.8±8.8 degrees and was most common in Type 2BN. All patients had revision with extension of fusion to a more proximal thoracic level, 11 patients had additional PJK/PJF at the new UIV and 9 required additional revision surgery.

Conclusion: In this series, the most common type of PJF was 2BN. It's most devastating form, associated neurologic injury, was not uncommon, and most of patients with neurologic deficit had type 2. Older age, previous surgery, and UIV at thoracolumbar junction were identified as risk factors of PJF. Further PJF following revision surgery commonly occurred.

PJK Classification

Type	
Type 1	Disc and Ligamentous Failure
Type 2	Bone Failure
Type 3	Implant/Bone Interface Failure
Grade	
Grade A	Proximal Junctional Increase 10° - 19°
Grade B	Proximal Junctional Increase 20° - 29°
Grade C	Proximal Junctional Increase 30° -
Spondylolisthesis	
N	No Obvious Spondylolisthesis Above UIV
S	Spondylolisthesis Above UIV

22. The T1 Pelvic Angle (TPA), a Novel Radiographic Measure of Global Sagittal Deformity, Accounts for Both Pelvic Retroversion and Truncal Inclination and Correlates Strongly with HRQOL

Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Nicolas Bronsard, MD, PhD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Thomas J. Errico; Virginie Lafage, PhD; International Spine Study Group

USA

Summary: Established radiographic parameters of sagittal balance like SVA, and PT can be modified by postural compensation, including pelvic retroversion and knee flexion, and by patient support in standing. We introduce the TPA, a novel measure sagittal alignment measure, which is less dependent on such postural factors. TPA accounts for both truncal inclination and pelvic retroversion, yet it can be measured on a full length intraoperative radiograph. Similar to SVA, the TPA was found to correlate strongly with HRQOL.

Introduction: Sagittal Vertical Axis (SVA) and Pelvic Tilt (PT) have been shown to correlate directly with Health Related Quality of Life (HRQOL) in adult spinal deformity (ASD). This study investigates the relationship of the T1 Pelvic Angle (TPA), a novel radiographic parameter of global sagittal deformity (Figure 1), and other established measures, correlating them with HRQOL. TPA accounts for both truncal inclination and pelvic retroversion, and it can be measured on a prone intraoperative long-cassette radiograph to gauge global correction, a function which is not possible with SVA or PT. Since the TPA is an angular and not a linear measure, it does not require calibration of the radiograph.

Methods: Multicenter, prospective, analysis of consecutive ASD patients. Inclusion criteria: ASD, age>18, and any of the

following: scoliosis Cobb angle >20 deg, SVA>5 cm, thoracic kyphosis>60 deg, and PT greater than 25 deg. Clinical measures of disability included ODI, SRS and SF36.
Results: 559 ASD patients (mean age 52.5) were enrolled. TPA correlated most strongly with SVA (r=0.837) and PI-LL (r=0.889) and PT (0.933). Categorizing the patients by increasing TPA (<10; 10-20; 20-30; >30) revealed a significant and progressive worsening in HRQOL (all p<0.001). TPA and SVA correlated strongly with ODI (0.435, 0.457), SF36 PCS (-0.440, -0.465) SRS (-0.304, -0.360). Utilizing a linear regression analysis, the threshold for TPA of 19.8 was found to correspond to a severe disability (ODI>40). The meaningful change in TPA was 4.1, correlating it to an ODI change of 15.
Conclusion: The TPA correlates strongly with HRQOL in patients with ASD. The TPA is related to both PT and SVA, but unlike SVA, it measures sagittal deformity independent of many postural compensatory mechanisms. It can be used as an intraoperative tool to measure global correction with a target TPA of less than 20.

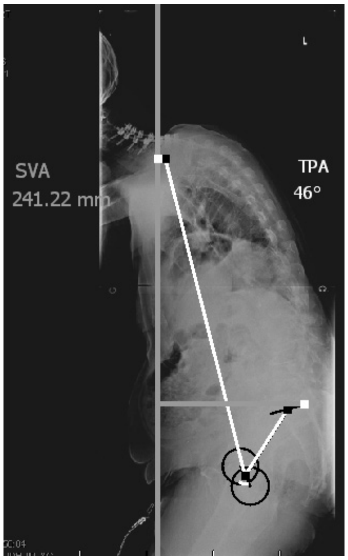


Figure 1: TPA and SVA depicted. TPA is the angle of a line from the center of T1 to the femoral heads (FH) and a line from the FH to the center of the S1 endplate.

23. Sacro-Pelvic Fixation Using the S2 Alar-Iliac (S2AI) Screws in Adult Deformity Surgery: A Prospective Study with Minimum Five-Year Follow-Up

Sophia Strike; Hamid Hassanzadeh, MD; Floreana Naef, MD; Paul D. Sponseller, MD; Khaled Kebaish, MD

USA

Summary: A prospective study to evaluate the S2 Alar-Iliac (S2AI) screw technique for sacro -pelvic fixation.
Introduction: Adult deformity patients requiring long fusion to the sacrum often require additional anchors into the Ilium. There are many available techniques however some may be difficult and may use complex connectors that can affect construct stability.
Methods: We prospectively reviewed 70 patients undergoing long fusion to the sacrum using S2AI technique. Functional outcome, radiographic data and complications were collected. Four patients died from unrelated causes during the study period, and six patients did not complete 5 year follow-up. The remaining 60 patients had five years of radiographic and clinical data.
Results: The mean age at the time of surgery was 58.3 yrs (±12.6, range 26-80), 75% of patients were females, 46 (77%) patients had multiple co-morbidities. Mean radiographic changes were (pre/post): thoracic kyphosis 8.96°(39.81/48.77), lumbar lordosis 11.84°(29.85/41.69), thoracic curve 11.46°(37.21/25.75), lumbar curve 15.21°(40.29/25.08). At five yrs, 98.3% of the patients showed radiographic fusion at L4-S1. Re-operation was performed on 5 patients: revision of broken rods (1), pseudoarthrosis proximal to L4 (2), junctional stenosis (1), residual deformity (1). One patient had removal of instrumentation and another patient had an S2AI screw replaced due to pain. Overall complication rate was 60.0 % (28.3 % minor, 31.7 % major). Complications specific to S2-iliac fixation: 3 patients had 5 (6.5%) S2AI screw fractures, none required revision, out of 115 screws total, 15 screws had >2 mm loosening (13.0%), and five screws had > 4 mm loosening (5.2%). There was a statistically significant improvement in all SRS 22 domains, ODI and SF-12, at post-op and at final follow up (pre/post/final): pain (1.85/3.48/3.21), self image (1.91/2.67/2.57), activity (2.43/2.79/2.96), mental (1.82/1.87/3.00), and satisfaction (1.67/1.98/3.45). The ODI also showed a mean decrease (75.01/38.46/28.41), the SF-12 improvement (physical 41.71/58.15/63.79, mental 43.12/42.87/53.05). There were two superficial and one deep wound infections.
Conclusion: The S2 Alar-iliac (S2AI) pelvic fixation has a low rate of technique-related complications and rare need for revision, which appears to be maintained at long term follow-up.

24. Rod Fractures in Spinal Deformity Surgery Involving Pelvic Fixation: Does Stainless Steel Fracture Less Often?

Michael Hellman, MD; Bryan Haughom, MD; Nathan Wetters; Mark F. Kurd, MD; Kasra Ahmadinia; Christopher DeWald, MD

USA

Summary: Spinal fixation involving the pelvis creates high stress on the posterior instrumentation. We compared the rate of rod fracture between cobalt chromium and titanium versus stainless steel. Our study is the first to show a decreased rate of fracture in stainless steel rods compared to titanium and cobalt chromium in the setting of spinal fixation involving the pelvis.
Introduction: There has been a significant trend towards using titanium and cobalt chromium for spinal deformity correction.

Spine fixation involving the pelvis results in high stress loads to posterior instrumentation. The surgeon must choose a rod with enough strength to prevent motion and psuedoarthrosis. Stainless steel is an excellent option that has fallen out of favor. If fixation fails additional surgeries siginicantly increase the morbitiy and mortality to this patient population. We hypothesize that stainless steel has lower rates of rod fracture in the setting deformity correction with pelvic fixation.
Methods: A retrospective cohort study analysed all spinal fusions for signifcant deformity requiring pelvic fixation between March 2005 and January 2011. Radiographs were reviewed at follow up visits looking for rod fracture. A chi-squared test was performed to compare the rate of rod fracture in titanium and cobalt chromium fixation verus stainless steel.
Results: 119 patients were included (100 women, 19 men) with an average age of 57.5 years. The average follow up time was 3.6 ± 1.5 years. Average fusion spanned 10.1 ± 4.4 levels. 48 patients had titanium, 41 patients had cobalt chromium, and 30 patients had stainless steel rods. Our rate of rod fracture was 20%. Stainless steel had a signifigantly lower rate of fracture compared to titanium and cobalt chromium combined (13.3% vs. 29.3 %; p = 0.04). Our reoperation rate was 10% for stainless steel and 19% for the combined cobalt chromium and titanium group.
Conclusion: No previous studies have compared rod fracture rates between these metals in the setting of pelvic fixation. There has been a trend towards using titanium and cobalt chromium rods for spinal deformity correction. We show that stainless steel rods have a lower rate of fracture when compared to titanium and cobalt chromium. There is significant morbidity when one must re-operate for rod fracture and pseudoarthrosis. While titanium and cobalt chromium have inherent advantages, our data show that stainless steel should be considered for deformity correction involving pelvic fixation.

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25. Outcomes of Brace Treatment for Adolescent Idiopathic Scoliosis: Factors Affecting the Results of the Treatment

Toru Maruyama, MD, PhD; Yusuke Nakao

Japan

Summary: According to the Scoliosis Research Society brace studies standardization criteria, a total of 29 patients who underwent brace treatment were followed until skeletal maturity. Average Cobb angle was 31.3° before treatment and 32.2° at final follow-up. Six patients (21%) progressed more than 6°: 79% were stabilized by the treatment. Three patients exceeded 45° and only one required surgery. These results were more favorable than the natural history. Better initial correction by the brace was predictive of the better outcome.
Introduction: There are still controversies regarding the effectiveness of brace treatment for adolescent idiopathic scoliosis (AIS). Purpose of this study was to analyze outcomes of brace treatment to demonstrate the effectiveness of brace treatment for AIS and to clarify the factors affecting the results of the treatment
Methods: According to the Scoliosis Research Society (SRS) AIS brace studies standardization criteria, patients with age 10 years or older, Risser 0-II, primary curve magnitude 25°-40°, and no prior treatment when the brace was subscribed were included in the study. At skeletal maturity, percentage of the patients whose curve progressed more than 6 degrees, whose curve exceeded 45 degrees, or who underwent surgery was investigated. These results were compared with natural history or other brace studies. Factors affecting the results were analyzed.
Results: A total of 29 patients, 24 females and 5 males, met the SRS inclusion criteria. Average age at the beginning of the treatment was 12.0 years (10 to 15). Risser sign was 0 in10, I in 6, and II in 13 patients. Curve pattern was thoracic (T) in 11, thoracolumbar or lumbar (TL) in 11 and double (D) in 7 patients. Average Cobb angle before treatment was 31.3°. Initial correction rate by the brace was 51.7% on an average (35.2% for T, 75.5% for TL, and 43.4% for D curve). Most patients wore their brace as part-time, at home or at night. All the patients were followed until skeletal maturity: the average follow-up period was 29 months. Average Cobb angle at follow-up was 32.2°. Of 29 patients, six (21%) progressed more than 6° and three (10%) exceeded 45°. Only one patient (3%) underwent surgical treatment during the study period.
These results were more favorable than the reported natural history or most of the other brace studies. Factors predicting the better results of brace treatment were Risser sign of I or II at the beginning of the treatment and better initial correction rate with the brace.
Conclusion: Seventy-nine percent of the curves with AIS could be stabilized by the treatment. Brace treatment was effective for the treatment of adolescent idiopathic scoliosis

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26. Incidence of Surgery After Brace Treatment in Patients with Adolescent Idiopathic Scoliosis

Hideki Murakami; Ken Yamazaki, MD

Japan

Summary: In the 88 AIS patients who underwent brace treatment following the SRS orthosis application criteria, the success rate was 59%. Orthotic dropouts accounted for 27.2%, and treatment progressed to surgery in 14.7% of all patients. Of the orthotic dropouts, 33% underwent surgery.
Introduction: Brace treatment for adolescent idiopathic scoliosis (AIS) patients was investigated following the inclusion and evaluation criteria established by the Scoliosis Research Society (SRS) Committee on bracing and nonoperative management in 2005.
Methods: Over the last 15 years, 603 AIS patients were registered: 262 (43.4%) underwent brace treatment. The patient

inclusion criteria were 10 years of age or older, 0-2 Risser sign, primary curve angle 25-40, the absence of past treatment, if female, either premenerchal or less than 1year postmenarchal, and 88 patients (34%) met these. The mean age was 11.9 years, all patients were female, and the mean duration of bracing was 77 months. An underarm brace was used in all patients.
Results: The mean Cobb angles before and after bracing and on the final follow-up were 31, 19, and 30, respectively, and the mean correction rate after bracing was 38.7%. Twenty-four patients (27.2%) dropped out from brace treatment. Regarding a 5 or smaller increase in the Cobb angle on the final follow-up as successful bracing therapy, it succeeded in 52 patients (59%). The highest success rate by level was 85% in the thoracolumbar spine, followed by 63.3% in the thoracic curve and 51.3% in the thoracolumbar double curve. The treatment was changed to surgery in 8 (33%) of the dropouts from brace treatment. The Cobb angle was 45 or greater at the completion of orthotic therapy in 12 patients (13.6%), and 4 (33%) of them underwent surgery. Treatment finally progressed to surgery based on course observation after brace therapy in 6 patients. Combining 3 dropouts who re-visited and underwent surgery without course observation, treatment finally progressed to surgery in a total of 13 patients (14.7%).
Conclusion: In the 88 AIS patients who underwent brace treatment following the SRS orthosis application criteria, the success rate was 59%. Orthotic dropouts accounted for 27.2%, and treatment progressed to surgery in 14.7% of all patients. Of the orthotic dropouts, 33% underwent surgery. The outcomes of brace treatment should be compared following the application criteria.

27. The Effect of Compliance Monitoring on Brace Use and Success in Patients with AIS

Lori A. Karol, MD; Donald Virostek, BS; Kevin M. Felton, BS, MLA; Lesley Wheeler, BS

USA

Summary: Compliance monitors were implanted into orthoses of 105 AIS patients who have reached maturity or underwent surgery. Patients were divided into 2 groups: one was provided their compliance information and counseled at each visit, while the other were unaware of the sensor's purpose. Counseled patients wore braces significantly longer per day than those who were not. Increased brace wear was documented in patients whose curves did not progress. Compliance data counseling improves brace wear and reduces curve progression.
Introduction: Purpose: The purpose of this study was to determine if physician counseling using compliance monitors improves brace use and decreases curve progression in AIS.
Methods: Methods: 201 patients (181 females/20males) have been prospectively enrolled. All were Risser 0, 1, or 2, were < 1yr postmenarchal, and had curves between 25 and 45 deg at brace prescription. Patients were placed into 2 groups: Group 1 were aware of the compliance monitor in their brace and were counseled at each visit regarding downloaded brace usage. Group 2 were not told the purpose of the monitor, and physican, orthotist, and patient were blinded to downloaded compliance data. This report analyzes the first 105 patients who have completed bracing.
Results: Results: 57 patients in Group 1 and 48 patients in Group 2 completed bracing or underwent surgery. Ave curve magnitude at initiation of bracing was 33.9 deg in Group 1 and 34.9 deg in Group 2 (p=.33). Group 1 wore orthoses an average of 13.4 hrs/day throughout their management, while Group 2 wore braces an average of 10.6 hrs/day (p=0.042). In the counseled group that finished bracing, 63.2% did not progress >5 deg, while 26.3% (15/57) underwent surgery. In Group 2, 45.8% did not progress >5 deg, while 39.6% (19/48) progressed to 50 deg or surgery. Noncounselled patients who underwent surgery wore braces 9.63 hrs/day compared to 11.52 hrs for the counseled group who underwent surgery. Patients with <6 deg of curve progression wore braces an ave 14.1 hrs/day. There was no statistical difference between hours worn in surgical Group 1 versus surgical Group 2, or between nonsurgical Group 1and Group 2 patients. Daily wear in children with progression < 5 deg was significantly greater than children who underwent surgery (p=0.0048).
Conclusion: Conclusions: Compliance counseling improves brace wear. Patients who wore braces more hours/day experienced less curve progression. Patients in both groups who progressed to 50 deg or surgery wore braces fewer hours than their successful counterparts. Compliance monitoring and counseling should be part of orthotic management in patients with AIS.

28. Serial De-Rotational Casting in Idiopathic and Non-Idiopathic Progressive Early Onset Scoliosis

Yazeed M. Gussous, MBBS; Safdar N. Khan, MD; Angela Caudill, MPT; Peter Sturm, MD; Kim Hammerberg, MD

USA

Summary: Serial de-rotational casting has been used as the definitive treatment or as a delay strategy in progressive idiopathic and non-idiopathic early onset scoliosis. We report the results of treatment, and comparative analysis between idiopathic and non idiopathic groups, and between patients who required surgical treatment to patients who were treated conservatively.
Acknowledgement: supported in PART, by grant 1UL1RR031973 from the Clinical and Translational Science Award CTSA program of the National Center of Research Resources, National Institutes of Health
Introduction: Serial de-rotational casting has been used as the definitive treatment or as a delay strategy in progressive idiopathic and non-idiopathic early onset scoliosis.

Methods: A retrospective chart and radiographic review was conducted for patients who underwent serial casting for progressive Early Onset Scoliosis (EOS) between 2005 and 2012 at a single institution.

Results: 74 consecutive patients entered serial cast treatment between 2005 and 2012. Of the 74 patients 28 are currently being casted, 30 completed cast treatment and were converted to TLSO (TLSO group), 9 were treated surgically, 6 were lost to follow-up, and one had no further treatment.

Diagnosis of Idiopathic EOS (IS) was found in 41 patients and 33 patients had Non-Idiopathic EOS (NIS). Overall, at presentation the IS group had an average Cobb angle (CA) of 49° and a RVAD of 37°. The NIS group had CA of 51° ($p=0.69$) and RVAD of 37° ($p=0.94$).

In patients currently being casted, 19 IS patients had a decreased CA from 47°to 27° and the 9 NIS patients had a decreased CA from 62° to 57° ($p=0.0002$). CA regression rate was significantly higher in IS group ($p= 0.0005$).

In the TLSO group following serial casting, the 17 IS patients had a decreased average CA from 46° to 18° and the 13 NIS patients from 42° to 32°. IS had higher CA regression rate than NIS group ($p<0.001$). At last follow-up, this was further reduced to 11° in the IS group and maintained at 32° in the NIS group ($p=0.21$).

In the IS group 5/41 were converted to growth constructs and 4/26 in the NIS group. At presentation the surgical patients had a higher age 29.3 vs. 20.4 months ($p=0.024$) and CA 62° vs. 42° ($p=0.002$), but no significant difference in RVAD or duration of cast treatment compared to the TLSO group.

Conclusion: IS patients had a better curve correction with casting than the NIS group. Casting initiated prior to two years of age yielded better curve correction in the IS group ($p<0.01$). Surgical patients had a higher age and Cobb angle at presentation than the TLSO group. RVAD was not a predictor of curve correction with serial casting.

29. Results of Serial Casting in Idiopathic and Non-Idiopathic Cases of Early Onset Scoliosis

Vishwas R. Talwalkar, MD; Josh Philbrick, MD; Pooya Hosseinzadeh, MD; Todd A. Milbrandt, MD, MS; Ryan D. Muchow, MD; Janet L. Walker, MD; Henry J. Iwinski, MD

USA

Summary: We studied results serial casting in 27 patients with early onset scoliosis (idiopathic and non idiopathic) with average follow up of 5.4 years. Our data shows significant improvement in Space Available for Lung (SAL), and spinal growth with casting.. Our data shows avoiding growing instrumentation in 85% of our patients with average delay of 70 months to surgery.

Introduction: Early onset scoliosis is known to progress rapidly. Growing instrumentation has been associated with high complication rates. Serial casting has been shown to slow the progression and delay surgery in patients with early onset scoliosis. We studied the effects of serial casting on thoracic volume, vertebral growth, and outcome of our patients that presented with both idiopathic and non idiopathic early onset scoliosis.

Methods: Retrospective chart review of patients treated at our institution with serial casting for scoliosis was performed. Age at presentation, type of scoliosis, number of casts, Cobb angles, T1-T12 length, and Space Available for Lung (SAL) was reviewed before and after the treatment. The curves were divided into idiopathic and non idiopathic groups .T test was used to measure the effects of casting.

Results: 27 patients met our inclusion criteria (Average age: 3.7 years). 17 patients had idiopathic and 10 patients had non idiopathic diagnosis and average follow up was 5.4 years. Mean Cobb angle at presentation and final follow up was 49.6 and 42 degrees, respectively. At the time of follow up 63% patients are being treated in braces, and 37% are treated surgically (15% with growing rods and 22% with spinal arthrodesis). The average time to surgery from initial presentation was 70 months. SAL in idiopathic curves was 0.98 and 1.05 at start and completion of casting respectively. SAL for non idiopathic curves was 0.93 and 1.20 at start and completion of casting. T1-T12 length measured 147 mm and 130 mm at start of treatment in idiopathic and non idiopathic curves, respectively. T1-T12 after casting was measured 184 mm and 161 mm for idiopathic and non idiopathic curves, respectively (P-value<0.05).

Conclusion: Our data shows improvement in SAL and spinal growth during serial casting. We were able to avoid growing instrumentation in 85% of our patients with early onset scoliosis. Our data confirms that serial casting is a viable option for treating early onset scoliosis even in patients who present with larger curves and are non idiopathic.

30. Pulmonary Function in Patients with Early Onset Idiopathic Scoliosis 24 Years After End of Brace Treatment

Aina J. Danielsson, MD, PhD; Tero Laine, MD, PhD; Kerstin Löfdahl-Hällerman, MD, PhD

Sweden

Summary: Patients with onset of idiopathic scoliosis before the age of ten and brace treated before maturity were reexamined 24 years after end of treatment. Pulmonary function was found to be within normal limits for most of the patients.

Introduction: Knowledge about pulmonary function in middle-aged patients with early onset idiopathic scoliosis (IS) is sparse. The aim was to determine outcome in terms of pulmonary function in patients that were treated with brace before maturity.

Methods: Consecutive patients with idiopathic scoliosis and diagnosis before the age of ten attended a clinical follow-up.

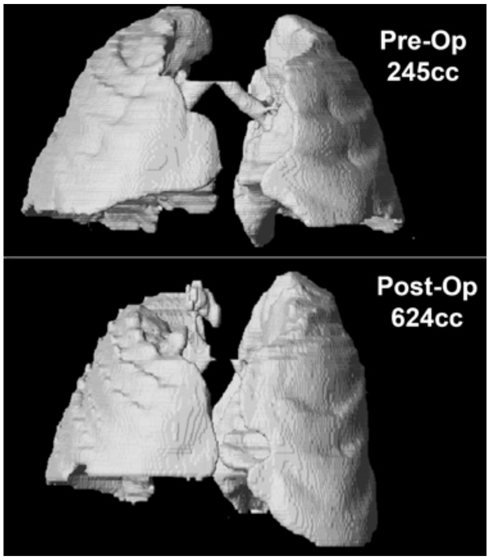
Sixty-three patients brace treated during adolescence and five untreated patients, 68% of the original group, underwent radiography and spirometry. Vital capacity (VC) and Total lung capacity (TLC) was determined and compared with pre-treatment values, which existed in 32 patients. Curve size was measured and curve apex was noted.
Results: Mean age at follow-up was 45.6 for untreated and 40.6 y for braced patients and curve size was similar in both groups, 36°. 27% of braced and 20% of observed patients had curve sizes >45°. Start of bracing was at mean age 10.6 years (2.8-17.1); treatment time mean 4.8 y and follow-up time after end of bracing 24.4 y.
Vital capacity increased significantly from 2.4 l before bracing (82% predicted, range 61-113) to 3.7 l (101 % predicted, range 60-133) at present follow-up. Brace treated patients with curve apex at T9 or above had a significantly reduced VC % predicted compared to those with apex more caudally (100 vs. 110%). For patients with curve apex above T9, no significant difference was found between those with curves larger or smaller than 45°, 94% vs. 102%. Five brace treated patients had values below 80%. The VC % predicted did not differ significantly between the braced and the untreated patients (119% vs.101%).
Conclusion: Patients treated by brace before maturity due to IS with onset before the age of ten gradually increased their pulmonary function long time after treatment. Both pretreatment values and findings 24 years later were within the normal ranges. No significant differences were found towards the untreated patients, although this group was very small.

31. CT Lung Volume Improvement After Surgical Treatment for Early Onset Scoliosis (EOS)

Charles E. Johnston, MD; Anna M. McClung, BSN, RN

USA

Summary: Increase in lung volume following surgical treatment for EOS can be demonstrated by CT scans in patients unable to perform standard pulmonary function testing (PFT). In 20 patients volumes were increased postoperatively. Thoracic dimensions T1-12 length, T6 coronal width, pelvic width and % curve correction were reliable surrogates for CT volume.
Introduction: Treatment of EOS must focus on gains in thoracic/lung volume as much as deformity management, in order to minimize thoracic insufficiency risk. In patients unable to perform standard PFTs, CT volume determination (CTvol) is an important objective anatomic measure of treatment effect on the thorax.
Methods: 20 patients had preop CT lung volumes performed, then postop at mean 2.7 yr later (IRB approved). 12 had non-congenital curves, 8 congenital . 11 patients had spine-based treatment (SB), 9 rib-based (RB). CTvol's were correlated to thoracic xray dimensions (T1-12 length, T6 coronal width, pelvic width) and curve magnitude.
Results: CT lung volume increased in all patients from mean 724cc preop (range 201-1267) to 1071cc (456-2021) at f/u. RB cases gained 65%,vs. 48% in SB (not signif). RB cases had smaller preop volume than SB(520 vs 889cc, p<.02)) due to most being congenital and scans at younger age. RB cases gained more % postop CTvol due to smaller preop volume (n.s.). T1-12 length correlated with CTvol preop r=.64,p=.002 and postop r=.58,p=.006. Coronal T6 width correlated best with CTvol r=.76 p<.0001preop and .82 p<.0001 postop, and less well with Δvol pre-to-post r=,54,p=.01. Pelvic width and CTvol correlated well (r=.7,p<.001 pre & post). There was NO correlation with MT Cobb angles but weak correlation with %curve correction r=.47,p=.03.
Conclusion: CT objectively demonstrates improved lung volume in all patients, presumably due to surgical treatment and growth. Thoracic dimensions (T1-12 spine length, pelvic width, and especially T6 coronal width) appear to be reliable surrogate measures for CT volumes. Curve magnitude and correction correlate less well with CTvol, assuming less importance in evaluating EOS outcome.



32. Magnetic Growth Rods Improve Pulmonary Function in Children with Early Onset Scoliosis

Wai Weng Yoon, BSc(Hons), MBBS, MRCS, FRCS(Tr&Orth); Fady S. Sedra, MBBcH, MSc, MRCS; Nanjundappa S. Harshavardhana, MD, MS(Orth), Dip. SICOT; Suken A. Shah, MD; Francesco Muntoni, MD, FRCPCH, FMed Sci; Colin Wallis, MBChB, FRCPCH, MRCP, MD, DCH, FCP(SA); Hilali H. Noordeen, FRCS

United Kingdom

Summary: This prospective study of magnetic growth rods with minimum 2 year follow up for the treatment of EOS in children with NMD demonstrated significant improvement in pulmonary function and deformity correction with sequential lengthening, without subsequent surgical interventions and anesthetic risk.

Introduction: Early onset scoliosis (EOS) has a large impact on pulmonary function and may lead to thoracic insufficiency syndrome (TIS). Growth rods are effective in driving spinal growth and increasing space available for the lung (SAL) but require multiple surgical interventions with anesthesia. Magnetic growth rod (MGR) insertion has many benefits including: reduction in operative procedures with repeated anesthetics, increased cost effectiveness and decreased surgical and psychological distress. Pulmonary function tests (PFT) provide functional, objective and quantitative information of impairment caused by scoliosis and may document benefit of interventions. This is the first study to evaluate MGR lengthening and change in pulmonary function over a minimum of 2 year follow up.
Methods: Six cases (2♀/4♂) of EOS secondary to NMD were treated at our hospital since 2009. Mean age at diagnosis was 2.8 Y (2.1-4.9), mean age at surgery was 7.5 Y (5-10) and mean follow-up was 2.5 Y (2.2-2.8). PFT (FVC + FEV1) were measured pre- and post-insertion of the MGR and at every lengthening subsequently in clinic for a minimum of 2 Y. Coronal and sagittal Cobb angles were measured pre and post op as well as length extension of the MGR. Dual magnetic growth rods were implanted in 4/6 patients. Lengthening commenced 3 months after implantation (to allow fusion at anchor sites) and data collected at 6 month intervals.
Results: Average coronal and sagittal correction was 34% and 28%, respectively at final followup. Kyphosis was corrected to a normal range and coronal plane deformity was siginificantly improved (p<0.03). The mean MGR lengthening achieved was 24.9mm (10.9-26.6mm). MGR improved pulmonary function in these very compromised children (see table): the Wilcoxon signed rank test identified a significant difference between the median pre-op and post-op FVC(p = 0.028) and FEV1(p = 0.027).
Conclusion: This study demonstrated that early intervention using MGR in NMD patients with EOS was associated with a significant improvement in post-op FVC + FEV1 and deformity correction with the added benefits of reduction in repeat anesthesia, surgical and psychological distress and cost.

Pulmonary Function Data for the Study Patients Pre-op and at Latest Follow Up

Outcome	Pre-op (N = 6)	Post-op (N = 6)	P-value
FVC % Predicted	27 [15 to 45]	41 [28 to 60]	0.028
FEV1 %Predicted	27 [15 to 43]	45 [25 to 66]	0.027

Table 1 – Pre-op versus Post-op comparisons. Data is presented as median (IQR).

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

33. Pulmonary Outcomes of VEPTR Expansion Thoracoplasty in Early Onset Scoliosis: A Longitudinal Study

Ozgur Dede, MD; Etsuro K. Motoyama, MD; Vincent F. Deeney, MD; Charles I. Yang, MD; Rebecca Mutich, BSRT; Austin Bowles, MS

USA

Summary: This study reports the mid-term results of VEPTR application in children with thoracic insufficiency syndrome. After an average of 6 years of follow up with serial expansion surgeries, pulmonary volume increased albeit, not in pace with overall growth. Respiratory compliance decreased significantly, likely due to chest wall stiffness.
Introduction: VEPTR expansion thoracoplasty is a common method used to manage thoracic insufficiency syndrome (TIS). Literature is scarce on the effects of this technique on pulmonary function. The aim of this study is to report the mid-term results of VEPTR expansion thoracoplasty (ETP).
Methods: Between 2002 and 2008, 21 children with TIS underwent ETP with VEPTR application and had complete chart data, pre-operative and follow-up radiographs and PFTs acquired at index implantation, first expansion and last expansion. Pulmonary function tests (PFTs) with forced and passive deflation techniques developed for children under general anesthesia (Spine 31:284, 2006) were performed prior to index and each expansion surgery, under the same anesthesia. Pulmonary and radiographic parameters were analyzed longitudinally.
Results: Average follow up was 6 years and average age at implantation was 4.8 years. The mean N of expansion surgeries per patient was 11, mean interval was 6.4 months. There were no major complications.
The mean pre-treatment Cobb angle was 80 and mean local kyphosis angle was 57 degrees (7-107 degrees). The initial coronal correction of was maintained at the final follow up (67 degrees), however local kyphosis angle deteriorated insignificantly (66 degrees)(p>0.05). The average gain in T1-12 was 20.5 mm (3.1 mm/year) and in T1-S1 was 29 mm (4.6mm/year) during the treatment period.
The SAL ratio improved from 0.77 to 0.87 (p<0.0001) and FVC increased from a mean of 0.65L to 0.96L (p<0.0001). However, % predicted for height (and arm span) decreased from 86% (77%) to 64% (58%), respectively, as the children gained an average of 23 cm height. Respiratory system compliance (Crs/kg) decreased from 1.4 to 0.86 (by 38.6%)(p<0.0001). A comparison of the largest two groups (congenital versus syndromic) showed no differences in radiographic or pulmonary parameters.
Conclusion: VEPTR thoracoplasty resulted in modest correction of Cobb angle with no significant change in sagittal alignment. FVC increased with a moderate increase in radiographic SAL. However, these increases did not keep up with the child's overall growth. Respiratory compliance decreased over time.

34. 25 Years of Vertical Expandable Prosthetic Titanium Rib (VEPTR) Treatment for Spinal and Chest Wall Deformities: A Review of the Original Feasibility Cohort from Entry to Exit

Megan K. Roth, PhD; Hope Trevino, AA; Lori Buegeler, RN, BC; Victor F. German, MD, PhD; John M. Shepherd, MD; John J. Doski, MD; Robert Thomas, MD; James W. Simmons, DO, PhD; Robert M. Campbell, MD; Ajeya P. Joshi, MD

USA

Summary: The first 33 Vertical Expandable Prosthetic Titanium Rib (VEPTR) cases were retrospectively reviewed for treatment outcomes from entry to exit. Patients displayed increases in thoracic height and width and lumbar height. Space available for lung (SAL) increased and Assisted Ventilation Rate (AVR) remained stable. Forced vital capacity (FVC) and forced expiratory volume (FEV1) decreased over time. These results highlight the long-term outcomes in this original group of patients.

Introduction: The safety and efficacy of VEPTR was based on a feasibility study of 33 patients. We reviewed the course of treatment for these patients from entry into program to exit.

Methods: We retrospectively reviewed the first 33 cases treated with VEPTR. Charts were reviewed for AVR, FVC and FEV1 % normal, operative course, and complications. Radiographs were measured for Cobb angle, SAL, thoracic height and width, lumbar height, thoracic kyphosis and lumbar lordosis.

Results: Complete records were available for 23 patients. Mean age at implant was 3.5 yrs old with 9.8 yrs in program. Exit was due to death in 5 cases. Mean number of surgeries was 17.2 with 1.5 implants and 10.1 expansions. Cobb angle tended to decrease from entry to exit (55 to 47 degrees; p=0.08). Thoracic height increased from 111.7 to 168.5mm (p<0.001) while lumbar height increased from 77.8 to 120.8mm (p<0.001). Thoracic width increased on both the convex (p<0.001) and concave (p<0.001) sides. Thoracic kyphosis increased from 17 to 42 degrees (p<0.01) and lumbar lordosis tended to increase (20 to 31 degrees; p>0.05). SAL improved from 0.77 to 0.89 (p<0.01). AVR tended to remain stable in most patients (n=15), while it improved in 2 and worsened in 2 (p>0.05). Despite this, FVC and FEV1 decreased from first to last record (p<0.05). The most common complications reported included tissue dehiscence (21), device migration (37), and device fracture (21).

Conclusion: VEPTR treatment of the first 33 patients resulted in several thoracic and respiratory improvements and a high rate of survival. Complications were typical and manageable.

Thoracic and Respiratory Measures in First 33 Patients Treated with VEPTR

	Pre-Implant	Post-Final Surgery
Cobb Angle	55.2°	47.2°
Thoracic Width Convex	64.4mm	82.9mm***
Thoracic Width Concave	84.2mm	117.4mm***
Thoracic Height	111.7mm	168.5mm***
Thoracic Kyphosis	17.1°	42.6°**
Lumbar Height	77.8mm	120.8mm***
Lumbar Lordosis	20.6°	31.4°
SAL	0.77	0.89**
FVC FEV1	47.8% 48.9%	39.7%* 38.5%*
AVR	0.4	0.8

*p<0.05 versus pre-implant; ** p<0.01 versus pre-implant; ***p<0.001 versus pre-implant

35. The Use of VEPTR for Treatment of Congenital Scoliosis Without Fused Ribs

Robert F. Murphy, MD; Alice A. Moisan, BSN; Derek M. Kelly, MD; William C. Warner, MD; Jeffrey R. Sawyer, MD

USA

Summary: VEPTR use in congenital scoliosis patients without fused ribs is an effective treatment, as evidenced by improved coronal Cobb angles and spine height with an acceptable complication rate.

Introduction: While VEPTR is effective in the treatment of early onset scoliosis (EOS) caused by congenital scoliosis (CS) with fused ribs, no studies to date have addressed the efficacy of VEPTR in the treatment of CS without fused ribs. Our hypothesis was that VEPTR is an effective treatment of EOS caused by CS without fused ribs in terms of growth, sagittal and coronal curve correction, with a complication rate similar or lower to that of EOS due to congenital scoliosis with fused ribs.

Methods: All patients from a large multi-center database with EOS due to CS without fused ribs who were treated with VEPTR were queried. Anteroposterior (AP) and lateral radiographs were used to measure the following parameters at three time points (pre-operative, immediate post-operative, and latest follow-up): coronal Cobb angle, sagittal kyphosis, lateral and AP spine heights, coronal and sagittal balance, and pelvic obliquity. Clinical data included age at implantation, time to follow-up, and complications. Student's t tests (paired, two-tailed) were used to compare values between the data sets.

Results: We studied 25 patients from 7 centers (13 female 12 male). Average age at implantation was 5+7 years. Average time to follow-up was 50 months. Several radiographic parameters improved significantly from preoperative radiographs to those taken at most recent follow-up: coronal Cobb angle (67° to 52°, p<0.0001), lateral spine height from T1-T12 (154 cm to

170 cm, p=0.041), and AP spine height from T1-T12 (135 cm to 157 cm, p=0.0001). However, kyphosis increased over the study period, (35° to 46°, p=0.036). Coronal balance, sagittal balance and pelvic obliquity did not demonstrate any significant changes. Seventeen patients had a complication (average 1.8, range 1-12 per patient). Eight complications were due to post-operative infection and 8 were due to device migration. Twenty complications required surgical treatment. The complication changed the treatment plan in 4 cases.
Conclusion: VEPTR use in CS patients without fused ribs is an effective treatment, as evidenced by improved radiographic parameters and an acceptable complication rate.

36. Proximal Junctional Kyphosis (PJK) Following Posterior Hemivertebrectomy with Short Fusion in Children Younger Than 10 Years of Age

Yiongsong Wang, MD; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Tetsuya Ohara; Yoshitaka Suzuki; Toshiki Saito; Ayato Nohara; Ryo Sugawara; Kyotaro Ota

Japan

Summary: This study was conducted to investigate whether proximal junctional kyphosis (PJK) develops following short fusion in children younger than 10 years of age with congenital scoliosis (CS). PJK occurred in 7 out of 37 patients. PJK was more common in patients with screw malposition at UIV, or with hemivertebra located on the lower thoracic or the thoracolumbar region.
Introduction: Although PJK may occur patients with early onset scoliosis (EOS) that have undergone spine fusion, few studies have been reported any relationship between PJK and spinal fusion in young children with CS. The purpose of this study were to investigate whether PJK or obvious proximal junctional angle (PJA) changes in the sagittal plane develops following short fusion in children younger than 10 years of age with CS, and to investigate the possible risk factors.
Methods: 37 children treated in a single institution between 1998 and 2010 were reviewed retrospectively. The inclusion criteria included 1) <10 years of age at the time of operation; 2) simple CS; 3) hemivertebra treated by posterior hemivertebrectomy with short fusion at a maximum of 5 motion segments; 4) min. F/U two years. The PJA from the caudal endplate of the upper instrumentation vertebral (UIV) to the cephalad endplate of the vertebra adjacent to the UIV, thoracic kyphosis (T5-T12), lumbar lordosis (T12-S1), global sagittal balance, and magnitude of scoliosis of the major curves and upper compensated curves were measured on lateral radiographs. PJK was defined by a PJA greater than 10 degrees during the F/U and at least 10 degrees greater than the prep. or early postop. measurement.
Results: PJK occurred in 7 out of 37 patients (18.9%), during an average of 4.5±3.2 years F/U (2-12 years). The UIV level of children with PJK was on T9 in 4 patients, and T11, T12, and L1 in one. Screw malposition at UIV was confirmed by postop. CT images in 6 patients. Only one patient with a screw deviation did not develop PJK during the F/U period. None of the patients with PJK was symptomatic, and no patients required revision surgery because of PJK. PJK occurred and progressed during the first two years after surgery followed by almost no progression or slight improvement in patients that could be followed up beyond two years postoperatively; in association with an increase of the lumbar lordosis.
Conclusion: PJK occurred in pediatric patients with simple congenital deformities following hemivertebrectomy and short fusion. PJK was more common in patients with screw malposition at UIV, or with hemivertebra located on the lower thoracic or the thoracolumbar region.

37. Correction and Complications in the Treatment of EOS: Is There a Difference Between Spine Versus Rib-Based Proximal Anchors?

Michael G. Vitale, MD, MPH; Howard Y. Park, BA; Hiroko Matsumoto, MA; Daren J. McCalla, BS; David P. Roye, MD; David L. Skaggs, MD, MMM; Behrooz A. Akbarnia, MD

USA

Summary: This study examines the advantages and disadvantages of various growing rod surgery techniques, namely the difference between spine and rib-based proximal anchor points. In terms of coronal angle correction and complication rate, these data suggest that spine-based proximal anchors are associated with greater correction; however, they exhibit a higher complication rate. A prospective multi-center study examining rib vs spine-based proximal anchors is underway.
Introduction: While the treatment options for early onset scoliosis (EOS) have greatly expanded, our knowledge of the comparative effectiveness of treatments has not kept pace. One subject of significant equipoise is the selection and placement of instrumentation anchor points. The purpose of this study is to examine the advantages and disadvantages of rib-based versus spine-based proximal anchors as part of posterior growing rods (GR) in the management EOS.
Methods: This is a retrospective review of data from two national EOS databases sourced from 45 centers. EOS patients with minimum 2 years follow up, age 2-10 years, and Cobb>50 who were implanted with GRs were included. Basic demographic information, radiographic measures, and complications were queried, which included any intraoperative complication, infection, implant failure, wound dehiscence, pneumonia, neurologic injury, neurogenic pain, device migration, and death.
Results: A total of 505 subjects, 260 rib-based proximal anchors (average 4.69 years follow up) and 245 spine-based proximal

anchors (average 5.24 years follow up), were analyzed. 19.0% were idiopathic, 33.3% congenital/structural, 21.2% syndromic, and 26.5% neuromuscular scoliosis. Spine-based GR achieved a 46.7% correction from pre-op to immediate post-implant Cobb as compared to 28.5% for rib-based. 1.4 complications per patient for spine-based anchors and 0.7 complications per patient for rib-based anchors were reported.
Conclusion: The current retrospective unmatched study suggests that patients with EOS who have spine-based proximal anchors experience greater correction in Cobb angle, but are at increased risk of complications as compared with rib-based proximal anchors. A prospective multi-center study comparing rib vs. spine-based proximal anchors is underway examining coronal/sagittal angles, growth, quality of life, and complications.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

38. Risk Factors for Proximal Junctional Kyphosis Associated with Growing Rod Surgery for Early Onset Scoliosis

Kota Watanabe; Morio Matsumoto, MD; Koki Uno, MD, PhD; Teppei Suzuki; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Haruhisa Yanagida, MD; Manabu Ito, MD, PhD; Toru Hirano; Ken Yamazaki, MD; Shohei Minami; Hiroshi Taneichi, MD; Shiro Imagama, MD; Katsushi Takeshita, MD; Takuya Yamamoto

Japan

Summary: Multicenter survey was conducted to determine the risk factors of PJK associated with GR for early onset scoliosis. The PJK occurred in 24% of the patients. The independent risk factors for PJK were greater thoracic kyphosis, greater proximal thoracic scoliosis, and more proximal level of LIV, and proximal anchor other than pedicle screw construct.
Introduction: Growing rod surgery (GR) has been widely used for the treatment of early-onset scoliosis (EOS). However, relatively high complication rate has been regarded as the downside of GR. Proximal junctional kyphosis(PJK) is one of the causes of implant-related postoperative complications. The purpose of this study was to determine the risk factors for PJK in the treatment of EOS using GR by multicenter survey.
Methods: 88 patients who underwent GR for EOS in 12 spine institutes were included in this study. The mean age at the time of surgery was 6.5±2.2 years (range, 1.5-9.8 years) and the mean follow-up period was 3.9±2.6 years (range, 2.0-12.0 years). The etiology of these patients were combined skeletal and visceral anomalies in 31 patients, mesenchymal disorders in 13, neurofibromatosis in 9, neuromuscular in9, congenital in 8, osteochondrodystrophy in 3, and iatrogenic in 1. Multiple logistic regression analysis was performed to determine the independent risk factors of PJK from clinical and radiographic parameters.
Results: 21(24%) PJK occurred in 88 patients. Implant-related complications occurred in 18 PJK patients (86% of PJK). Among clinical and radiographic parameters, the significant independent risk factors for PJK were preoperative thoracic kyphosis (Odds ratio; OR, 12.98), proximal thoracic scoliosis (OR, 4.53), and level of lower instrumented vertebra (LIV) (OR, 0.32), and pedicle screw construct for proximal anchor (OR, 0.45).
Conclusion: PJK occurred in 24% of the patients. The significant independent risk factor for PJK was greater thoracic kyphosis, greater proximal thoracic scoliosis, and more proximal level of LIV, and proximal anchor other than pedicle screw construct.

39. Traditional Growing Rods Versus Magnetically Controlled Growing Rods in Early Onset Scoliosis: A Case-Matched Two Year Study

Behrooz A. Akbarnia, MD; Kenneth M. Cheung, MBBS(UK), FRCS(England), FHKCOS, FHKAM(Orth); Gokhan H. Demirkiran; Hazem B. Elsebaie, FRCS, MD; John B. Emans, MD; Charles E. Johnston, MD; Gregory M. Mundis, MD; Hilali H. Noordeen, FRCS; Jeff Pawelek; M. Shaw, FRCS; David L. Skaggs, MD, MMM; Paul D. Sponseller, MD; George H. Thompson, MD; Muharrem Yazici, MD; Growing Spine Study Group

USA

Summary: In a carefully case-matched series of 12 patient pairs, magnetically controlled growing rods (MCGR) and traditional growing rods (TGR) had similar major curve correction after minimum 2-year follow-up. MCGR patients underwent fewer surgical procedures than TGR patients (17 vs. 69, respectively). There was slightly greater (3.5 mm/year) annual T1-S1 growth in TGR patients compared to MCGR patients.
Introduction: Traditional growing rod (TGR) surgery is a treatment technique used in skeletally immature patients with progressive spinal deformities. Recent studies have shown repeated TGR lengthenings can significantly increase the risk of complications. Magnetically controlled growing rods (MCGR) are available outside the U.S. and early results have been promising. The purpose of this study was to compare the effectiveness of MCGR to TGR for the treatment of early onset scoliosis.
Methods: MCGR patients were selected based on the following criteria: <10 years old, major curve >30 degrees, T1-T12 <22 cm, no previous spine surgery and >2-year follow-up (>2 YR). 17 MCGR patients met the inclusion criteria and 12 of 17 had complete data available for analysis. Each MCGR patient was matched to a TGR patient by etiology, gender, single vs. dual rods, pre-op age (+/-10 months) and pre-op major curve (+/- 20 degrees). Etiologies were classified by idiopathic (I), congenital (C), neuromuscular (N) and syndromic (S). One male MCGR patient was matched to a female TGR patient since a male-male match could not be performed. Annual T1-S1 growth was defined as the increase in T1-S1 from post-index surgery to >2

YR divided by the length of follow-up.
Results: MCGR patients had a mean age of 6.8 years and mean follow-up of 2.5 years. Mean follow-up was greater for TGR patients by 1.6 years. Distribution of etiologies included four N, four S, three I and one C patient. Major curve correction was similar between MCGR and TGR patients throughout treatment (Table 1). Mean T1-S1 increase from index surgery was greater in TGR compared to MCGR patients. Annual T1-S1 growth was 7.1 mm/year for MCGR and 10.6 mm/year for TGR patients. TGR patients had a total of 69 surgeries, 49 of which were lengthenings. MCGR patients had a total of 17 surgeries and 137 non-invasive lengthenings. There were 8 revisions in TGR (67%) and 5 revisions in MCGR patients (42%) due to complications.
Conclusion: In this small yet carefully matched series, major curve correction was similar between MCGR and TGR patients throughout treatment. MCGR patients had 52 fewer surgical procedures than TGR patients. Annual T1-S1 growth was slightly greater in TGR patients compared to MCGR patients.

		Pre-op (mean)	Initial Post-op (mean)	$\geq$2 YR Post-op (mean)	Pre to Post Δ (mean)	Post to >2 YR Δ (mean)	Pre to >2 YR Δ (mean)
Major Curve	MCGR	59°	32°	38°	43%	-25%	35%
	TGR	60°	31°	41°	47%	-27%	32%
T1-S1 Spinal Length	MCGR	270 mm	295 mm	307 mm	18 mm	15 mm	38 mm
	TGR	264 mm	311 mm	347 mm	41 mm	36 mm	77 mm

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

40. Implant Revisions with Shilla Patients at Five Year Follow-Up: Lessons Learned

Richard E. McCarthy; Frances L. McCullough, MNSc

USA

Summary: The 1st 40 pts. treated with the Shilla Growth Guidance method were analyzed for implant problems necessitating surgical revision. Rod fractures occurred in 15 pts. at the junction of the 4.5/3.5 transition, adjacent to the crosslink, or adjacent to the apical fusion. Screw loosening or pullout was noted in 13 pts. Now 4.5 rods are used exclusively and growing screws are placed more deeply into the vertebral body. This has resulted in fewer implant problems in more recent pts.
Introduction: The 1st 40 original pts. treated for early onset scoliosis (EOS) with the Shilla growth guidance method were carefully analyzed for implant related problems that necessitated surgical revision.
Methods: Medical records were reviewed for returns to the operating room related to implant problems.
Results: Of the original 40 pts, 27 (67%) had revisions for implant issues. The avg. age at index was 6+8 years with 72 degrees of curve. 15 pts. had a 4.5 mm rod that transitioned to a 3.5 rod for greater flexibility. Other rods were 4.5 (81%) or 5.5 (11%). 15 had rod fractures with 3 pts. having 2 instances of fx, 7 of these in 3.5 rods (others 4.5). Rods fractured at the junction of the 4.5 / 3.5 transition (8), adjacent to the crosslink (2) or adjacent to the apical fusion (8). These rod issues were noted at 62 mo. post op for 4.5 rods and 14 mo. for 3.5 rods (majority < 14 mo). Screw problems occurred with loosening and/or pull out in 13 pts; upper screws 9 times and in lower screws 8 times. They presented at varied times but most commonly in the more active pts. who challenged the implants.
Conclusion: As a result of this analysis, 4.5 rods are used exclusively. Growing screws are placed more deeply into the vertebral body to insure maximum resistance to pull out. Greater thoracic kyphosis is contoured into upper rods and mild lordosis into the lower section of the rods. As a result, fewer implant problems are being seen in more recently studied patients.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

41. Early Onset Scoliosis Treated with Growing Rods Has a Greater Increase in T1-S1 Length, Better Cobb Correction and More Than Twice the Number of Surgeries Compared to Shilla

Lindsay Andras, MD; Elizabeth Joiner, BS; Richard E. McCarthy, MD; Scott J. Luhmann, MD; Paul D. Sponseller, MD; John B. Emans, MD; David L. Skaggs, MD, MMM; Growing Spine Study Group

USA

Summary: When comparing the treatment of early onset scoliosis with Shilla vs. dual growing rods, Shilla treatment is associated with fewer surgeries and growing rods are associated with better Cobb angle correction and increased T1-S1 length.
Introduction: The purpose of this study is to compare treatment of early onset scoliosis with Shilla versus dual growing rods.
Methods: A multi-center case-matched comparison of patients with early onset scoliosis treated with Shilla vs. dual spine-spine growing rods (GR) from 1995-2009 was performed. Radiographic outcomes and complications were recorded. 37 Shilla patients from 3 centers were matched with 37 GR patients from the Growing Spine Study Group database by age at index surgery (±1 year), preoperative Cobb angle (±15°), and diagnosis (neuromuscular, congenital, idiopathic, syndromic). Average follow up did not differ significantly between groups (GR=4.1 yrs, Shilla=4.6 yrs; p=0.148).
Results: Comparing pre-operative to latest follow-up (mean > 4yrs) improvement in average Cobb angle was 35° (72° to 37°) in the GR group versus 24° (69° to 45°) in the Shilla group (p=0.019). T1-S1 length increased 8.5cm in patients treated with GR compared to 6.4cm in Shilla patients (p=0.031). The Shilla patients had significantly fewer surgeries (2.8) than the

GR group (7.0) (p<0.001) but had a higher rate of unplanned surgeries for implant complications (Shilla = 1.4, GR = 0.6; p = 0.016). When revisions for implant complications done at the time of scheduled lengthenings were included, the two groups did not differ significantly in number of procedures for implant complications (Shilla=1.4, GR=1.0, p = 0.2395). The overall complication rate did not differ significantly between groups (Shilla = 1.8 (range, 0-8), GR = 1.6 (range, 0-9); p = 0.7145).
Conclusion: The GR group had a significantly greater improvement in Cobb angle and a greater increase in T1-S1 length than Shilla. GR patients had more surgeries, but Shilla patients had more unplanned procedures. The rate of complications overall did not differ significantly between the two groups.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

42. Risk Factors for Unsatisfactory Correction of Spinal Deformity Associated with Growing Rod Surgery for Early Onset Scoliosis

Kota Watanabe; Morio Matsumoto, MD; Koki Uno, MD, PhD; Teppei Suzuki; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Haruhisa Yanagida, MD; Manabu Ito, MD, PhD; Toru Hirano; Ken Yamazaki, MD; Shohei Minami; Hiroshi Taneichi, MD; Shiro Imagama, MD; Katsushi Takeshita, MD; Takuya Yamamoto

Japan

Summary: Multicenter survey was conducted to determine the risk factors of unsatisfactory correction associated with GR for early onset scoliosis. 28% of the patients showed unsatisfactory scoliosis correction and 30% of the patients showed unsatisfactory kyphosis correction. The significant independent risk factors for unsatisfactory deformity correction by GR were preoperative scoliosis of more than 90° and kyphosis of 50°.
Introduction: Growing rod surgery (GR) has been widely used for the treatment of early-onset scoliosis (EOS). However, we have often experienced unsatisfactory correction of the curves after GR. Unsatisfactory correction by GR may be associated with poor clinical and radiographic outcomes at the final follow up. The purpose of this study was to determine the risk factors for unsatisfactory correction of spinal deformity in the treatment of EOS using GR by multicenter survey.
Methods: 88 patients who underwent GR for EOS in 12 spine institutes were included in this study. The mean age at the time of surgery was 6.5±2.2 years (range, 1.5-9.8 years) and the mean follow-up period was 3.9±2.6 years (range, 2.0-12.0 years). The etiologies of these patients were syndromic in 56 patients, idiopathic in 14, neuromuscular in 9, congenital in 8. Unsatisfactory correction by GR was defined as the Cobb angle more than 60° in scoliosis and 40° in thoracic kyphosis at final follow up. Multiple logistic regression analysis was performed to determine the independent risk factors of unsatisfactory correction of both in scoliosis and kyphosis respectively from the clinical and preoperative radiographic parameters.
Results: 24 patients (28%) and 25 patients (30%) resulted in unsatisfactory scoliosis and kyphosis correction, respectively. Among candidate risk factors, significant independent risk factors for unsatisfactory correction in scoliosis were preoperative Cobb angle of more than 90°(Odds ratio; OR, 5.19) and level of upper instrumented vertebra(OR, 1.97). In terms of kyphosis, those factors were preoperative Cobb angle in the coronal plain of more than 90°(OR, 7.72), thoracic kyphosis more than 50°(OR, 5.32), occurrence of complications (OR, 6.00), and level of lower instrumented vertebra (OR, 0.42).
Conclusion: The significant independent risk factors for unsatisfactory deformity correction by GR were preoperative scoliosis of more than 90° and kyphosis of 50°. Thus, the first GR surgery should be performed before the deformity deteriorating to these magnitudes to avoid unsatisfactory corrections.

43. Adult Deformity Surgery (ASD) Patients Recall Fewer than 50 Percent of the Risks Discussed in the Informed Consent Process Preoperatively and the Recall Rate Worsens Significantly in the Postoperative Period

Rajiv Saigal, MD, PhD; Aaron J. Clark, MD, PhD; Justin K. Scheer, BS; Justin S. Smith, MD, PhD; Shay Bess, MD; Praveen V. Mummaneni, MD; Ian McCarthy, PhD; Robert A. Hart, MD; Khaled Kebaish, MD; Eric Klineberg, MD; Vedat Deviren, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

USA

Summary: Complication rates in ASD are high and it's important that patients recall preop discussion of key complications to mitigate medical legal risk. Patients who experience complications may claim they were never informed simply because they cannot recall. Patients undergoing ASD surgery were assessed for recall and severity ranking after informed consent process. Despite ranking the process as important, patient recall remains very poor and declines over time. The perception of the severity of complications significantly differs between patient and surgeon.
Introduction: Complication rates in ASD are high. Although informed consent is standard, there's a paucity of data to assess retention. Patients who experience complications may claim they were never informed of the risks simply because they cannot recall them. The goal of this study was to objectively quantitate retention of key portions of the consent process.
Methods: Patients having ASD surgery underwent standard surgeon guided informed consent followed by watching a 20min video detailing 11 complications. At preop, hospital discharge,

6wks, 3 and 6mos post-op, pts took a quiz assessing recall of the 11 complications, rated both the commonality and severity of each complication: 0(minor)-10(very severe), and were scored on a 16 point mini-mental status exam (MMSE-BV).
Results: 30 pts (median age 60.5yrs[26-83)]). Immediate preop recall after video viewing was 41%. Postop recall (vs preop) was worse on discharge (23%, p<0.001), 6wks(21%, p<0.001) and 6mos (20%, p=0.004). Preop MMSE-BV was 15, discharge (14), postop visit (15), and 6mos (15).
Patients rated the process important (10, scale 0-10) and the video helpful (9). Patient severity scores were lower than surgeons for need for additional surgery, medical complications, new weakness, blindness, and death (all p<0.05). Patient severity scores were higher than surgeons for transfusion and CSF leak (all p<0.05). There was no association at any postop timepoint between recall and the following: subjective severity score, prior spinal surgery, ICU stay, total hospital stay, ASA class, MMSE-2 and postoperative complications (p>0.5).
Conclusion: Patients feel the informed consent process is important but their recall of key risks remains poor and declines over time despite even video augmentation. Significant progress remains to improve informed consent retention. Despite being well informed in an augmented informed consent process, patients cannot recall most surgical risks discussed.

44. How Patients Decide: Randomization Versus Surgery Versus Non-Surgical Treatment for Symptomatic Adult Lumbar Scoliosis

Brian J. Neuman, MD; Keith H. Bridwell, MD; Christine Baldus, RN, MHS; Lukas P. Zebala, MD; Christopher I. Shaffrey, MD; Charles C. Edwards, MD; Tyler Koski, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Steven D. Glassman, MD; Stefan Parent, MD, PhD; Stephen J. Lewis, MD; Lawrence G. Lenke, MD; Jacob M. Buchowski, MD, MS; Charles H. Crawford, MD

USA

Summary: An NIH grant was obtained to evaluate, through a prospective, randomized controlled & observational trial, the effectiveness of operative & non-operative interventions for adult symptomatic lumbar scoliosis. Baseline data was analyzed to identify variables influencing patients to participate in the study. Patients choosing surgery were of higher economic status and had a greater proportion of participants with education beyond high school. Patients with worse HRQOL scores, greater back pain with ambulation, and greater lumbar curvature chose surgery or randomization.
Introduction: Multiple factors play a key role in a patient's decision to be randomized or to choose an observational operative or nonoperative course for lumbar scoliosis. The purpose of this study is to determine which variables correlate with a patient's treatment choice.
Methods: Eligible candidates (40 to 80 years of age, lumbar Cobb≥ 30° & ODI score≥ 20 or SRS scores ≤ 4) from 9 centers were offered participation in a randomized or observational cohort. Treatment consisted of standard non-operative care versus surgery, consisting of correction, decompression and instrumented fusion. Baseline variables (demographics, socioeconomic, HRQOL questionnaires [ODI, SRS], x-rays & functional treadmill test) were collected prior to treatment.
Results: 273 patients were enrolled: 43 randomized (RAND), 113 chose nonsurgical care (OBS-NS) and 117 opted for surgery (OBS-S). The OBS-S had a proportionally higher level of education (p=0.021) & greater income (p=0.048). The RAND and the OBS-S had worse SRS (3.1, 3.1 vs 3.3 p<0.04) and ODI scores (37.6, 36.8 vs 32 p<0.045) than the OBS-NS. There were no significant differences in QOL or radiographic findings between the RAND and OBS-S groups. OBS-S had worse back pain NRS scores compared to OBS-NS (6.3 vs 5.5 p=0.009) while the RAND group had worse leg pain NRS scores than the OBS-NS (4.5 vs 3.1 p=0.013). The RAND and the OBS-S had greater lumbar curves than the OBS-NS (55.1, 55.7 vs 49.5 p< 0.037). The OBS-S group reported an increase in back pain after a functional treadmill test but not leg pain compared to the OBS-NS group: [Change in Back NRS 1.84 vs 0.86 (p<0.007) and Change in Leg NRS 1.68 vs 1.06 (p=0.138)]. There was no correlation with sagittal balance parameters. When asked why they did not want to be randomized, 17% reported now was the best time for surgery, 22% felt they had exhausted non-operative treatment, 41.5% were not interested in surgery, 16% preferred to select their treatment and 3.5% other reasons.
Conclusion: Patients with worse HRQOL scores, greater back pain especially with ambulation and greater lumbar curves are more inclined to be randomized or undergo surgery. Also, higher economic status and higher education level correlates with a patient's decision to undergo surgery.

45. Pulmonary Function Following Adult Spinal Deformity Surgery: Minimum Two-Year Follow-Up

Ronald A. Lehman, MD; Daniel G. Kang, MD; Lawrence G. Lenke, MD; Jeremy J. Stallbaumer, MD; Brenda A. Sides, MA

USA

Summary: We performed the largest study to date evaluating pulmonary function tests (PFTs) following surgery in 164 adult spinal deformity patients with minimum 2-year follow-up. Our results demonstrate significant decline in all measures of pulmonary function following deformity surgery, with a clinically significant decline (≥10%predFEV1) in pulmonary function in 27% of patients. However, we found patients with pre-op pulmonary impairment (<65%pred FEV1) may actually benefit from deformity correction surgery. Revision surgery more frequently (35% v 23%) results in a clinically significant decline in PFTs.
Introduction: Pulmonary function following adult spinal deformity remains uncertain. We hypothesized patients

with pre-op PFT impairment (<65%pred FEV1) and those undergoing revision surgery may be at risk for exacerbated decline in pulmonary function.

Methods: PFTs were prospectively collected on 164 adult spinal deformity patients (150F, 14M, avg age 45.9) undergoing surgical treatment at a single institution, with minimum two year follow-up (avg 2.81). There were 100 (61%) primary and 64 (39%) revision surgery patients, and the majority had posterior only surgery (77%). Radiographs for 154 patients were analyzed for main thoracic (MT) and sagittal T5-T12 (Sag) curve magnitude/correction.

Results: For all patients, there was a significant change in MT Cobb from 47.4 to 24.9 deg (avg -22.5, p=0.00), and Sag Cobb from 35.5 to 30.0 deg (avg -5.41, p=0.00). We also found a significant decline in absolute and %pred PFT, with %pred FEV1 and %pred FVC decreasing 5.26% (p=0.00) and 5.74% (p=0.00), respectively. A clinically significant decline (≥10%pred FEV1) was observed in 27% of patients. PFT impairment increased from 14 (8%) patients pre-op to 23 (14%) patients after surgery, but was not statistically significant (p=0.31). Interestingly, patients with pre-op PFT impairment had a significant improvement in absolute and %pred FEV1 after surgery compared to those without pre-op impairment (2.8% v -6.19%, p=0.03), with no significant differences in MT/Sag curve correction between the two groups. Revision surgery patients had no difference in post-op %pred PFTs; however there were significantly more patients with a clinically significant decline in PFTs [23 (35%) v 22 (22%), p=0.03].

Conclusion: We performed the largest study to date evaluating pulmonary function tests (PFTs) on 164 adult deformity patients finding a significant decline in all measures of pulmonary function at two years following surgical correction. Surprisingly, there was a significant postop improvement in patients who had preoperative PFT impairment.Also, revision surgery more frequently results in a clinically significant decline in PFTs.

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46. Variance in Complication Rate Reporting Among High Volume Spinal Deformity Centers: Analysis of a Multi-Center Prospective Database

Eric Klineberg, MD; Jacob M. Buchowski, MD, MS; Kai-Ming Fu, MD, PhD; Justin S. Smith, MD, PhD; Oheneba Boachie-Adjei, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Shay Bess, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Richard Hostin, MD; Gregory M. Mundis, MD; Munish C. Gupta, MD; International Spine Study Group

USA

Summary: Surgical complications can adversely affect patient satisfaction and add to the overall cost of health care delivery. Minor and major complications are reported based on established criteria, however due to their relative importance, may be reported differently. We found that reporting of minor spine surgery complications is highly variable among institutions. In contrast, after controlling for excessive EBL, major complications were reported consistently. Reporting differences may account for significant variability in minor complications, but seem to effect major complications less.

Introduction: Post-surgical complications are typically divided into major and minor. Minor complications are less likely to affect clinical outcome, thus may be minimized. Conversely, major complications can have a significant impact on patient outcome. The current study focuses on reporting rates of complications in adult spine deformity (ASD) surgery across 6 institutions.

Methods: Multicenter prospective ASD database analyzed for surgical complications. Basic demographic, radiographic, and operative indices were obtained. Inclusion criteria: ASD, >18 yrs, >4 levels fused, and min 3 mo f/u. Each site contributed ≥20 pts. Complications were defined as minor or major per previously published criteria. Multivariate statistical analysis was utilized.

Results: 221 patients from 6 institutions (range 20-59 pts/site) met inclusion criteria. Baseline demographics include a mean age of 58 yrs (range/site 47-63 yrs), mean ASA grade 2 (range/site 1.6-2.66), mean sagittal vertical axis 62mm (range/site 24-91mm), and mean max Cobb angle 41° (range/site 28-55°). Surgical differences include: mean levels fused (12, range/site 10-13 levels), mean surgical time (419min, range/site 358-536min), and mean EBL (1.9L, range/site 1.1-3.4L). Minor complications per site varied significantly from 10%-71%. Minor complications are reported most often at sites with younger patients with primary coronal deformities compared to the other sites (71%, P<0.03). Similar major complications rates are reported across all sites (22%-58%), with the exception of EBL, which is significantly higher at one site (p<0.016). When controlling for EBL, all sites have statistically similar major complication (19-31%). Significant EBL (>4L), nerve root injury, deep infection, rod breakage, junctional kyphosis, and pseudoarthrosis are the most common major complications. Aside from EBL, all major complications were evenly distributed.

Conclusion: Reporting of minor spine surgery complications is highly variable. Major complications are more consistently reported. In the current study, the mean major complication rate for adult spinal deformity surgery is 24%. The level of surgeon concern, stringency of data collection, and the clinical impact of a given event may contribute to this inconsistency.

47. Comparing Prospective to Retrospective Acute Neurologic Complication Rates in Complex Adult Spinal Deformity Procedures: Is There a Difference?

Michael P. Kelly, MD; Lawrence G. Lenke, MD; Adam L. Shimer, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Stephen J. Lewis, MD; Christopher P. Ames, MD; Leah Y. Carreon, MD, MSc; Steven D. Glassman, MD; Michael G. Fehlings, MD, PhD; Frank J. Schwab, MD; Virginie Lafage, PhD

USA

Summary: We compared a very similar group of complex adult spinal deformity patients evaluated by the prospective Scoli-Risk 1 trial (SRS/AOSpine sponsored, 15 sites) to a retrospective group of patients (5 sites) and found a statistically higher rate acute of lower extremity motor neurologic complications in the prospective (17.8%) vs retrospective (8.7%) groups (p=0.008). This emphasizes the importance of documenting neurologic complications via a prospective protocol for optimal accuracy.

Introduction: Debate continues as to the accuracy of retrospectively vs prospectively accumulated data regarding the rate of complications. We utilized the multicenter Scoli-Risk 1 trial (sponsored by the SRS and AOSpine) prospectively accrued data on 256 pts and compared these pts to a retrospectively accrued multicenter group of 207 pts with near-identical diagnoses/procedures to ascertain if there was a difference in the reported acute lower extremity (LE) motor neurologic complication rate.

Methods: 256 pts (15 centers) in the Scoli-Risk 1 trial were prospectively analyzed (Pro Group) and compared to 207 pts (4 centers) retrospectively analyzed (Retro Group) with the same enrollment criteria of complex adult spinal deformity (ASD) which included: 1. Primary deformity with > 80-deg Cobb angle; 2. Revision deformity having any type of osteotomy; 3. Any type of 3-column osteotomy (3-CO). The Pro Group had 202/256 (78.9 %) 3-COs vs 132/207 (63.8%) in the Retro group. The ave ages of the Pro Group vs Retro Group (57.1 vs 55.7) and Female:Male ratios (171 (66.7%):84 vs 135 (65.2%):68) were quite similar. The Pro Group had complete ASIA neurologic exams performed prospectively preop and at 6 weeks postop, while the Retro Group had retrospective chart reviews to document neurologic complications following surgery.

Results: 194/256 (75.8%) of the Pro Group had a NL LE motor exam preop vs 135/207(65.2%) which was statistically different (p=0.013). Overall, 44/256 (17.2%) of pts in the Pro Group had acute motor neurologic deterioration following surgery vs 18/207 (8.7%) in the Retro Group, with the difference in these neurologic complication rates statistically significant (p=0.008). Of those with a postop motor deficit, 38/44 (86.4%) in the Pro Group vs 16/18 (88.9%) in the Retro Group (p=0.788) had a 3-CO performed during surgery.

Conclusion: There was a statistically higher acute lower extremity neurologic complication rate in pts assessed prospectively (17.2%) vs those assessed retrospectively (8.7%) in complex ASD pts with similar diagnoses and procedures. This highlights the importance of using prospectively reported data when quantifying neurologic complication rates in deformity surgery.

48. Administrative Databases Overestimate Hospital Readmission Rate Following Spinal Deformity Correction Surgery

Beejal Y. Amin, MD; Paul D. Ackerman, MD; Sigurd H. Berven, MD; Shane Burch, MD; Vedat Deviren, MD; Serena S. Hu, MD; Bobby Tay, MD; Christopher P. Ames, MD; Dean Chou, MD; Praveen V. Mummaneni, MD

USA

Summary: We evaluated the clinical accuracy of the UHC database to identify relevant causes of readmission for deformity surgery. We found that the algorithm was identifying 25% of cases inappropriately as readmissions rather than as staged surgeries. Payor proposals to withhold reimbursement for readmissions may rely on these inaccurate database reports.

Introduction: Hospital readmission rate is one quality metric by which payors (CMS) evaluate institutional efficiency and physician performance. The purpose of the present study is to verify the clinical relevance of the UHC readmission rate in patients undergoing spinal deformity surgery at our institution.

Methods: Data for 5,783 consecutive patient encounters managed by 9 spine surgeons at UCSF from 2007 to 2011 were abstracted from the University HealthSystem Consortium (UHC) using the Clinical Data Base/Resource Manager. 695 patients were treated for spinal deformity as defined by ICD-9 code. A manual chart review was done to drill down reasons for readmission in this cohort.

Results: Of the 695 patients, 95 patients (13.7%) were rehospitalized within 30 days of the discharge date. Thirteen patients were readmitted twice within 30 days, and 3 patients were readmitted three times within 30 days - for a total of 111 patient encounters. According to the UHC algorithm, the top three reasons for readmission following deformity surgery were surgical site infection (SSI) (7.9%), planned readmission for staged procedures (4.5%) (which is not clinically relevant), and post-operative hematoma (1.2%). Failed instrumentation also accounted for 1.0% of readmissions. The UHC algorithm overestimated clinically relevant readmissions by 25% because planned staged surgery was counted as a readmission.

Conclusion: Benchmarking algorithms for defining hospital readmission rates must take into account planned, staged surgery in order to be more clinically relevant. Current methods for measuring readmissions using the all-cause algorithm overestimated the clinically relevant readmission rate by more than 25% at our hospital. Proposals to deny reimbursements for readmissions must take into account that administrative databases may not correctly identify clinically relevant readmissions.

49. Upper Thoracic Versus Lower Thoracic Upper Instrumented Vertebrae Endpoints Have Similar Outcomes and Complications in Adult Scoliosis at Two-Year Follow-Up

Han Jo Kim, MD; Oheneba Boachie-Adjei, MD; Justin K. Scheer, BS; Richard Hostin, MD; Khaled Kebaish, MD; Justin S. Smith, MD, PhD; Gregory M. Mundis, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Robert A. Hart, MD; Shay Bess, MD; Vedat Deviren, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

USA

Summary: Despite UT terminations having larger coronal and sagittal plane deformities, longer operative times and LOS, UT and LT UIVs have similar complication rates and similar radiographic and clinical outcomes at two year follow up.

Introduction: The optimal upper instrumented vertebrae (UIV) for stopping long fusions to the sacrum/pelvis are controversial. While an upper thoracic (UT) endpoint might portend itself to greater operative times, blood loss and higher rates of pseudarthrosis, the risk for the development of proximal junctional kyphosis (PJK) may be less as well as the risk for revision surgery. The purpose of this study was to compare the UT and lower thoracic (LT) UIV in long fusions to the sacrum for Adult Scoliosis.

Methods: Patients from a prospective database were selected based on fusions to the sacrum/pelvis with UIV of T1-6 (UT Group) and those with a UIV of T9-L1 (LT group). Demographic data, operative details and radiographic outcomes were compared. Scoliosis Research Society Scores (SRS) and Oswestry Disability Index (ODI) were collected as well as complication data.

Results: 198 patients (UT=91, LT=107) with mean age of 61.6 were followed for an average of 2.5 yrs. Demographic variables were similar between groups except for higher numbers of females in the UT group (86% vs 65%) and a slightly higher BMI in the LT group (28.7 vs. 26.9). Pre-operatively, the UT group demonstrated significant more lumbar scoliosis (53.6 vs. 33.2, p<0.01), thoracic scoliosis (41.6 vs 31.7, p=0.01) and thoracolumbar kyphosis (17.9 vs. 8.9, p=<0.01). The UT group demonstrated a greater length of stay (LOS) (9.1 vs 7.4, p<0.01) and longer operative times (430 min vs 371 min, p<0.01). EBL was similar (1947cc vs 1887 cc, p=0.08). Rates of complications were similar between groups (57% vs 39%, p=0.20), as were those which required revision surgery (15% vs 22%, p=0.19). The UT group had a higher percentage of patients with ≥2 complications (55% vs 43%, p =0.38) but not statistically significant. Although the LT group had a higher PJK angle (19.2 vs 16.5, p=0.37), the UT group had a higher number of cases requiring revision for PJK (3 vs 2, p=0.45). SRS and ODI Outcomes were similar between groups.

Conclusion: Despite UT terminations having larger coronal and sagittal plane deformities, longer operative times and LOS, UT and LT UIVs have similar complication rates and similar radiographic and clinical outcomes at two year follow up.

50. Risk of Spinal Implants and the Development of Proximal Junctional Kyphosis for Adult Kyphoscoliosis

Jamal McClendon, MD; Timothy R. Smith, MD, PhD, MPH; Patrick A. Sugrue, MD; Sara E. Thompson, BA; Brian A. O'Shaughnessy, MD; Tyler Koski, MD

USA

Summary: Proximal junctional kyphosis (PJK) may result from an increased postoperative junctional stress concentration. The cumulative incidence of PJK is dependent on the patient's curve type and the rod utilized for correction and stabilization.

Introduction: PJK is a recognized postoperative entity with incidence as high as 39%. The etiology remains largely unknown, however some have speculated it being multi-factorial. Our study is the first to look at spinal implants and posterior construct density in the development of PJK.

Methods: Consecutive adult patients who received elective spinal fusion >5 in the thoracic, thoracolumbar, or lumbar spine were retrospectively analyzed between 2007 and 2010. Demographics, preoperative, operative, and postoperative factors influencing development of PJK were analyzed with minimum 2 year follow-up. Patients < 18 years of age, patients with neuromuscular or congenital scoliosis, fusions in the cervical or cervicothoracic spine, and non-elective conditions (infection, tumor, trauma) were excluded. One-way ANOVA and logistic regression was performed.

Results: 75 patients (15M:60F) with mean age of 59.4 years (SD=10) having 117 surgeries were analyzed. Mean BMI=29.2kg/m2 (range 18-56 kg/m2) with mean preoperative ODI 49.72 (range 6-86). There were 78 prior fusions with 30 prior pseudoarthrosis. Mean preoperative SVA=7.2, and mean levels fused=8. There were 3 VCRs and 17 PSOs performed. 66 surgeries had some form of interbody fusion. Cumulative incidence for PJK was 25.6%, and for pseudoarthrosis was 17.9%. Incidences of PJK were significant for SRS Curve Classification Types: (18/62=29%) for TL/L, (1/9=11%) for TL/L/MT, and (11/29=38%) for K, p<0.5. Age, gender, and BMI was not significant. Implant density (#screws + #hooks)/surgical levels was not significant for development of PJK. However, 12/34 (35%) surgeries with stainless steel rods vs 11/59 (19%) surgeries with cobalt-chrome rods developed PJK. Multivariate logistic regression showed SRS Curve Type and rod type to be significant for development of PJK, p<0.05. Miminum 2-year follow-up was achieved in 116 of 117 surgeries. Mean and median follow-up was 2.8 years. Postoperative SVA=2.4 and postoperative ODI was 27.4 (range 0-74).

Conclusion: Development of PJK appears to be statistically related to curve type and rod selection; however implant density did not achieve statistical significance.

51. Proximal Junctional Kyphosis and Clinical Outcomes in Two Different Proximal Upper Instrumented Vertebral Levels (Proximal Thoracic Versus Distal Thoracic) After Adult Spinal Instrumented Fusion to Sacrum

Yoon Ha, MD, PhD; Keishi Maruo, MD; Linda Racine; William Schairer; Serena S. Hu, MD; Vedat Deviren, MD; Shane Burch, MD; Bobby Tay, MD; Dean Chou, MD; Praveen V. Mummaneni, MD; Christopher P. Ames, MD; Sigurd H. Berven, MD

Republic of Korea

Summary: This study compared the clinical outcome and different characteristics of proximal junctional kyphosis (PJK) in two different upper instrumented vertebra (UIV) (proximal thoracic PT vs. distal thoracic DT) after surgical correction of adult spinal deformity. Although, prevalence of PJK was not statistically significantly different in both PT UIV and DT UIV, compression fracture is more associated with DT PJK and subluxation is frequently found in PT PJK. PJK requires surgical treatment developed earlier than radiographic PJK.

Introduction: To compare the postoperative proximal junctional change and prevalence of revision surgery between UIV level either to the PT or DT spine in patients who received a spine fusion to the sacrum for the treatment of adult spinal deformity.

Methods: This retrospective study evaluated clinical and radiographic data from 89 (22 PT, 67 DT) consecutive adult deformity patients (minimum two years follow up) treated with long instrumented posterior spinal fusion to the sacrum. We divided patients into two groups, PT group (UIV between T2 and T5) and the DT group (UIV between T9 and L1). Perioperative surgical data was compared between groups. Global and segmental spinopelvic parameters were analyzed with preoperative, early postoperative, and final standing radiographs. Patient reported outcome measurements (VAS, SRS-22, ODI and SF36) were compared.

Results: The prevalence of PJK (radiological and surgical) was 34% in DT and 27% in PT (p=0.609). Patients who had PJK that required surgical correction was 11.9% (8 of 67) in DT and 9.1% (2 of 22) in PT (p=1.0). Operative time (p=0.387) and estimated blood loss (p<0.05) were slightly higher in PT. The rate of revision surgery was 48.0% (DT) and 54.5% (PT) (p=0.629). In DT, onset of surgical PJK was significantly earlier than radiological PJK (p<0.01). Types of PJK were different in both PT and DT. Compression fracture was more common in DT, while subluxation was more common in PT. Postoperatively, the PT group had less thoracic kyphosis (p=0.02), sagittal imbalance (p<0.01) and less pelvic tilt (p=0.04). Clinical outcomes (VAS, SF36, ODI, SRS22) were significantly improved in both PT and DT.

Conclusion: Prevalence of PJK was not statistically significantly different in both PT and DT. However, compression fracture is more associated with DT and subluxation is frequently found in PT. Therefore, in patients being considered for a long spine fusion to DT UIV who may be at higher risk for compression fracture of UIV, a UIV level in the proximal thoracic spine should be considered.

52. Age at Surgery Not BMP Exposure Predicts Cancer After BMP Exposure: Analysis of 127,087 Cases

Michael P. Kelly, MD; Nicholas J. White, MPH; Wilson Ray, MD; Margaret A. Olsen, PhD, MPH

USA

Summary: BMP may provide a small risk for the diagnosis of malignancy following use in spinal fusion surgery. The effect of aging is far stronger than any effect from BMP, however. These data will aid in patient counseling prior to fusion procedures using BMP and guide future clinical studies.

Introduction: Bone Morphogenetic Protein-2 (BMP) is used as a device in spine surgery to increase fusion rates. Recent publications have raised a concern that BMP exposure may confer increased risk of developing a malignancy. Given this rare event, large numbers of patients are needed to show any effect of BMP.

Methods: Data came from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Database (SID) for California and the HCUP American Hospital Association (AHA) Linkage Files. Admissions with an ICD-9-CM procedure code indicating a spinal fusion performed between January 1, 2004 and December 31, 2009 were included. Procedure codes were used to classify each fusion by utilization of BMP; location on the spine; surgical approach (posterior, anterior, circumferential); number of fused levels; and original or refusion. Comorbid diagnoses were collected. Patients were followed for subsequent malignancy codes. Univariate analyses were performed to obtain odds ratios estimating the effect of patient demographics, surgical characteristics, and patient comorbidities on the likelihood of developing cancer. For the multivariate analysis, a Cox proportional hazards model was created estimating the likelihood of a patient developing cancer after their fusion.

Results: 127,087 patients were identified, with 36,729 receiving BMP at the time of surgery. 2718(2.14%) Malignancies were diagnosed in the f/u period(NoBMP: 2.15% vs BMP: 2.11%, p=0.653). Increasing age showed the strongest association with the diagnosis of cancer(Age 40-44 HR 1.79 (1.292 - 2.479), Age 60-64 HR 10.42 (7.748 - 14.016), Age 80-84 HR 19.73 (14.48 - 26.88)). Comorbid diagnoses showing strong relationships included renal disease (HR 1.655 (1.35 - 2.03), inflammatory arthropathies (HR 3.15 (2.40 - 4.14)), and liver disease (HR 1.27 (1.03 - 1.56). Exposure to BMP was associated with a small increase in a subsequent diagnosis of cancer (HR 1.186 (1.126 - 1.250).

Conclusion: Exposure to BMP during a spine fusion procedure may confer a small increased risk of a subsequent diagnosis of malignancy. Age at the time of spine surgery confers a much larger risk of a subsequent malignancy diagnosis, nearly 20x at age 80. Clinical series are needed to further explore this possible relationship.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

53. Minimum Five-Year Comparison of Different Age Groups Who Underwent Primary Long Instrumented Fusions to the Sacrum for Adult Spinal Deformity

Sang D. Kim, MD, MS; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Ian G. Dorward, MD; Brian J. Neuman, MD; Kevin R. O'Neill, MD, MS; Christine Baldus, RN, MHS; Linda Koester, BS; Azeem Ahmad, BA, BS

USA

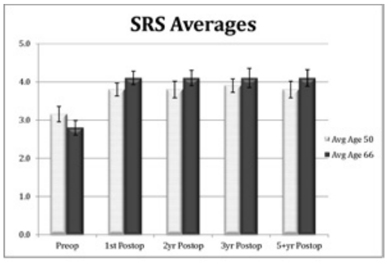
Summary: Outcomes of primary long instrumented fusion to the sacrum/pelvis for adult spinal deformity demonstrated significant improvements that are maintained for over five years. Improvements are greater in the elderly population despite higher complication rates.

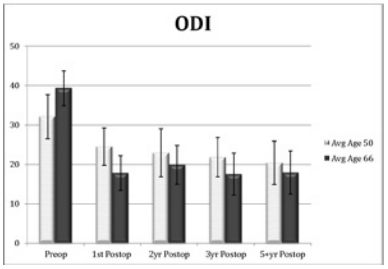
Introduction: Studies reporting complications and outcomes after adult spinal deformities are frequently limited to 2-year follow-ups. Late complications such as pseudoarthrosis are often encountered after this period and their effects on outcomes on different age groups are unknown.

Methods: Analysis of primary long instrumented fusions from thoracic spine to the sacrum/pelvis for spinal deformity was analyzed for surgeries performed from 2002 to 2007 at one institution. All patients had a minimum of 54 months follow up with Scoliosis Research Study (SRS) and Oswestry disability index (ODI) outcome scores and xrays. Patients were excluded if they had prior multi-level instrumented surgeries in the thoracolumbar spine. Patient's demographics, medical history, functional scores and radiographic measurements were analyzed.

Results: Seventy-two patients (69%) met the inclusion criteria with follow-ups of 5.4±0.7 years. Group A (45 patients with an average age of 50 years [95% CI 47, 53]) and Group B (27 patients with an average age of 66 years [95% CI 64, 68]) were compared. Preoperative and operative data revealed no difference in major Cobb angles, sagittal vertical alignment, comorbidities, body mass index, levels fused, length of surgery, length of stay or estimated blood loss. Postoperatively, the elderly group had higher complication rates (59% vs 36%) and pseudoarthrosis (15% vs 4%). Nevertheless, the five year postop average SRS scores increased from 3.2±0.7 to 3.8±0.7 (P = 0.0001) for Group A and 2.8±0.5 to 4.1±0.6 (P <0.0001) for Group B. ODI scores decreased from 32.1±19.3 to 20.4±12 (P = 0.005) in Group A and 39.3±12 to 17.9±14.9 (P < 0.0001) in Group B. Overall improvements in SRS and ODI scores were greater in the elderly patient population (P = 0.003).

Conclusion: Long fusions to the pelvis and ilium for adult spinal deformity surgery result in significant improvements in SRS and ODI outcome measurements especially in the elder patient population and these improvements are maintained for more than five years despite high complication rates.





SRS averages and ODI outcome scores from preop to 5+ year postoperative visits for the two groups with 95% CI.

54. Cost-Utility Analysis of Surgical Treatment for Adult Spinal Deformity

Ian McCarthy, PhD; Michael F. Obrien, MD; Christopher P. Ames, MD; Thomas J. Errico; Han Jo Kim, MD; Gregory M. Mundis, MD; Frank J. Schwab, MD; Eric Klineberg, MD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; David W. Polly, MD; Richard Hostin, MD; International Spine Study Group

USA

Summary: This is a cost-utility analysis of surgical treatment for adult spinal deformity with extended follow-up on observed payments and quality-adjusted life-years (QALYs) following primary surgery. Through projected 10 year follow-up, the average cost-effectiveness ratio ($/QALY) was $37,973 based on payments received by the hospital. The incremental QALY gained per dollar in hospital payments ranged from $58,027 to $357,950, depending on the assumed reduction in QALYs had surgical treatment not taken place.

Introduction: Cost-utility analysis is critical to the efficient allocation of health care resources. The current study examines the cost-effectiveness of surgical treatment of adult spinal deformity (ASD) with extended follow-up on observed costs, payments, and QALYs following primary surgery, including any related readmissions.

Methods: Single-center, retrospective analysis of consecutive patients undergoing primary surgery for ASD. Payments (expressed in 2010 dollars) to the hospital were collected from administrative data, with QALYs calculated from the SF-6D. Payments and QALYs were discounted at 3.5% per year. The

study analyzed the average cost-effectiveness ratio (ACER) and a range of incremental cost-effectiveness ratios (ICERs) based on improvement in QALYs from baseline and alternative assumptions of the reduction in HRQOL without surgical intervention. Results were projected through 10-year follow-up, and 95% confidence intervals (CIs) were calculated using nonparametric bootstrap methods.
Results: Three-year follow-up was available for 239 of 278 eligible patients (86%), which were predominantly female (n=203, 85%) with average age of 49 (range 18 to 82). Total per-patient payments averaged $211,529, including any readmissions over the follow-up period. Discounted QALYs averaged 1.9 over 3-year follow-up. Projecting through 10-year follow-up, the ACER ($/QALY) was $37,973. ICERs ranged from $58,027 based on an assumed 20% reduction in quality-of-life per year without surgery to $357,950 assuming no reduction in quality-of-life without surgery (Table 1).
Conclusion: This study considers the cost-effectiveness of surgical treatment for ASD with a range of assumptions regarding the reduction in HRQOL without surgery. The results illustrate the potential for ASD surgery to be highly cost-effective provided accurate identification of patients likely to deteriorate in HRQOL without surgery. Future research should pursue direct measurement of the incremental improvement in QALYs attributed to surgery as well as outpatient resource utilization and indirect costs/benefits resulting from changes in absenteeism or productivity at work.

55. Multi-Segmental Primary Tumors and Solitary Metastasis of the Thoracolumbar Spine: 38 Patients Treated with Multilevel en bloc Spondylectomy and Reconstruction

Alessandro Luzzati

Italy

Summary: Total en-bloc spondylectomy (TES), the sole radical-treatment option for sarcoma and solitary spine metastases, minimizes local recurrences, improves patient quality of life and increases survival rates. The authors report the experience in a series of 38 patients treated with en-bloc multiple spondylectomy (19x2, 15x3, 3x4, 1x5 segments) for primary spinal sarcomas (26), solitary metastases (6) and aggressive primary benignant tumors (5). The clinical results of this series demonstates that, in multisegmental-spinal-tumor patients, oncological resections can be reached by multilevel TES.
Introduction: Total en-bloc spondylectomy (TES), the sole radical-treatment option for sarcoma and solitary spine metastases, minimizes local recurrences, improves patient quality of life and increases survival rates. Reconstruction after multisegmental-spinal-tumor surgery used to be considered to exceed surgical-feasibility limits. This study analyzes onco-surgical results after multilevel-thoracolumbar TES in a series of 38 patients
Methods: 38patients (20f/18m; age 63-8y) treated with multilevel-thoracolumbar TES (19x2, 15x3, 3x4, 1x5 segments) for primary spinal sarcomas (26), solitary metastases (6) and aggressive primary benignant tumors (5), were retrospectively investigated. The Tomita classification system staged all patients as type 6 (multisegmental/extracompartimental). Spondylectomies were performed with posterior stabilization and anterior reconstruction, with carbon composite vertebral cages in 30 cases, with autogenous bone graft in 4, with auto-omogenous bone graft in 4 cases . Patient charts and current clinical follow-up results were analyzed for histopathological tumor type, pre- and post-operative data (symptoms, surgery duration, blood loss, complications, intensive care, adjuvant therapies) and disease course. Latest imaging was analyzed at follow-up. Oncological status was evaluated using cumulative disease-specific and metastases-free survival analysis
Results: : Mean 26 month (24-124) follow-up showed 34 patients walking post-surgery without any support. Postoperative neurological major deficits were seen in one patient. Wide resection margins were attained in 9, marginal in 25 patients, contaminated in 4. Adjuvant therapy was performed in 29 patients. Local recurrence was found in 3 patients, 31 patients showed no evidence of disease, 2 died within the first month, 3 were alive with disease, while 2 DOD 10 and 27 months post-surgery. One patient required revision of the implant, due to mechanical failure.
Conclusion: : In multisegmental-spinal-tumor patients, oncological resections can be reached by multilevel TES. Although the surgical procedure is challenging, our encouraging midterm results and low complication rates clearly favour and validate this technique.

56. Sacrectomy and Adjuvant Radiotherapy for the Treatment of Sacral Chordomas: A Single-Centre Experience Over 27 Years

Arjun A. Dhawale, MD; Joseph P. Gjolaj, MD; H Thomas Temple, MD; Frank J. Eismont, MD

USA

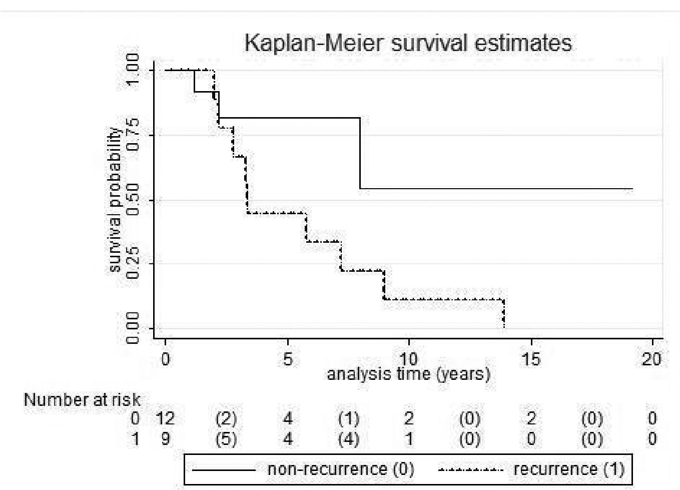
Summary: There are few long- term studies on treatment of sacral chordomas with >20 patients, and factors related to survival are not fully understood. We report our results in 21 patients treated at a single center with en bloc resection +/- adjuvant radiotherapy. Despite the complications, increased long-term survival can be achieved with en bloc resection and adjuvant radiotherapy of sacral chordomas. Proximal extent of tumor and size may be related to recurrence and survival. As surgeon experience has increased, recurrence rates have diminished.
Introduction: There are few long- term studies on treatment of sacral chordomas with >20 patients, and factors related to

survival are not fully understood. We report our results in 21 patients treated at a single center.

Methods: Patients were treated with en bloc resection +/- adjuvant radiotherapy with minimum follow-up ≥2 years. Demographics, treatment details, complications and recurrence were evaluated. Retrospective cohort design was used to assess the impact of recurrence and other factors on sacral chordoma survival. Analysis included summary statistics as applicable, hypothesis testing with Mantel- Hansen -Cox analysis, log- rank test, Cox proportional hazard model, and Kaplan-Meier survival estimates.

Results: There were 21 patients (12 males, 9 females) with mean age 61 years (16-79 years) and mean follow-up of 5.8 years (max 19.2 years). Tumor stage was IB in 20 and IIIB in 1 and mean size was 10.5 cm. Fourteen patients underwent combined AP en bloc resection and 7 underwent posterior resection. Margins were positive in 5, marginal in 6 and wide in 10. After treatment, normal bowel , and bladder control were present in 4 and 5 patients respectively. Complications included wound infections (4), significant wound complications (9), fistula (2), DVT (1) and PE (1). Median survival was 7.2 years for all patients. Eight (40%) had local/metastatic recurrence. Mean interval before recurrence was 2.5 years (1-5 years). None of the 8 patients treated in the past nine years had any recurrence. Patients who were treated for recurrence survived a mean of 5.7 years (0.8- 9 years) after first recurrence. Apart from a marginally statistically significant association with proximal extent of tumor (p=0.05) there were no significant factors for recurrence. There was a statistically significant association of recurrence and survival (RR=3.8, 95% CI, 1.0-15.3, p =0.04). Tumor size was marginally associated with survival, (HR =1.07, 95%CI 1.0-1.19).

Conclusion: Despite the complications, increased long-term survival can be achieved with en bloc resection and adjuvant radiotherapy of sacral chordomas. Proximal extent of tumor and size may be related to recurrence and survival. As surgeon experience has increased, recurrence rates have diminished.



57. The Effect of Surgery on Health Related Quality of Life and Functional Outcome in Patients with Metastatic Epidural Spinal Cord Compression: The AOSpine North America Prospective Multi-Center Study

Michael G. Fehlings, MD, PhD; Branko Kopjar; Charles G. Fisher, MD, MHSc; Alexander R. Vaccaro, MD, PhD; Paul Arnold; Laurence D. Rhines, MD; James Schuster, MD, PhD; Joel Finkelstein, MSc, MD, FRCS(C); Mark B. Dekutoski, MD; Ziya L. Gokaslan, MD; John C. France, MD

USA

Summary: This prospective study shows that surgery improves pain and functional outcomes in patients with MESCC.

Introduction: Studies suggested that combined surgery and radiotherapy provides optimal neurological recovery in patients with epidural spinal cord compression (MESCC). The impact of surgery on functional and quality of life outcomes is less clear.

Methods: To date, 163 patients with solitary symptomatic MESCC were enrolled in a prospective multi-center, ongoing cohort study. Patients were followed for 12 months.

Results: The average age was 59 years (SD 12, range 29-85) with 57% males. Common primary sites were lung (23%), breast (15%), prostate (13%), kidney (13%), other genitourinary (4%) and, unknown (16%). Baseline Visual Analog Pain (VAS) level was 7.1 (SD 2.4); the ODI was 43.3 (SD 24.3); the SF36v2 Physical Component Score (PCS) was 32.3 (SD 7.7) and, the EQ-5D was 0.39 (SD 0.26). 43% of the subjects had normal ASIA motor impairment grade "E"; 38% had grade "D"; 15% "C", 1% "B" and, 2% "A".

Median survival was 234 days (95% CI 151—304 days). 33% survived 12 months or more. Survival was strongly associated with the site of the primary neoplastic disease (P < .05). About 64% of patients with breast cancer and only 14% of patients with lung cancer survived 12 months. Median survivals were 569 and 105 days in the breast and lung cancer groups, respectively. Patients who survived 3 months experienced significant improvement in pain, function and health utility. At 3 months, Pain VAS improved for 1.8 (SD 2.9) (P < .01) and, ODI for 11.6 (SD 32.0) (P < .01) and EQ5D .15 (SD .31) (P < .01). The improvement in SF36v2 PCS and MCS were not statistically significant. The gains in EQ5D, ODI and VAS Pain were maintained in patients who survived 6 months.

Conclusion: Surgically treated patients with MESCC are a diverse group of patients with different prognoses. Survival prognosis is associated with type of primary cancer with lung cancer being associated with the poorest prognosis and breast cancer with the best. The surviving patients experience clinically relevant symptoms improvement and gains in function and utility. Our analysis supports use of surgery in patients with survival expectancy of 3 months or more.

58. Variations in Sagittal Spino-Pelvic Alignment Between Different Curve Patterns of Adolescent Idiopathic Scoliosis: Is the Evolution of Thoracic Scoliosis Different Than Lumbar?

Tom P. Schlösser, MD; Suken A. Shah, MD; Samantha J. Reichard; Kenneth J. Rogers, PhD; Koen L. Vincken, PhD; Rene M. Castelein, MD, PhD

Netherlands

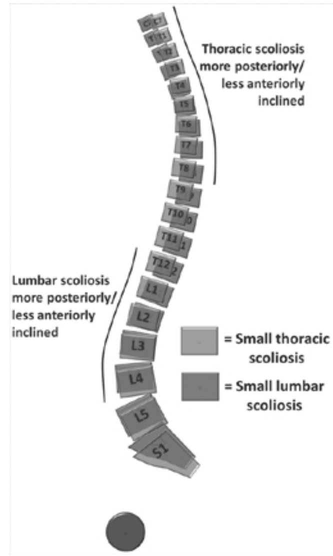
Summary: In this multicenter analysis the role of sagittal spino-pelvic alignment in the etiopathogenesis of different types of adolescent idiopathic scoliosis was examined. Sagittal parameters of adolescent idiopathic scoliosis patients with small thoracic and small lumbar curves were compared with a control cohort. Significant differences between controls and the scoliotic cohorts, as well as between the scoliotic cohorts were found. Our results support the theory that sagittal profile differences play a role in the development of different types of idiopathic scoliosis.

Introduction: It has previously been shown that rotational stiffness of spinal segments is decreased by posteriorly directed shear loads. Posterior shear loads act on backwardly inclined segments of the spine as determined by the individual's inherited sagittal profile. Accordingly, it can be inferred that: (1) Certain sagittal spinal profiles are more prone to develop a rotational deformity that may lead to idiopathic scoliosis; (2) Lumbar scoliosis develops on a different sagittal spinal profile than thoracic scoliosis.

Methods: Out of a database of 1500 adolescent idiopathic scoliosis patients, standardized lateral radiographs of the spine of all patients with thoracic (n=128) and lumbar (n=64) curves with a Cobb's angle less than twenty degrees were selected. Adolescents without any spinal pathology were included in the control cohort (n=95). A systematic, semi-automatic measurement of thoracic kyphosis, lumbar lordosis, T9 sagittal offset, C7 and T4 sagittal plumb lines, pelvic incidence, pelvic tilt, sacral slope as well as parameters describing inclination of each individual vertebra between C7 and L5 and length of the posteriorly inclined segment was performed for each subject using in-house developed computer software.

Results: Significant differences between controls and the scoliotic groups, as well as between the two scoliotic groups were found (figure 1). Thoracic kyphosis was decreased in thoracic scoliosis compared to lumbar scoliosis patients and controls. For thoracic scoliosis, a longer posteriorly inclined segment, and steeper posterior inclination of C7-T8 was observed compared to both lumbar scoliosis and controls. In lumbar scoliosis, the posteriorly inclined segment was shorter and located lower in the spine, and T12-L4 was more posteriorly inclined than in the thoracic group. Lumbar lordosis, pelvic incidence, pelvic tilt and sacral slope were similar for the two scoliotic subgroups as well as the controls.

Conclusion: This study demonstrates that even at an early stage in the condition, the sagittal profile of thoracic adolescent idiopathic scoliosis differs from lumbar scoliosis and controls. This supports the theory that differences in sagittal profile play a role in the development of different types of idiopathic scoliosis.



Sagittal profile and vertebral inclination of small thoracic and lumbar adolescent idiopathic scoliosis.

59. An Independent Evaluation of the Validity of a DNA-Based Prognostic Test for Adolescent Idiopathic Scoliosis

Benjamin D. Roye, MD, MPH; Margaret L. Wright, BS; Hiroko Matsumoto, MA; Petya Yorgova, MS; Geraldine I. Neiss, PhD; Daren J. McCalla, BS; Joshua E. Hyman, MD; David P. Roye, MD; Suken A. Shah, MD; Michael G. Vitale, MD, MPH

USA

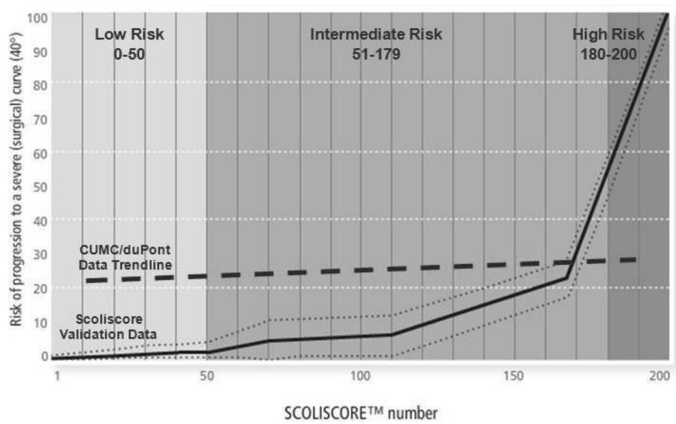
Summary: This study sought to validate the ability of ScoliscoreTM, a DNA-based prognostic test, to stratify risk of progression in patients with Adolescent Idiopathic Scoliosis (AIS). 85 patients from two institutions obtained Scoliscores and were followed to skeletal maturity, curve progression, or surgery. There was no difference in Scoliscore between patients with curve progression and those without. The NPV of the test in our population was 0.88 and the PPV was 0.23.

Introduction: Scoliscore was designed to estimate the risk of curve progression to >40° in AIS patients. The role of this test in clinical practice remains unclear as a third party has not validated the test results. The purpose of this study was to determine if Scoliscore effectively stratifies risk of progression in our AIS patients.

Methods: 85 patients at two centers were administered the Scoliscore after meeting inclusion criteria (Caucasians with AIS, aged 9-13 with an initial Cobb angle 10°-25°). Two groups were created: a progression group (Cobb>40° or fusion) and a non-progression group (skeletal maturity without curve progression). Scoliscore values and risk levels were compared between the two groups.

Results: The average Scoliscore for all 85 patients was 111 ± 58 (2-193). 23 patients (27%) had curve progression to >40° or fusion. Scoliscore risk distribution in our population was 18.8% low (0-50), 65.9% intermediate (51-179), and 15.3% high (180-200). There was no significant difference in Scoliscore between patients with curve progression (108 ± 51) and those without (107 ± 63) (p=.279). The Positive Predictive Value (PPV) of the test was 0.23 (95% CI: 0.06-0.54) and the Negative Predictive Value (NPV) was 0.88 (95% CI: 0.60-0.98). Among patients with high risk scores, 23.1% had curve progression, compared to 12.5% of with low risk scores (See figure). Scoliscores and rates of progression were not affected by brace wear.

Conclusion: Scoliscores did not differ between patients with and without curve progression. The trend line in our study was not consistent with the risk of progression chart previously published. This deviation may be due to differences in our test population, such as higher acuity of practice in tertiary pediatric hospitals, (in)accuracy in race information, failure of non-progressers to follow-up, or limited sample size. As more of our patients reach skeletal maturity we will be better able to determine the clinical utility of this test. This preliminary work is the first attempt to externally validate and better understand the prognostic ability of the Scoliscore test.



60. The Simplified Skeletal Maturity Method and Its Correlation with Curve Progression in Idiopathic Scoliosis

Prakash Sitoula, MD; Kushagra Verma, MD, MS; James O. Sanders, MD; Petya Yorgova, MS; Geraldine I. Neiss, PhD; Kenneth J. Rogers, PhD; Laurens Holmes, PhD, DrPH; Peter G. Gabos, MD; Suken A. Shah, MD

USA

Summary: This study sought to validate use of the simplified skeletal maturity score of Sanders to predict curve progression in idiopathic scoliosis. 135 patients with initial hand films were reviewed, followed to skeletal maturity and curve progression recorded. Risk of progression was similar to that described by Sanders. All patients with initial curves 35°- 45° in the SMSS 1, 2 and 3 progressed to ≥50°. No patients with initial curves 10°-30° in the SMSS stages 5-7 progressed to ≥50°.

Introduction: The simplified skeletal maturity score (SSMS) of Sanders has been utilized to predict curve progression in idiopathic scoliosis. This study aimed to validate that initial study with a larger sample size and assess the correlation of the SSMS to curve progression in idiopathic scoliosis.

Methods: A retrospective review of 1100 patients (girls aged 8-14 years and boys aged 10-16 years) with idiopathic scoliosis (IS) evaluated between 2005 and 2011 was performed. Data collected at initial and final follow-up: age, height, weight, family history, gender, menarchal status (girls), curve magnitude, modified Lenke curve type (1-6), Risser stage, duration of follow-up and initial SMSS. The end-point was defined by skeletal maturity (Risser stages 4 and 5 or girls 2 years post-menarche) or curve progression to ≥50°. Patients with less than 1 year follow-up, non-idiopathic curves or previous spine surgery were excluded. Chi square test was used to show distribution of curves within the SSMA as well as curve progression, while an exact logistic regression model was used to predict curve progression, given SSMS and final Cobb angle.

Results: There were 135 patients, 113 (83.7%) girls and 22 (16.3%) boys. Mean age of girls was 12.2 years (8.4-14 years) and of boys was 14.1 years (12.6-15.6 years). Distribution of patients within SMSS 1 through 7 was: 5, 25, 36, 34, 6, 26 and 3 respectively and modified Lenke curve types 1- 6 was: 20, 8, 55, 4, 32 and 16 respectively. All patients with initial Cobb angles (35°- 45°) in the SMSS 1, 2 and 3 progressed to ≥50°. On the other hand, no patients with initial 10°-30° curves in the Sanders stages 5-7 progressed to ≥50°. The observed progression in patients with an initial curve of 30° was: SMSS 2=86%, SMSS 3=60% and SSMS 4=20%. The percentage progression to >50° for all initial curves of 15°- and 20° was less than 50%. No patient with an initial curve of 10° progressed to surgery in this cohort.

Conclusion: This substantially larger cohort shows a strong predictive correlation between SSMS and initial Cobb angle for probability of curve progression in idiopathic scoliosis to surgery. This information may prove useful for counseling patients regarding their prognosis.

61. Different Brace Treatment Outcomes: Making the Case for Biological Endophenotypes Classification in AIS Patients

Frederique Desbiens-Blais, MS; Julie Joncas, BSc; Marie Beausejour; Alain Moreau, PhD; Ginette Larouche; Ginette Lacroix, RN; Jean-Marc Mac-Thiong, MD, PhD; Hubert Labelle, MD; Carl-Éric Aubin, PhD, PEng; Stefan Parent, MD, PhD

Canada

Summary: Functional analysis of blood cells derived from AIS patients revealed a differential signalling dysfunction

of receptors coupled to G inhibitory proteins allowing their classification into three functional subgroups or biological endophenotypes. Significant differences in the probabilities of brace treatment success were found according to the biological endophenotypes of AIS patients, suggesting a genetic predisposition to clinical outcomes. Improving AIS patients' stratification could enhance bracing outcomes for selected patients.

Introduction: The objective was to evaluate AIS patient bracing outcome in regards to their functional classification among three biological endophenotypes acquired through a cell-based assay used to better stratify AIS patients.

Methods: A retrospective study was performed with 67 AIS patients previously stratified among three biological endophenotypes according to a cell-based assay allowing their classification into three functional groups (FG1, FG2 or FG3). Patients completed TLSO brace treatment respecting standard prescription criteria. Cobb angles were measured by a single blind observer in brace and at the end of treatment and compared to their initial values. Progression of the curvature was defined by a 6° Cobb increase and treatment was considered a success if final Cobb angle was ≤ 45° or no surgery was required. Association between group classification and treatment outcome was analysed with Chi2 test. Logistic regression models were performed for odds ratio calculation. Group comparability at time of prescription was verified using ANOVA and Chi2 test: no differences for mean Cobb angle for all curves, Risser sign nor age.

Results: The patient distribution is reported in Table 1 (15 in FG1, 27 in FG2, and 25 in FG3). Globally, the majority who had brace succes were from FG2 and FG3. There was a clear association between the functional group and the success of the treatment regarding the final cobb ≤ 45°criteria (Chi 2 (2, 67)=8.4, p = 0.015). Being classified as FG3 was 7.9 times more likely to lead to treatment success than failure compared to FG1 (p=0.007). Success in treatment in regards to preventing surgery was statistically different between the groups (Chi 2 (2, 67)=5.96 , p = 0.05). It is 6.4 times more likely to prevent surgery than to have one in group FG3 compared to FG1 (p=0.02).

Conclusion: Bracing seemed less effective in AIS patients classified in FG1 group with an increased likelihood to progress over 45° when compared with the other 2 groups. Outcomes of bracing were most favorable for patients presenting the FG3 endophenotype. Improving patient's stratification by the mean of predictive tests could help provide a personalized treatment based on the patient's genetic susceptibility to respond to brace treatment.

Final Cobb ≤ 45°					
	success	failure		Odds ratio	
FG1	6 (40%)	9 (60%)		1	
FG2	16 (59%)	11 (41%)		2,18	p=0,235
FG3	21 (84%)	4 (16 %)		7,88	p=0,007
Total	43 (64%)	24 (36%)	χ^2=8,4 (p=0,015)		
Cobb angle progression ≤ 6°					
	success	failure		Odds ratio	
FG1	6 (40%)	9 (60%)		1	
FG2	13 (48%)	14 (52%)		1,39	p=0,612
FG3	15 (60%)	10 (40%)		2,25	p=0,224
Total	33 (49%)	34 (51%)	χ^2=1,6 (p=0,444)		
No need for surgery					
	success	failure		Odds ratio	
FG1	8 (53%)	7 (47%)		1	
FG2	20 (74%)	7 (26%)		2,5	p=0,177
FG3	22 (88%)	3 (12%)		6,4	p=0,02
Total	50 (74%)	17 (25%)	χ^2=5,96 (p=0,05)		

Table 1: Statistical analysis of the patient distribution comparing 3 success criteria (Cobb at the end of treatment ≤ 45°, Cobb angle progression ≤ 6° and no need for surgery)

62. Vitamin D Insufficiency and Its Association with Low Bone Mass in Girls with Adolescent Idiopathic Scoliosis (AIS)

Tsz Ping Lam, MBBS; Wing Sze Yu, MPhil; Queenie Wah Yan Mak, PGd(Ed), BSc(FNS); Franco Tsz Fung Cheung, MPhil; Kwong Man Lee, PhD; Bobby K. Ng, MD; Ling Qin; Jack C. Cheng, MD

Hong Kong

Summary: This is a case-control study comparing Vit-D status and its correlation with areal bone mineral density (aBMD) between AIS girls and age and gender-matched normal controls. The mean serum 25(OH)Vit-D levels were similar between AIS and controls. The positive correlation between serum 25(OH) Vit-D and aBMD that was seen in controls was not present in AIS subjects. Whether there is abnormal physiology in form of Vit-D resistance and its role in the etiopathogenesis of AIS warrant further studies.

Introduction: AIS is associated with both low bone mass and elevated serum bone alkaline phosphatase. The greater the latitude of the geographical region, the higher is the prevalence of AIS. These specific features were compatible with the presence of either Vit-D insufficiency or abnormal physiology with Vit-D. It is important to evaluate the roles of these potentially treatable conditions on the etiopathogenesis of AIS. The objectives of this study were to compare Vit-D status and its correlation with aBMD between AIS girls and normal controls.

Methods: 215 AIS and 186 non-AIS healthy girls (mean age 12.9±0.6 and 12.9±0.5 yeas old respectively, p=0.449) were recruited in the summer and winter season. aBMD at bilateral femoral necks was measured with Dual Energy X-ray Absorptiometry (DXA) and serum 25(OH)Vit-D was measured with liquid chromatography tandem mass spectroscopy.

Results: The mean aBMD at the right and left side for AIS subjects were 0.752±0.109, 0.745±0.107, and that for controls were 0.785±0.114 and 0.785±0.117 gm/cm2 respectively. The mean 25(OH)Vit-D levels for AIS and controls were 41.6±14.4 and 39.5±11.5 nmol/L respectively (p=0.103). With multivariate linear regression analysis using aBMD as the dependent variable and after adjustment for age, body weight, armspan, season, physical activity and dietary calcium intake levels, the p-value of the regression coefficient for 25(OH)Vit-D level for the right and left side for controls were 0.055 and 0.047, while that for AIS were 0.804 and 0.466 respectively.

Conclusion: Both the AIS and control group had mean 25(OH) Vit-D levels located at the insufficiency range. The positive correlation between Vit-D level and aBMD that was seen in normal controls was not present in AIS subjects, thus spelling out the possibility of Vit-D resistance being present in AIS. Whether the lack of correlation is responsible for low bone mass that characterizes AIS and how this is related to the etiopathogenesis of AIS warrant further studies.

Funding source: Research Grants Council of the Hong Kong S.A.R., China (Project no: 468809 and 468411).

63. Quantitative Measurement of Abnormal Bone Quality and Strength with Bone Micro-Architecture and Rod-Plate Configuration in Osteopenic Adolescent Idiopathic Scoliosis (AIS)

Wing Sze Yu, MPhil; Ka Yan Chan; Wai Ping Fiona Yu, MPH, BSc; Kwong Man Lee, PhD; Bobby K. Ng, MD; Ling Qin, PhD; Tsz Ping Lam, MBBS; Jack C. Cheng, MD

Hong Kong

Summary: Adolescent Idiopathic Scoliosis was associated with osteopenia. In this study, we quantitatively measured bone quality and strength parameters including bone micro-architectural and rod-plate configurations profiles with HR-QCT and to investigate its relationship with osteopenia in AIS Vs controls. Our findings demonstrated abnormal bone quality in AIS and unique alteration of trabecular bone profile and more rod-like trabeculae in osteopenic AIS. The % difference in SMI between osteopenic and non-osteopenic AIS (15.6%) was highest among all the Trabecular Bone Micro-architecture parameters.

Introduction: Multiple studies have documented the presence of systemic osteopenia in AIS. Osteopenia was associated with severe curves and as one of the prognostic factor of curve progression in AIS. This pilot study aimed to measure the quantitative bone quality and strength parameters including bone micro-architectural and rod-plate configurations profiles with in vivo High-Resolution Quantitative CT (HR-QCT) and to investigate its relationship with osteopenia in AIS Vs normal controls.

Methods: 234 AIS and 211 controls between 11-13 years old were recruited. aBMD of bilateral femoral necks was measured by DXA. Subjects were classified into the osteopenic (Z-score≤-1) and non-osteopenic (Z-score>-1) subgroup. Bone Morphometry, vBMD and Trabecular Bone Micro-architecture were measured using HR-pQCT. To consolidate our understanding on the trabecular bone micro-architecture, Structural Model Index (SMI), which quantify the trabeculae rod/plate-like configuration, was further determined in 73 AIS and 48 controls.

Results: In the multivariate analysis, AIS was associated with lower Cortical Area, Cortical Thickness, Cortical vBMD, Trabecular vBMD, BV/TV, Trabecular Number, greater Trabecular Separation and SMI indicating predominance of rod-like trabeculae. In the subgroup analysis, osteopenic AIS showed a lower Trabecular Thickness, greater Trabecular Separation and SMI when compared to the normal BMD AIS. In contrast, among the controls, only lower BV/TV and Trabecular Thickness was noted between the osteopenic and normal BMD subgroups. Two-way ANOVA showed a significant interaction between AIS and osteopenia on Trabecular Thickness.

Conclusion: We demonstrated an abnormal bone quality in AIS and unique alteration of trabecular bone profile in osteopenic AIS. The % difference in SMI between osteopenic and non-osteopenic AIS was highest among all micro-architectural parameters. One clinical significance was the call for developing a composite prognostic factor incorporating both BMD and SMI for more accurate prediction of curve occurrence and progression. The unique AIS and osteopenia-related alteration of trabecular structure further suggested the presence of systemic dysfunction in regulation and modulation of bone mineralization and growth in AIS.

64. A Prospective Randomized Double-Blinded Study Comparing Postoperative Pain Control Modalities for Patients Undergoing Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

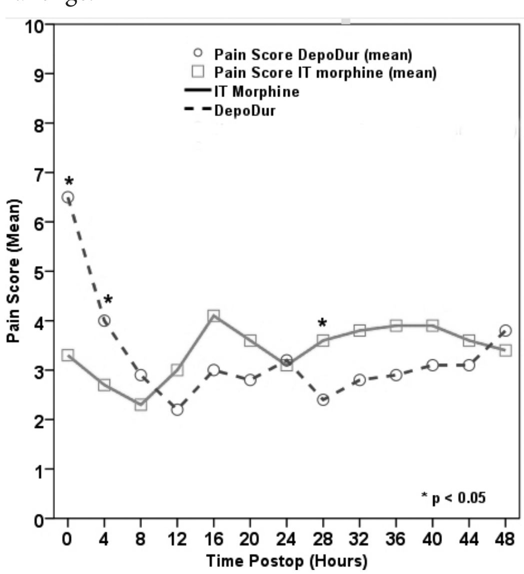
Mindy Cohen, MD; Jeannie Zuk, PhD; Jeffrey Galinkin, MD; Mark A. Erickson, MD

USA

Summary: The purpose of this double-blinded, randomized study was to compare the duration of pain relief between Extended-release epidural morphine (EREM) and intrathecal (IT) morphine in adolescents who underwent spinal fusion with instrumentation. Subjects in the IT morphine group experienced significantly lower pain scores in the first 8 hours of surgery while patients in the EREM group had significantly lower pain scores 8-44 hours after surgery. Total morphine consumption was similar between the two treatment groups.

Introduction: After spinal fusion surgery, intrathecal (IT) morphine plus patient-controlled analgesia (PCA) morphine provides safe analgesia. We hypothesized that Extended-release epidural morphine (EREM) would provide longer pain relief

than IT morphine in pediatric scoliosis patients. The primary outcome was total morphine use via PCA for 48 hours after surgery.
Methods: This study was double-blinded and randomized: IT morphine (7.5 mcg/kg) vs. EREM (0.15 mg/kg). All subjects had the same postoperative pain management regimen, including morphine PCA. Data collection at 4 hour intervals included: morphine (mg), pain score, headache, nausea, and pruritus. All patients were healthy adolescents with idiopathic scoliosis.
Results: Seventy-one subjects completed the study: 37 in IT morphine and 34 in EREM. Total morphine consumption over 48 hours did not differ significantly (mean +/- S.D.): IT morphine 46.1 mg +/- 33.1 vs. EREM 52.5 mg +/- 32.3. Length of postoperative hospital stay did not change with treatment group (mean +/- S.D.): IT morphine 4.9 +/- 1.3 vs. EREM 4.9 +/- 0.8.
The difference between pain scores was significant at 0, 4, and 28 hours. Mean pain scores for the IT morphine treatment group were lower during the first 8 hours after surgery. Then, the pain increased in the IT morphine group, while the EREM treatment group had lower pain scores until 44 hours after surgery.
Adverse events were similar between the two treatment groups. Analysis of adverse effects such as pruritus and nausea is forthcoming.
Conclusion: Adolescent idiopathic scoliosis patients used similar amounts of morphine after surgery regardless of treatment group. Pain scores differed at some time points based on treatment group. Further analysis of the adverse effects data may reveal additional differences between treatment groups. Finding the optimal option for postoperative pain management in patients with adolescent idiopathic scoliosis undergoing posterior spinal fusion remains unsolved. Our evidence lends significant and valuable information towards the solutions for this challenge.



65. Post-Operative DVT Rate After Spine Surgery

William Schairer; Andrew C. Pedtke, MD; Serena S. Hu, MD
USA

Summary: We used large state-level databases to assess venous thromboembolism (VTE = DVT or PE) incidence within 90 days of spine surgery in over 350,000 patients. We included patients undergoing surgery for degenerative, traumatic, cancer, infection indications, as well as for complications of prior surgery. The overall VTE rate was low (1.31%), but was much higher in patients with non-degenerative diagnoses. Multivariate modeling showed that increased age, longer fusions, multiple procedures, and anterior thoracic and lumbar surgery had higher VTE risk.
Introduction: VTE after spine surgery is a serious complication, but chemoprophylaxis is concerning for the risk of epidural hematoma. Current literature report variable rates of VTE and have weaknesses in sample size, specificity of diagnosis, and methodological problems with adequate patient follow-up.
Methods: Linkage of state-level inpatient, ambulatory surgery, and emergency department administrative databases were used to track patients for VTE diagnosis within 90 days of discharge after a spine procedure. Patients were grouped by indicating diagnosis and by type of surgery. Cox proportional hazard analysis identified risk associated with different procedures, controlling for known risk factors.
Results: Of 366,271 patients enrolled, one-third underwent spine decompression alone while two-thirds received spine fusion. The overall rate of VTE was 1.31% (1.28-1.35 95% CI), but varied widely depending on diagnosis - from as low as 10.8% for patients presenting with a spine infection to as low as 1.02% for patients with a structural degenerative diagnosis [Table 1]. Posterior cervical fusion had a higher rate of VTE than anterior cervical fusion, while anterior thoracolumbar and lumbosacral fusions had higher rates than the posterior approach. Additional risk factors included patients receiving long spine fusions and having multiple procedures during the hospitalization.
Conclusion: The rate of spine VTE varies widely depending on diagnosis and procedure. It is important to thoroughly risk stratify patients who present for spine surgery in order to identify patients at increased risk who should be monitored for the development of VTE.

66. Defining Rates and Causes of Mortality Associated with Spine Surgery Using a Scoliosis Research Society (SRS) Registry-Based System: Does Collection of Less Data Improve Compliance?

Ellen C. Shaffrey; Justin S. Smith, MD, PhD; David M. Ibrahimi, MD; Manish Singh, MD; Lawrence G. Lenke, MD; David W. Polly, MD; Ching-Jen Chen, BA; Jeffrey D. Coe, MD; Paul A. Broadstone, MD; Steven D. Glassman, MD; Alexander R. Vaccaro, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD

USA

Summary: Based on the newer simplified SRS M&M collection system, the rate of mortality for spinal deformity surgery was 1.5 per 1,000 cases. Compared with the older system, the newer system had significantly improved surgeon compliance and had similar mortality rates. Although analyses based on the newer system are more limited due to less data collected, the present study suggests that this approach achieves better compliance and may prove effective, especially if supplemented with focused data collection modules.

Introduction: The SRS collects case data from its members; previously, this included details for all spine cases and all complications. To reduce time burden and improve compliance, collection was changed to focus on a few major complications for specific deformity diagnoses and only for cases with complications. Our objective was to compare the data and submission compliance for the two systems.

Methods: Data were extracted from the SRS for 2004-2007 (old system) and 2009-2011 (new system). The new system collected data for 3 complications: death, neurologic deficit, and blindness and for diagnoses of scoliosis, spondylolisthesis, and kyphosis. As an anchor for comparison, mortality rates were compared between the systems. Compliance was calculated as: number of submitting surgeons/number of members.

Results: Between 2009-2011, 87,161 deformity cases were reported, with 131 deaths (1.5/1,000 cases). Of these 131 patients, mean age was 50, mean ASA grade was 2.8, 10% were smokers and 18% has diabetes. Rates of death (per 1,000 cases) were: idiopathic scoliosis (0.4), congenital scoliosis (1.3), neuromuscular scoliosis (3.6), other scoliosis (3.1), spondylolisthesis (0.6) and kyphosis (4.7). Common causes of mortality included respiratory (48), cardiac (32), sepsis (12), organ failure (9), blood loss (7) and stroke (6). Compared with the old system, the new system had greater average annual compliance (625/787 [79%] vs 446/725 [62%], $p<0.001$), greater number of deformity cases per reporting surgeon per year (139 vs 90) and had modestly but significantly lower mortality rates (1.5 vs 1.8/1,000 cases; $p<0.001$). Causes of death were comparable between systems.

Conclusion: Based on the simplified SRS M&M collection system, the rate of mortality for spinal deformity surgery was 1.5/1,000 cases. Compared with the older system, the newer system had significantly improved compliance and similar mortality rates. Although the newer system is limited by less data collected, it achieves better compliance and may prove effective, especially if supplemented with focused data collection modules.

† 67. Induction of SHP2-Deficiency in Chondrocytes Causes Severe Scoliosis and Kyphosis in Mice

Nobuhiro Kamiya; Daniel J. Sucato, MD, MS; B. Stephens Richards, MD; Harry Kim

USA

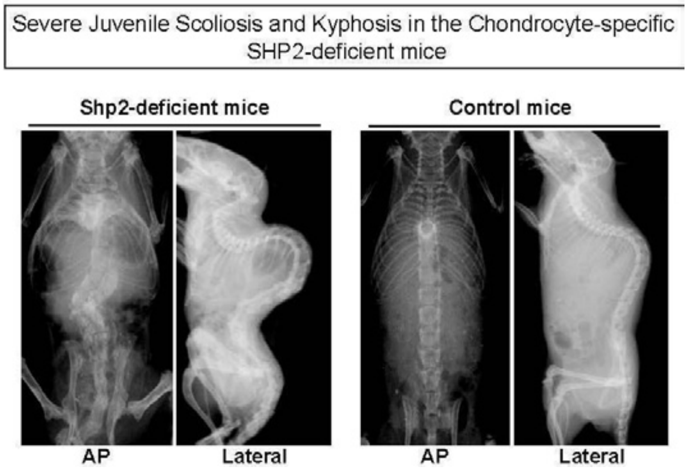
Summary: Currently, a genetic animal model of scoliosis is unavailable. Here, we developed severe scoliosis in mice by inducing SHP2-deficiency specifically in chondrocytes during a juvenile stage. To our knowledge, this is the first mouse model relevant to idiopathic scoliosis in literatures. We believe this genetic scoliosis model will be useful in studying how a disruption of a specific molecular pathway produces vertebral growth disturbance and juvenile scoliosis. This study was supported by SRS New Investigator Research Grant (N.K.).

Introduction: Progressive early-onset idiopathic scoliosis is a serious, potentially life-threatening condition, and the most clinically challenging form of idiopathic scoliosis. The pathophysiology and molecular mechanisms responsible for this are largely unknown, due to a lack of genetic animal models of scoliosis. The purpose of this study was to investigate the effect of targeted SHP2-deficiency in chondrocytes on the development of scoliosis during a juvenile growth stage in mice.

Methods: We generated genetically engineered mutant mice with inducible deletion of SHP2 in chondrocytes. In the mutant mice, we induced Cre activity from 4-weeks-old with tamoxifen injection in order to inactivate SHP2 function specifically in chondrocytes from juvenile to adolescent growth stages. Radiographic, micro-CT, and histological assessments were performed to analyze spinal deformity.

Results: In the SHP2-deficient mice, a progressive kyphoscoliotic deformity (i.e. thoracic lordosis and thoracolumbar kyphoscoliosis) developed about 2 weeks of the initiation of SHP2-deficiency. The 3-dimensional micro-CT analysis confirmed the kyphoscoliotic deformity with a rotational deformity of the spine and osteophyte formation. H&E staining demonstrated a severe lordosis in the upper thoracic region compared with only slight lordosis in the control mice. Safranin O staining revealed a disorganization of vertebral growth plate cartilage in the SHP2-deficient mice compared with controls. The thickness of the growth plate cartilage on the vertebral endplate was variable and a loss of normal pattern of chondrocyte organization was present in the SHP2-deficient mice. Interestingly, when SHP2 was disrupted during later stages (i.e. adolescent to adult), no spinal deformity developed, indicating that there is a window of susceptibility to the development and onset of spinal deformity in this model.

Conclusion: SHP2 plays an important role in normal spine development during skeletal maturation as chondrocyte-specific deletion of SHP2 at a juvenile stage produced severe kyphoscoliotic deformity. This new mouse model will be useful for future investigations of the role of SHP2-deficiency in chondrocytes as a mechanism leading to the development of juvenile scoliosis.



Using mouse genetic-engineering techniques, we induced SHP2-deficiency during a juvenile stage of mouse development. Severe scoliosis and kyphosis were identified in the SHP2-deficient mice as assessed by x-ray (i.e. AP and lateral views).

┼ 68. The Relationship Between Serum Vitamin D Levels, Successful Fusion and Fusion Strength: A Quantitative Analysis

Melodie F. Metzger, PhD; Linda E. Kanim, MA; Li Zhao; Samuel T. Robinson, BS; Rick B. Delamarter, MD

USA

Summary: To date, there is no published data on the effect of inadequate serum levels of vitamin D on the success of establishing a solid bony union after a spinal fusion procedure. Data generated in this preliminary study suggest proper screening and supplementation of vitamin D prior to surgery could potentially improve fusion outcomes.

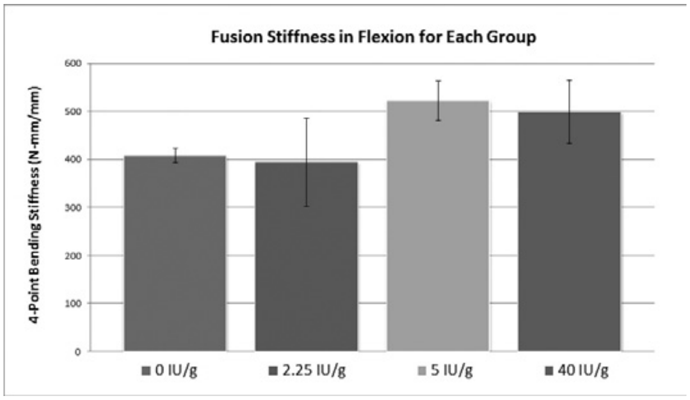
Introduction: Vitamin D insufficiency has been increasingly reported worldwide. Surprisingly there is no experimental data on the relationship between vitamin D and spinal pseudoarthrosis despite numerous studies demonstrating its importance in the formation of bone and fracture healing. This disregard is seen clinically with only 12% of surgeons checking metabolic tests (including vitamin D) prior to fusion and only 20% as part of a pseudoarthrosis workup [1]. Therefore we investigated the hypothesis that vitamin D insufficiency reduces the stiffness, volume of new bone, and rate of successful fusion after autologous fusion procedure in a rat model.

Methods: 48 rats were randomized into four experimental groups based on vitamin D supplementation provided in their rat chow: controls (CD, 5 IU/g), deficient (DD, 0 IU/g), insufficient (ID, 2.25 IU/g), and hyper-vitamin D (HD, 40 IU/g). Diets were modified 4 weeks prior to surgery and maintained post-surgery through sacrifice. Fusion was performed using a tailbone autograft implanted into the L4/L5 transverse processes. Rats were sacrificed 3 months post-surgery and fusion was evaluated via manual palpation, μCT, radiographically, and biomechanically. Plasma was collected at surgery and sacrifice and 25(OH)D levels were determined via radioimmunoassay.

Results: Vitamin D plasma levels were diet dependent and stable from surgery to sacrifice (DD: 9.3±1.6 ng/mL pre surgery to 6.3 ± 1.0 sacrifice; ID:20.6±3.3 to 15.6±5.0; CD:28.3±4.6 to19.6 ±5.6; HD:97.4±13.6 to 88.4±9.9, $p < 0.0001$). Manual palpation fusion rates were correlated to the level of vitamin D in the diet with 83% fused in the HD group compared to 61% for CD, 58 % for ID, and 45 % for DD. Radiographic fusion and density were significantly related to the amount of vitamin D in diet ($p<0.05$). Control and hyper-vitamin D fusions were stiffer in 4-point bending compared to the deficient and insufficient group ($p<0.05$), Figure 1.

Conclusion: Our results suggest vitamin D modulates the consolidation of autograft bone after grafting for spinal fusion and could potentially provide a simple, readily available, cost effective means to improve fusion outcomes.

1. Diapola et. al., Spine J 2009



┼ 69. Intrawound Vancomycin Powder Eradicates Surgical Wound Contamination: An In Vivo Rabbit Study

Lukas P. Zebala, MD; Tapanut Chuntarapas; Michael P. Kelly, MD; Michael Talcott, DVM; Suellen C. Greco, DVM; K. Daniel Riew, MD

USA

Summary: Using an In Vivo rabbit model, our data support the findings of clinical studies that have demonstrated the benefit of intrawound vancomycin powder as an effective prophylaxis against SSI. Intrawound vancomycin appears to be an effective agent to prevent acute surgical site infections.

Introduction: Surgical site infection (SSI) remains a complication of spine surgery despite routine use of prophylactic antibiotics. Retrospective clinical studies on intrawound vancomycin have reported decreased SSI in spine surgery. The purpose of this study was to assess the efficacy of intrawound vancomycin powder to prevent SSI in a controlled rabbit spine surgery model.

Methods: Twenty New Zealand White (NZW) rabbits underwent lumbar partial laminectomy and wire implantation. Surgical sites were inoculated with cefazolin and vancomycin sensitive Staphylococcus aureus (1 x 10^8 colony forming units, CFU/ mL) with 100μL injected into the wound prior to closure. Preoperative cefazolin was administered to all rabbits. Ten rabbits had vancomycin powder (100 mg) placed into the wound prior to closure. Rabbits were euthanized on postoperative day 4 and tissue and wire samples were obtained for bacteriologic assessment. Independent samples t-test was used to assess mean group differences and Fischer's exact test for categorical variables. Significant p-value was <0.05.

Results: Vancomycin and control rabbits were similar in weight (4.1±0.5, 4.0±0.4 kg, p=0.6), gender and length of surgery (21.7±7.7, 16.9±6.7 minutes, p=0.15), respectively. Bacterial cultures of surgical site tissues were negative in all vancomycin rabbits and positive in 10/10 control rabbits (p<0.0001). Bacterial growth occurred in 39/40 control samples and 0/40 vancomycin samples (p<0.0001). All blood and liver samples were sterile. No rabbit had evidence of sepsis nor vancomycin toxicity. Gross examination of the surgical sites showed no differences between the groups.

Conclusion: In a rabbit spine infection model, intrawound vancomycin powder in combination with preoperative cefazolin eliminated Staphylococcus aureus surgical site contamination. All rabbits treated with only prophylactic cefazolin had persistent Staphylococcus aureus contamination.

┼ 70. Injectable Gelatin Utilized as Hemostatic Agent in Long Deformity Surgeries: Does it Embolize?

Craig A. Kuhns, MD; Cristi R. Cook, DVM; John Dodam; Stacey B. Leach, DVM; Keiichi Kuroki, DVM, PhD; Tyler Jenkins, BS; Anne M. Tallmage, BS; Daniel G. Hoernschemeyer, MD

USA

Summary: We investigated the potential for pulmonary emboli with the use of FloSeal® to stop the bleeding from pedicles in long deformity surgery. We utilized 2 adult pigs cannulated and tapped the pedicles from the T-spine to the sacrum with segmental injection into the pedicles of FloSeal®. Intraop echo demonstrated showering of embolic material when the hemostatic agent was used and the post-mortem microscopic evaluation of the lung revealed the occlusion of multiple small vessels with FloSeal

Introduction: Bleeding from long posterior spinal deformity cases can be substantial especially when surgeries involve multiple segmental fixation points extending from the mid to upper T-spine down to the sacrum. To stop the morbidity of excessive blood loss surgeons often try to stop the bleeding utilizing injectable gelatin hemostatic agents. FloSeal is one of these agents and we sought to investigate the potential for intra-operative embolization

Methods: 2 adult Yucatan mini-pigs were anesthetized and underwent sequential segmental and bilateral pedical screw tract cannulation from the T-spine down to the sacrum. At every level the tracts were cannulated, palpated and then tapped. FloSeal was injected into the pedicles to stop bleeding or to simulate its use in a long adult human spinal deformity case. FloSeal was injected into each pedicle to total 2 cc and then stopped or stopped prior to 2 cc when the pedicle pressurized and no further agent could be injected. Pedicle screws were inserted after the agent was injected. Trans esophageal echo was utilized to visualize the right atrium and ventricle. Post mortem evaluation was performed of the heart and lungs

Results: Hemostatic agent injected into the pedicles caused a consistent large showering of the right atrium and ventricle in both pigs visualized on intra-op echo. A second large showering occurred during screw insertion after the FloSeal was injected. In both pigs microscopic examination of the lungs after H+E stain clearly identified material in many small vessels consistent with FloSeal

Conclusion: Hemostasis during long thoracolumbar spinal deformity surgery is a constant challenge especially given the trend for segmental bilateral pedicle screw fixation. Injecting FloSeal into the pedicles to stop bleeding in this animal study clearly led to showering emboli that was visualized intraop by transesophageal cardiac echo as well as evident in many small vessels on post-mortem evaluation of the lungs. Even though we don't often see or detect clinical sequellae after use use of hemostatic agents in human deformity surgery there may be some patients where this emboli makes a substantial difference in their cardio-pulmonary function and could potentially lead to a catastrophic outcome.

┼ 71. Medular Tolerance to Intraoperative Manipulation: Differences Between Acute and Slow Progressive Compression: Experimental Study

Elena Montes; Jesús J F. Burgos, PhD; Gema De Blas, MD, PhD; Carlos Barrios, MD, PhD; Eduardo Hevia, MD; Luis Miguel Antón-Rodrigálvarez, PhD; Carlos Correa Gorospe

Spain

Summary: This experimental study shows the neurophysiologic changes occurring during acute versus slow progressive compression of the spinal cord. Acute brisk compression is poorly tolerated causing complete and irreversible damage. While, in slow progressive compression the spinal cord shows bigger tolerance, and neural recovery is possible after compression release.

Introduction: The aim of this experimental study was to establish, by means of neurophysiologic monitoring, the degree of compression needed to cause neurologic injury to the spinal cord, and see if these limits varied by the speed of the compression applied.
Methods: The pig's spinal cord, of 5 domestic pigs (weight 35 kg), was exposed from T7 to T11. A couple of sticks, attached to a precision compression device, were placed at each spinal cord side (at T8 pedicle level). The sticks were approximated each other either at 0.5 mm every 2 minutes (progressive spinal cord compression) or suddenly 2.5 mm (acute compression). Cord to cord motor evoked potentials were obtained with two epidural catheters, for each sequential approach of the sticks, stimulating proximal to T6 and distal to T10.
Results: The mean dural sac width was 7.1 mm. For progressive compression, increasing latency and decreasing amplitude of the evoked potentials were observed after a mean displacement of the sticks of 3.2 ± 0.9 mm, the evoked potentials finally disappearing after a mean displacement of 4.6 ± 1.2 mm. The potentials always returned (mean time 16.8 ± 3.2 minutes) after the compression was released. The evoked potentials in acute compression (2.5 ± 0.3 mm) immediately disappeared, with no signs of recovering after 30 minutes.
Conclusion: The spinal cord showed marked sensibility to acute compression, which caused complete and irreversible injury. On the other hand there is certain tolerance when compression is applied progressive and slow. From a clinical point of view, it seems mandatory to avoid maneuvers of rapid mobilization or acute, even minimal, contusions of the thoracic cord.

┼ 72. Critical Events Before Spinal Cord Injury in a Porcine Compression Model

Vishal Sarwahi, MD; Etan P. Sugarman, MD; Aviva G. Dworkin, BS; Abhijit Pawar, MD; Marina Moguilevitch, MD; Terry D. Amaral, MD; Beverly Thornhill, MD; Adam L. Wollowick, MD; Alan D. Legatt, MD, PhD

USA

Summary: Iatrogenic spinal cord injury is a devastating complication of spinal deformity surgery. Our technique is to use real time laser Doppler flowmetry (LDF) measurements of spinal cord blood flow to identify critical events pre-injury.
Introduction: Multimodal neuromonitoring is currently the preferred method of spinal cord monitoring. However, it cannot detect spinal cord perturbation pre-injury. We hypothesize that LDF correlates well with intraoperative SSEP and MEP neuromonitoring, and that it can alert the surgeon of an acute, reversible injury before signal changes, allowing for interventions to prevent it or mitigate it. Furthermore we hypothesize that there are critical events throughout the procedure: pressure change, ischemia, time, and volume, which will aid in damage prevention.
Methods: After prone positioning and induction, multi-level laminectomies are performed in the mid-thoracic region. LDF electrodes are placed on the exposed dura in multiple areas to measure spinal cord blood flow and to assess real-time microcirculatory changes in the spinal cord. Spinal cord injury via compression is induced cephalad to laminectomy by inflating the balloon incrementally until MEP signals disappear. After injury occurs, as detected by a loss of MEP signals, several interventions were carried out: raising the systolic blood pressure, expanding the intravascular volume with colloids, and iv lidocaine. After interventions a wake up test was performed and a CT scan was done to measure the thoracic spinal canal volume.
Results: The mean reading 3 minutes before motor signals loss was - 24.4% from the baseline for 9 pigs. When the pressure of the balloon was on average (avg) less than 7 psi the blood flow was close to baseline, but on avg. as it reached over 7 and until 11 psi this was considered a gray zone where ischemia was seen. In terms of time, 3 min before the loss of motor signals is considered a critical. Lastly, the critical volume of less than 0.75cc was on avg. a safe zone, and greater than 0.75cc to 1.5 cc was detrimental. This was equal to 50% or greater compromise of the spinal canal volume (1.43 cc).
Conclusion: The critical events before spinal cord injury appeared to be: 50% canal compromise, 7-11psi pressure gradient, and 24.4% decrease in blood flow. In addition, the critical time appears to be 3minutes before the loss of motor signals. These data will prove useful in strategizing interventions for spinal cord injury prevention.

*73. Sagittal Parameters in Failed Paediatric Spinal Deformity Operations

Julian J. Leong, FRCS, PhD; Nitin Shetty, FRCS; Tejas K. Yarashi, MBChB; Alexa J. Offen, BSc; Stewart Tucker, FRCS

United Kingdom

Summary: Paediatric spinal deformity surgery has traditionally concentrated on correcting coronal imbalance. However, sagittal malalignment has been shown to correlate with adult spinal disability, in particular spino-pelvic parameters. A large retrospective database of over 4000 operated paediatric spinal deformity patients was examined, where 55 were found to have had revision surgery for pseudarthrosis or adjacent segment disease. Their pelvic incidence and lumbar lordosis mismatch was found to be higher than a matched control group.
Introduction: Sagittal imbalance in adult spinal deformity has been identified as a strong predictor of severe disability. However, less is known for paediatric spinal deformity. This study attempts to review the sagittal parameters in post operative paediatric spinal patients, and correlates these findings with the incidence of subsequent pseudarthrosis and adjacent segment disease.
Methods: The hospital database between 7th January 1992 and 29th December 2010 was interrogated to identify all paediatric

spinal deformity patients. Readmissions were identified and manually classified using hospital diagnostic/procedural codes, clinic letters, or radiographs. Radiographs of patients readmitted for surgery for pseudarthrosis and adjacent segment disease were examined, and the pelvic incidence (PI), lumbar lordosis (LL) and pelvic tilt (PT) were measured. Random matched control post operative radiographs were selected from the same period, and the sagittal parameters were measured for comparison.
Results: In 19 years, 4528 primary spinal deformity operations were identified, and 596 readmissions were recorded. Of which, 42 were for pseudarthrosis and 13 for adjacent level degeneration, where an average of 45 months delay was found between revision surgery and the index operation. The other reasons for readmission included: removal or trimming of metalwork (4.2%), recurrent deformity (1%), infection (2%), costoplasty (2.1%) injection (2.4%), and scar revision (0.1%). The PI and LL mismatch was higher in the patients who required revision surgery for pseudarthrosis and adjacent level degeneration, when compared to match controls (Fig 1). A clear difference in PT was not demonstrated between the groups.
Conclusion: Sagittal parameters may play an important role in paediatric spinal deformity surgery. Patients with high PI and LL mismatch appeared to require revision surgery either for pseudarthrosis or adjacent level degeneration; this would be consistent with previous reports in adult spinal deformity. Surgical goals in paediatric spine deformity should include restoring the natural sagittal parameters.

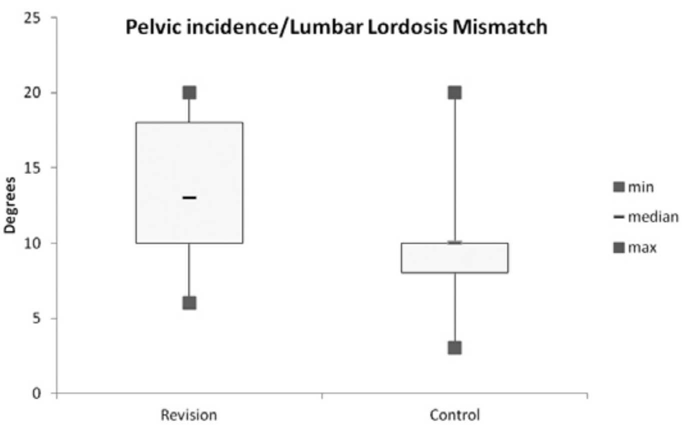


Fig 1 PI and LL mismatch between the revision group and control

*74. Lumbar Disc Degeneration on Unfused Segments in Adolescent Idiopathic Scoliosis: Long-Term Follow-Up Study Comparing Different Surgical Approaches

Ayato Nohara; Noriaki Kawakami, MD, DMSc; Taichi Tsuji, MD; Tetsuya Ohara; Yoshitaka Suzuki; Toshiki Saito; Ryo Sugawara; Kyotaro Ota; Kazuki Kawakami

Japan

Summary: Disc degeneration (DD) on the distal unfused segments in patients with adolescent idiopathic scoliosis (AIS) is regarded as an adverse effect of surgical treatment. This study compared the occurrence of DD among patients treated by different surgical approaches 10 years after surgery and indicated higher incidence of DD on adjacent segments of lower instrumented vertebra (LIV) in anterior fusion and on L5/S1 in posterior fusion.
Introduction: The purpose of this study was to investigate the occurrence of DD in distal unfused segments after three types of scoliosis surgery in AIS patients with a minimum F/U of 10 years. The patients were classified by anterior fusion (Group-A), posterior fusion (Group-P), and two-staged combined anterior & posterior fusion (Group-AP).
Methods: This study was a retrospective comparative study. The inclusion criteria of this study were: 1) AIS, 2) a minimum F/U of 10 years, 3) LIV: L2 - L4. 75 patients met all these criteria. Group-A included 21 patients (mean age: 16.0, Lenke type; 5C, 6C, number of fused segments (FS): 4.8). Group-P included 39 (mean age: 15.8, Lenke type: 1, 2, 3C, 5C, FS: 11.9). Group-AP included 15 (mean age: 17.1, Lenke type: 1C, 3C, 5C, 6C, FS: 11.8). The thoracic curve (TC), lumbar curve (LC), coronal balance (CB), L4 tilt, adjacent disc wedging (ADW), were evaluated preoperatively (preop.), immediately postoperatively (i-postop.), and 10 years postoperatively (10-postop.). DD was evaluated according to the Pfirmann's grading system using MRI images obtained 10 years after surgery.
Results: Scoliosis in all groups was corrected and maintained even at the time of 10-postop with a significant increase of ADW in Group-A (Table 1). DD occurred in 66.7% of Group-A, 66.7% of Group-P, and 60.0% of Group-AP. DD at the disc segments adjacent to LIV was seen in 52.4% of Group-A, 5.1% of Group-P, and 33.3% of Group-AP. DD on L5/S1 was recognized in 19.1% in Group-A, 57.9% of Group-P, and 33.3% of Group-AP. DD at adjacent level and L5/S were significant differences between Group-A and Group-P. 9 patients (42.9%) in Group-A, 18 patients (46.2%) in Group-P and 9 patients (60.0%) in Group-AP complained of 10-year postoperatively low back pain.
Conclusion: Although ASF has the tangible advantage of shorter fusion in comparison to posterior fusion, it showed a significantly higher incidence of DD on the adjacent disc segments of LIV with an increase of intervertebral disc wedging than posterior long fusion; the latter showed a higher incidence of DD on the L5/S disc. Clinical symptoms were not related to occurrence of DD at even 10 years after surgery.

Table 1. Correction of Scoliosis in Three Groups

		Group-A	Group-P	Group-A-P
Patients		21	39	15
Thoracic Curve	Pre. Op	35.8° *	64.1°	57.1°
	P.0. 10Y	22.0°	26.4°	24.2°
Lumbar Curve	Pre. Op	52.2° *	39.0°	60.9°
	P.0. 10Y	16.8°	17.3°	19.6°
Adjacent Disc Wedging	Pre. Op	4.5°	7.8°	4.4°
	Post. Op	7.3° *	4.2°	7.7°
	P.0. 10Y	9.0°	4.5°	6.6°
Decompensation (Pts.)	Pre. Op	4	5	4
	Post. Op	9	5	1
	P.0. 10Y	1	0	0

* P<0.01

*75. A New Predictive Model of Progression for Adolescent Idiopathic Scoliosis Based on 3D Spine Parameters at the First Visit: The Results of a Six-Year Prospective Observational Study

Marie-Lyne Nault, MD, PhD; Jean-Marc Mac-Thiong, MD, PhD; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BSc; Hubert Labelle, MD; Jacques A. de Guise, PhD; Stefan Parent, MD, PhD

Canada

Summary: A predictive model was developed to predict the Cobb angle at skeletal maturity in AIS. Analyses were based on a prospective cohort of 158 AIS patient from an initial 3D spinal reconstruction. The predictive factors of the model are type of curvature, skeletal maturity, initial Cobb angle, angle of plane of maximal curvature, 3D wedging of two disks and intervertebral rotation at the apex level. This is the first time that 3D parameters are identified as risk factors of progression.
Introduction: Prediction of curve progression remains challenging in adolescent idiopathic scoliosis (AIS) at the first visit. Prediction of progression is based on curve type, curve magnitude and skeletal or chronological age. Three-dimensional consideration is becoming more and more popular in the scoliosis research community either for classification or treatment planning. The objective of this study was to develop a predictive model of the final Cobb angle in adolescent idiopathic scoliosis based on 3D spine parameters.
Methods: A prospective cohort of 194 AIS was followed from skeletal immaturity to maturity (mean 37,4 months). A total of 158 patients could be included in analyses (81%). Computerized measurements were done on reconstructed 3D spines radiographs of the first visit. There were 6 categories of measurements: angle of plane of maximum curvature, Cobb angles (kyphosis, lordosis), 3D wedging (apical vertebra, apical disks), rotation (upper and lower junctional vertebra, apical vertebra, thoracolumbar junction), torsion and slenderness (height/width ratio). A general linear model analysis with backward procedure was done with final Cobb angle (either just before surgery or at skeletal maturity) as outcome and 3D spine parameters as predictors. Skeletal maturity stage and type of curvature were also included in the model.
Results: A predictive model was obtained with a determination coefficient (R2) of 0,702. Included predictors were a 3 stages skeletal maturity system and type of curvature. The initial frontal Cobb angle was also included as well as the angle of the plane of maximal curvature. The 4 others predictors were the 3D wedging of two different disks level, and the apical intervertebral rotation. In comparison, using the same data of this prospective cohort, the traditional parameters of Lonstein and Carlson (Cobb angle, chronological age and Risser sign) gave a R2 of 0,488.
Conclusion: This study has lead to the development of a predictive model of final Cobb angle in AIS based on information available at first visit. It is the first time that 3D parameters are identified as risk factors of progression which supports the recent interest of 3D analysis in AIS. This new model will help clinicians make better clinical decisions.

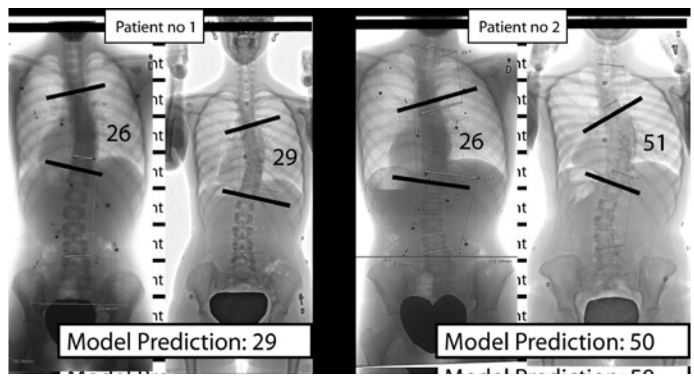


Figure 1: Example of 2 patients. Left radiograph is from first visit and right radiograph at skeletal maturity.

*76. Prospective, Multi-Center Assessment of Acute Neurologic Complications Following Complex Adult Spinal Deformity Surgery: The Scoli-Risk-1 Trial

Lawrence G. Lenke, MD; Michael G. Fehlings, MD, PhD; Christopher I. Shaffrey, MD; Kenneth M. Cheung, MBBS(UK), FRCS(England), FHKCOS, FHKAM(Orth); Leah Y. Carreon, MD, MSc

USA

Summary: The Scoli-Risk-1 trial is a SRS/AOSpine collaborative, prospective, multicenter observational study with a primary aim of assessing the accurate neurologic complication rate following complex adult spinal deformity surgery using the detailed ASIA scoring system. 256 patients were enrolled from 15 centers around the world and a 17.2% (44/256 pts) acute lower extremity motor deficit rate was confirmed at 6 weeks postoperative evaluation.
Introduction: The SRS and AOSpine organizations collaborated

on the Scoli-Risk 1 study in order to confirm the precise neurologic complication rate following a consecutive series of complex adult spinal deformity (ASD) surgeries in a prospective, multicenter observational trial. This report compares the preop to 6-week postop lower extremity motor scores (LEMS) using the detailed the ASIA Neurological Examination.

Methods: 256 complex ASD pts from 15 sites (9 North American, 3 Asia/Pacific, 3 European) were enrolled from Sept 2011 to Oct 2012. Diagnoses included primary coronal/sagittal deformity >80° (n=78), cong. deformity (n=13), revision deformity requiring osteotomy (n=107) and/or pts undergoing a 3-column osteotomy (3-CO) (n=202/256 79% all pts) There were 171 females (67%) and 84 males (33%) with a mean age of 57.7 yrs (range 18-85). All pts had preop and 6-week postop complete ASIA neuro exams performed by ASIA-certified examiners. This study examines specifically the LEMS (25 pts/side=50 pts max) to ascertain the acute LE motor complication rate.

Results: 194/256 (76%) pts had a normal (NL) LEMS preop (NL Group) while 62 (24%) had some motor weakness (mean 44.1±7.1; (abnormal) ABNL Group). At 6 weeks postop, there was a statistically significant decline in LEMS in the NL Group (49.1±2.9 (range 1-20 pt decline; p<0.0001), while there was no LEMS change in the ABNL Group (44.7±9.0, p=0.23). Of the 256 pts, 212 (83%) either stayed the same (n=172) or improved (n=40) neurologically postop, while 44 (17%) had a worse LEMS postop (preop NL Group 32 pts, 73%; preop ABNL Group 12 pts 27%) (Table 1). Risk factors for deterioration in the LEMS postop included older age (mean 56.8 without vs 61.7 with decline, p=0.03) and a strong trend for revision pts undergoing an osteotomy (p=0.09), but surprisingly not in those undergoing a 3-CO (p=0.23).

Conclusion: The Scoli-Risk-1 trial found a 17.2% (212/256) acute LE motor weakness complication rate following complex ASD surgery. Age (p=0.03) and to a lesser extent revision osteotomy procedures (p=0.09) were risk factors for LE motor loss. This neuro complication rate should be considered the "Gold Standard" in these types of complex procedures due to the strict protocol and detailed ASIA exams.

Table 1. LEMS Normal vs Abnormal

	Normal LEMS Preop (n=194)	Abnormal LEMS Preop (n=62)
No LEMS Change	162	10
Worsening of LEMS	32	12
Improvement of LEMS	0	40

LEMS: lower extremity motor score

*77. Incidence and the Risk Factors of Major Surgical Complication in Patients with Complex Spine Deformity: A Report from an SRS GOP Site

Mitsuru Yagi, MD, PhD; Cristina Sacramento-Dominguez, MD, PhD; Han Jo Kim, MD; Oheneba Boachie-Adjei, MD; FOCOS Research Associates

Japan

Summary: Post op Complication was seen in 27% of surgically treated patients with complex spine deformity at an SRS GOP site 3column osteotmy is seen as an independent risk factors of both post-op complication and neurological deficit. The significant correlation of 3 column osteotomy and post-op neurological deficit seen in the present study and should be a guide for surgeons in their preoperative planning and surgical management of severe spine deformity especially in an outreach site where resources are limited.

Introduction: Corrective spine surgery for complex spine deformity is technically demanding. It often requires a multidisciplinary approach to manage these patients perioperatively. As the SRS promotes global outreach in regions with limited resources the incidence and risk factors for major pot operative complications is largely unknown. The purpose of this study is to report the incidence and to identify the risk factors of perioperative complications in surgically treated patients with complex spine deformity.

Methods: 432 consecutive patients with complex spinal deformity of various etiologies who underwent instrumented spinal fusion were reviewed. Radiographic and demographic data were review for pre-op, and immediate post-op. Potential risk factors include age, etiology, type of procedure. Multi-variate logistic regression analysis (LRA) was performed to indicate the independent risk factor of post-op complication and neurological deficit. P value of < 0.05 with CI of 95 % was considered significant.

Results: The average age was 15.0 yrs (1-47 yrs). The etiology was idiopathic scoliosis (n=207), congenital scoliosis (n=101), infectious (n=89), and others. 84 pts had 3 column osteotomy. Major complication was seen in 90 cases. Major complication consisted of neuro deficit (n=23; transient (n=16) and permanent (n=7), deep wound infection (n=14), implant related (n=18), progressive deformity (n=5), DEATH (n=6) No blindness was encountered. multi-variate LRA indicated 3 column osteotomy as an independent risk factor for both post-0p complication and neurological deficit. (Complication; p = 0.004, OR: 2.19 (1.28, 3.76), Neuro deficit; p = 0.0,4 OR: 2.45 (1.02, 5.92)).

Conclusion: Post op Complication was seen in 27% of surgically treated patients with complex spine deformity at an SRS GOP site 3column osteotmy is seen as an independent risk factors of both post-op complication and neurological deficit. The significant correlation of 3 column osteotomy and post-op neurological deficit seen in the present study and should be a guide for surgeons in their preoperative planning and surgical management of severe spine deformity especially in an outreach site where resources are limited.

*78. Recombinant Human Bone Morphogenetic Protein-2 (rhBMP-2) Use in Adult Spinal Deformity (ASD) Does Not Increase Major, Infectious or Neurological Complications and May Decrease Return to Surgery at One Year: A Prospective, Multi-Center Analysis

Shay Bess, MD; Breton Line, BSME; Christopher I. Shaffrey, MD; Eric Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Douglas C. Burton, MD; Munish C. Gupta, MD; Robert A. Hart, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Justin S. Smith, MD, PhD; International Spine Study Group

USA

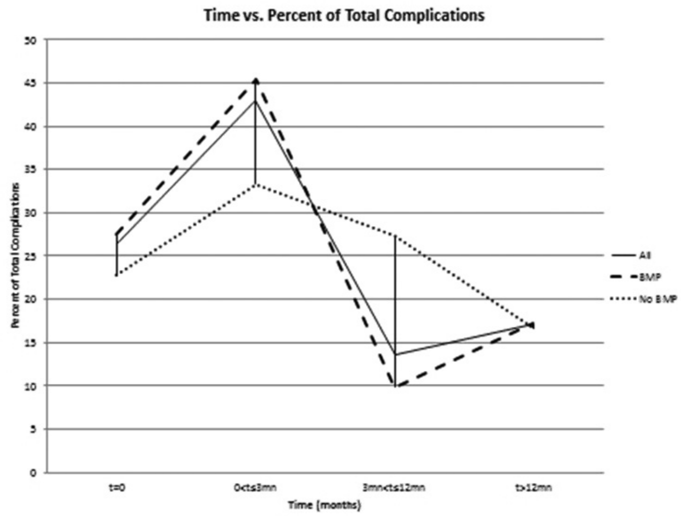
Summary: Prospective, multi-center analysis of postoperative complications at one year for BMP vs. NOBMP use in 261 consecutive ASD patients demonstrated total and minor complications were greater for BMP vs. NOBMP (p<0.05). Major, wound, infectious and neurological complications were similar for BMP vs. NOBMP. At 0-3 months, NOBMP had lower incidence of total and minor complications than PBMP and I+PBMP (p<0.05). At 3-12 months NOBMP had greater incidence of major complications and complications requiring surgery than PBMP and I+PBMP.

Introduction: Previous analysis demonstrated similar acute postoperative major, neurological and wound complications for ASD patients receiving rhBMP-2 vs. NOBMP. Purpose: evaluate one year complication rates for the same operative cohorts.

Methods: Multicenter, prospective analysis of postoperative complications for consecutive ASD patients receiving rhBMP-2 (BMP) or no BMP (NOBMP). Inclusion criteria: ASD, age ≥ 18 years, spinal fusion≥ 4 levels, minimum one-year follow up. BMP evaluated by location of use: posterior only (PBMP), interbody only (IBMP), interbody + posterior (I+PBMP). Incidence and timing of complications evaluated and multivariate analysis performed.

Results: 261 patients, mean follow up 30.3 months (range 12.2-47.9), met inclusion criteria. BMP (n=158; mean posterior dose 2.5mg/level, mean interbody dose 5 mg/level) and NOBMP (n= 103) had similar demographics, deformity and total fusion levels . BMP had greater operative time, osteotomies/patient, and APSF (p<0.05). BMP had greater total (1.4 vs.0.6) and minor complications/ patient (0.9 vs. 0.3) vs. NOBMP (p<0.05). Major, neurological, and wound complications were similar BMP vs. NOBMP. At 0-3 months, NOBMP had lower incidence of total complications (18% vs. 45% vs. 36%) and minor complications (7.8% vs. 40% vs. 24%) vs. PBMP (N=93) and I+PBMP (N=58; p<0.05). At 3-12 months NOBMP had greater incidence of major complications (63% vs. 32% vs.40%), and complications requiring surgery (13% vs. 1.1% vs.3.5%) than PBMP and I+PBMP (p<0.05; Figure). Neurological, wound and infection complications/patient during specific time frames were similar for all groups. Correlations between rhBMP-2 use and major, neurological and wound complications were small to non-existent (r2 <0.15).

Conclusion: RhBMP-2 use for ASD surgery, at reported dose/level, had similar one year major, infectious and neurological complications as NOBMP but complication timing differed. Complication timing should be considered for rhBMP-2 use in ASD.



Complication Timing for BMP vs. NOBMP Use In ASD

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

*79. Comparative Analysis of Osteotomies During Adult and Pediatric Spinal Fusions: A Retrospective Review of >6,000 Cases from the Scoliosis Research Society Morbidity and Mortality Database

Samuel K. Cho, MD; Natalia N. Egorova, PhD, MPH; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; John Caridi, MD; Yongjung J. Kim, MD

USA

Summary: Osteotomies are useful when correcting spinal deformities but carry potential for complications. We report the largest series of adult (n=3,990) and pediatric (n=2,854) patients who underwent four different osteotomies during spinal fusion and found significant difference in complication rates with three-column osteotomies having higher complications, including mortality for adults and neurologic deficit for both children and adults, when compared to Smith-Petersen osteotomy.

Introduction: Various osteotomies are used to correct spinal deformities but potentially increase complication rates. We compared four different osteotomies and assessed complication rates in adult and pediatric patients who underwent spinal fusion using a large multi-institutional database.
Methods: The Scoliosis Research Society morbidity and mortality database was queried for pediatric (<18 years) and adult patients (>18 years) who had spinal fusion from 2004-2007. Patient demographics, surgical characteristics, and complications were analyzed based on osteotomy type. Two-tailed Fisher's exact test was performed.
Results: Of 3,990 adult cases, 1,747 (44%) had Smith-Petersen osteotomy (SPO), 1,027 (26%) pedicle subtraction osteotomy (PSO), 903 (23%) anterior discectomy/corpectomy (AC), and 313 (8%) three-column resection (VCR). 2,854 pediatric cases were divided into 1,717 (60.2%) SPO, 419 (14.7%) PSO, 340 (11.9%) AC, and 298 (10.4%) VCR. Diagnosis for adults included scoliosis (n=1,304, 32.7%), kyphosis (n=1,107, 27.7%), other (n=603, 15.1%), degenerative (n=452, 11.3%), spondylolisthesis (n=224, 5.6%), fracture (n=222, 5.6%), and missing (n=78, 2.0%). The majority of pediatric diagnosis were scoliosis (n=2,038, 71.4%) and kyphosis (n=691, 24.25). Overall complication rates for adults were 10.9% (n=98) for AC, 16.3% (n=285) for SPO, 22.8% (n=234) for PSO, and 27.8% (n=87) for VCR with significant difference (p <0.0001) when each osteotomy was compared to SPO. Adult mortality rates were 0.1% (n=2) for SPO, 0.4% (n=4) for AC, 0.7% (n=7) for PSO, and 1.3% (n=4) for VCR. Neurologic deficit was found in 2.2% (n=20) for AC, 2.6% (n=46) for SPO, 5.8% (n=18) for VCR, and 5.9% (n=61) for PSO (p<0.0001 for VCR and PSO compared to SPO). In children, complications rates were 9.0% (n=154) for SPO, 12.9% (n=54) for PSO, 16.2% (n=55) for AC, and 19.8% for VCR (n=59). There were 7 mortalities (0.2%). Neurologic deficit was found in 1.6% (n=27) for SPO, 4.4% (n=15) for AC, 3.3% (n=14) for PSO, and 9.1% (n=27) for VCR.
Conclusion: Most osteotomies were performed for scoliosis (32.7% in adults and 71.4% in children) and kyphosis (27.7% in adults and 24.2% in children). Complication rates were significantly higher for three-column procedures, including mortality for adults (0.7% for PSO and 1.3% for VCR) and neurologic deficit for both adults (5.8% for VCR and 5.9% for PSO) and children (9.1% for VCR and 3.3% for PSO), when compared to SPO.

*80. Antifibrinolytics Reduce Blood Loss in Adult Spinal Deformity Surgery: A Prospective Randomized Controlled Trial

Kseniya Slobodyanyuk; Thomas Cheriyan; Frank J. Schwab, MD; Kushagra Verma, MD, MS; Christian Hoelscher, BS; Austin Peters; Tessa Huncke, MD; Baron S. Lonner; Thomas J. Errico

USA

Summary: A randomized, double-blinded, placebo controlled comparison of tranexamic acid (TXA) and aminocaproic acid (EACA) in reducing blood loss in spine surgery. TXA and EACA were found to reduce blood loss relative to placebo, with no difference between the medications.
Introduction: Adult spinal deformity (AD) surgery usually involves substantial blood loss The antifibrinolytics TXA and EACA have been shown to improve hemostasis in large blood loss surgeries. This study aimed to provide high-quality evidence regarding relative efficacies of TXA, EACA and placebo in reducing bleeding and transfusions in spine surgery.
Methods: A prospective, randomized, double-blinded comparison of intraoperative TXA, EACA and placebo in AD. Fifty two patients (ages 18-80) undergoing posterior spinal fusion of at least five levels for correction of AD were randomized to one of three groups. Primary outcome measures were intraoperative and total blood loss (TBL) and transfusions. Secondary outcomes were change in hematocrit (Hct) and complications.
Results: For patients age ≥50, intraoperative blood loss in both TXA (1297±190 mL) and EACA groups (1278±223 mL) was less than control (2954±1116 mL, p=0.02). Similarly, TBL was reduced in TXA or EACA compared to placebo in patients age ≥50 (TXA 3085±1261 mL; EACA 2857±854 mL; control 5468±2881 mL; p=0.01).
For patients age <50, there was no significant difference between the groups in terms of intraoperative and TBL.
Postoperative transfusion rates were statistically different between EACA (10%) and placebo (29%) (p=0.03), However, there was no difference in intraoperative or postoperative transfusion rates between other groups.
No differences were noted in postoperative blood loss and change in Hct. One patient in each treatment arm was diagnosed with pulmonary embolism and one patient in the TXA group expired postoperatively; no thromboembolic events were reported for placebo.
Conclusion: TXA and EACA antifibrinolytics reduce blood loss in posterior adult deformity surgery in patients older than 50 years.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

*81. Two-Year Prospective, Multi-Center Analysis of Consecutive Adult Spinal Deformity (ASD) Patients Demonstrates Higher Fusion Grade, Lower Implant Failures and Greater Improvement in SRS-22r Scores for Patients Treated with Recombinant Human Bone Morphogenetic Protein-2 (BMP)

Shay Bess, MD; Breton Line, BSME; Eric Klineberg, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Douglas C. Burton, MD; Khaled Kebaish, MD; Robert A. Hart, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; International Spine Study Group

USA

Summary: Minimum 2 year follow up of multicenter, consecutive, prospectively enrolled ASD patients (n=141) treated with BMP vs. NOBMP (mean BMP doses: posterolateral= 2.6mg/level, interbody= 5.3 mg/level) demonstrated BMP had higher mean Lenke fusion grade (1.9 vs. 1.5), lower implant failure rate (1.8 vs. 13%), and greater improvement in SRS-22r total (0.9 vs. 0.5), mental (0.4 vs. -.02), and pain scores (1.0 vs. 0.4) than NOBMP, respectively (p<0.05). Major complications, infections, and neurological complications were similar for BMP vs. NOBMP.

Introduction: Theoretical advantages of BMP use include high fusion rates and improved outcomes, however little data exists evaluating fusion grade, complications and health related quality of life (HRQOL) for ASD patients treated with BMP. Purpose: evaluate fusion grade, complications and HRQOL associated with BMP vs. no BMP use in a prospective, multicenter, consecutive ASD cohort, minimum 2 year follow-up.

Methods: Multicenter, prospective analysis of consecutive ASD patients receiving BMP (BMP) or no BMP (NOBMP). Inclusion criteria: ASD, age ≥ 18 years, spinal fusion≥ 4 levels, complete demographic and radiographic data, and minimum two-year follow up. ASD=scoliosis ≥20 degrees, sagittal vertical axis ≥5cm, pelvic tilt ≥25 degrees, or thoracic kyphosis> 60 degrees. Spine fusion evaluated using Lenke grade, complications noted, baseline and 2 year postoperative HRQOL (SRS-22r, SF-36, ODI) analyzed.

Results: 141 of 189 patients had complete two year data (75% follow-up); mean follow up 35.8 months (range 24.1-47.9). BMP (n=110; mean BMP doses: posterolateral= 2.6mg/level, interbody= 5.3 mg/level) and NOBMP (n= 31) had similar preop deformity, baseline HRQOL, and total posterior fusion levels (BMP=11.6, NOBMP=12.9). BMP was older (56 vs. 49 years), had more anteroposterior surgery (25 vs. 6.5%), and fewer pedicle subtraction osteotomy/patient (0.12 vs. 0.3), than NOBMP, respectively (p<0.05). BMP had more minor complications (61% vs. 29%) and fewer implant failures (1.8 vs. 13%) than NOBMP, respectively (p<0.05). Mean BMP fusion grade was greater than NOBMP (1.9 vs. 1.5; p<0.05). BMP had greater 2 year improvement in SRS-22r total (0.9 vs. 0.5), mental (0.4 vs. -.02), and pain (1.0 vs. 0.4) scores than NOBMP, respectively (p<0.05).

Conclusion: BMP use in ASD, at reported BMP dose/level, demonstrated higher fusion grade, fewer implant failures, similar major complications, and greater HRQOL improvement at 2 year follow-up than NOBMP. Research is needed evaluating long term complications and outcomes.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

82. Affordable Care Act (Obamacare) Versus Medicare Reimbursement for Spinal Surgeons: Analysis of Hourly Earnings for Four Degenerative and Three Scoliosis Surgeries

Dennis Crandall, MD; Melissa Gebhardt, PA-C; Michael S. Chang, MD; Jason Datta, MD; Terrence Crowder, MD

USA

Summary: Surgeon reimbursement per hour of work for 2012 Medicare and Accountable Care Act (ACA) patients (27% below Medicare) was evaluated using 4 common spine surgeries and 3 scoliosis surgeries done by 10 spine surgeons at one hospital. Care included preop and postop visits through one year, offset by a range of overhead percentages. Reimbursement/hour was compared to other professions. Using 60% overhead, hourly pay for Medicare single-level fusion paid $131(ACA=$96); laminectomy paid $55 (ACA=$39, or the same as a nurse).

Introduction: The Affordable Care Act (ACA) reimbursement for surgeons is 27% below 2012 Medicare, leading some surgeons to question their ability to care for these patients. We examined surgeon reimbursement/hour work under Medicare and ACA for common surgeries performed for degenerative disease and adult scoliosis. Surgeon hourly pay was compared to other professions.

Methods: Hospital data was reviewed for all patients undergoing 4 common surgeries by 10 surgeons during 2012:1) 1 level laminectomy; 2)1 level posterior spinal fusion(PSF) and TLIF; 3) 2 level PSF/1 level TLIF; 4)anterior cervical discectomy/fusion/plating(ACDFP). Three types of scoliosis surgery were also reviewed: 1)Small Degen Scoliosis(SDS)- 3 level laminectomy(lami)+ posterior spinal fusion(PSF) L2-5; 2) Adult Idiopathic scoliosis (IS)- PSF T4-L4; 3)Large Degen Scoliosis(LDS)- PSF T11-S1+ 3 level lami+ 1 level TLIF. Time spent in patient care included in the global fee (preop discussion, intubation, positioning, surgery, dictation, family discussion, rounding time, postop visits at 2, 6, 12 wks) and additional billable care (surgical consult, pre-op visit, postop visits at 6,9,12 mo) were recorded. The total hrs spent in surgeon-provided care was divided by Medicare and ACA reimbursements to obtain $/hr surgeon payment for each surgery, and adjusted by a range of practice overhead (40%, 50%, 60% and 70%).

Results: Operative times: lami- 2.1 hrs (1.4-3.4hrs), PSF/TLIF-

2.8 hrs (2.1-4.0hrs), 2 level PSF/TLIF- 3.7 hrs (2.1-5.6hrs), ACDFP- 2.3 hrs (1.5-3.3hrs) SDS-5.6 hrs (5.0-6.1hrs), IS-5.7 hrs (4.5-8.5hrs), LDS-6.9 hrs (5.0-8.3hrs). Hospital length of stay: Lami- 1 day (1-3days), PSF/TLIF- 3 days (1-5days), 2 level PSF/TLIF- 3 days (1-6days), and ACDFP- 1 day (1-2days), SDS-5.75 days(4-8days), IS-5.6 days(4-9days), LDS-6.1 days(4-9days). Total care time: Lami- 8.85 hrs, PSF/TLIF- 10.58 hrs, 2 level PSF/TLIF - 11.42 hrs, ACDFP - 7.82 hrs, SDS-12.65 hrs, IS-12.81 hrs, LDS-14.26 hrs.

Conclusion: Medicare and ACA reimbursement will impact the economic viability of many surgical practices, in some cases paying the surgeon the same as a nurse. Spine surgeons must become creative in order to earn what average orthopedic and neurosurgeons make.

Pay Per Hour of Surgeon Work - by procedure (60% OH)

	OR Time (hrs)	Hospital stay (days)	Total Care (hrs)	Medicare	Afford. Care Act
1 Laminectomy	2.1 (1.4-3.4)	1 (1-3)	8.85	$54.85	$39.77
1 PSF+TLIF	2.8 (2.1-4.0)	3 (1-5)	10.58	$131.96	$95.67
2 PSF+1 TLIF	3.7 (2.1-5.6)	3 (1-6)	11.42	$138.28	$100.25
1 ACDFP	2.3 (1.5-3.3)	1 (1-2)	7.82	$130.37	$94.52
Small Deg Scoli	5.6 (5.0-6.1)	5.75 (4-8)	12.65	$193.42	$140.23
Adult Idiop Scoli	5.7 (4.5-8.5)	5.6 (4-9)	12.81	$94.59	$68.57
Large Deg Scoli	6.9 (5.0-8.3)	6.1 (4-9)	14.26	$152.85	$110.81

	Average pay $/hour
Neurosurgeon	$237.37
Ortho Surgeon	$200.04
Oral Surgeon	$112.75
Chief Executive	$107.41
Lawyer (general)	$79.54
Veterinarian	$62.12
Physician Asst.	$45.95
Nurse	$39.93

83. Combined Orthopaedic and Neurosurgical Attending Surgeon Approach to Adult Spinal Deformity Surgery: A Multi-Center and Multi-Disciplinary Perspective

Rajiv K. Sethi, MD; Erion Qamirani, MD, PhD; Alexander A. Theologis, MD; Jean-Christophe Leveque, MD; Christopher P. Ames, MD; Vedat Deviren, MD

USA

Summary: Current complication rates in adult spinal deformity surgery are unacceptably high, with a reported rate of 40-86%. New multi-disciplinary approaches are therefore needed to mitigate risk and increase patient safety for an elderly population undergoing reconstructive spinal surgery. A combined orthopaedic and neurosurgical attending approach to adult spinal deformity surgery can enhance patient safety and substantially reduce perioperative complication rates by approximately 50% compared to current rates. This is the first report detailing this approach at two spinal deformity centers.

Introduction: A dual attending surgeon approach to adult spinal deformity surgery has multiple benefits, including a significantly lower overall complication rate, compared to a single surgeon approach at individual institutions. However, its effectiveness has yet to be demonstrated at multiple centers. This study is the first to present the combined outcomes of patients at two different institutions who underwent adult deformity surgery by an attending neurosurgeon and orthopaedic surgeon operating together.

Methods: 312 consecutive cases were retrospectively reviewed at two tertiary spinal deformity centers in Seattle and San Francisco. All cases were performed by an attending neurosurgeon and orthopaedic spinal surgeon together and included spinal deformity procedures involving 9-15 levels via the posterior approach. Three column osteotomies performed through a posterior approach, minimally invasive lateral approaches, and traditional anterior approaches were also included. Outcome measures included 30- and 90-day readmission rates for wound infections requiring reoperation, hardware failure requiring reoperation, pneumonia, urinary tract infection (UTI), stroke, thromboembolic events (deep venous thrombosis and/or pulmonary embolism), iatrogenic neurological injury, and death.

Results: See Table 1. The average patient age was 64 years (18-88 years). The overall 30-day complication rate was 18%. The overall 90-day complication rate was 23%. The 90-day complication rates were as follows: wound infection requiring reoperation (6%), UTI (5%), need for re-operation for hardware failure (4%), thromboembolic events (2%), pneumonia (2%), neurological injury (1%), stroke (<1%), and death (<1%).

Conclusion: A combined orthopaedic and neurosurgical attending approach to adult spinal deformity surgery can enhance patient safety and substantially reduce perioperative complication rates by approximately 50% compared to current rates. This is the first report detailing this approach at two spinal deformity centers.

84. Effect of Preoperative Indications Conference on Procedural Planning for Treatment of Scoliosis

Charles M. Chan, MD; Howard Y. Park, BA; Joshua E. Hyman, MD; Michael G. Vitale, MD, MPH; David P. Roye, MD; Hiroko Matsumoto, MA; Benjamin D. Roye, MD, MPH

USA

Summary: This study examined the effect of preoperative indications conference on procedural planning for treatment of scoliosis in index, revision, and scheduled lengthening cases. There was a rate of change of 27% for index surgeries and 18% for revisions. Index adolescent idiopathic scoliosis (AIS) surgeries were most likely to experience a change of plan with addition of fusion levels being the most common change.

Introduction: While there are established general guidelines for scoliosis treatment, levels of fusion, construct options, and necessity for osteotomies are often the subject of debate in the planning of scoliosis surgery. To overcome this difficulty, we used consensus based decision making. The purpose of this study is to determine the effect of preoperative indications conference on the intended plan of surgery and to identify

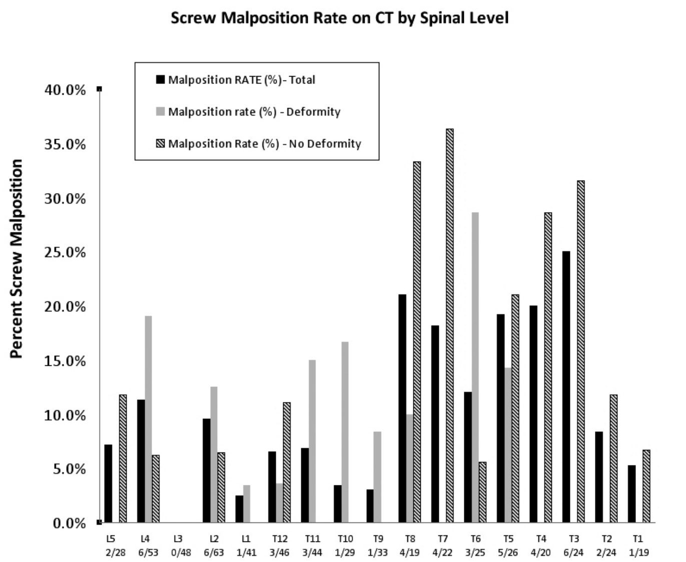
characteristics that increased the likelihood for change.
Methods: All planned pediatric scoliosis surgeries between October 22, 2012 to January 28, 2013 were presented at preoperative indications conference held with five attending pediatric orthopaedic surgeons present. The operative surgeon was asked to commit to a surgical plan prior to each conference. A consensus-based plan was made at the end of each case presentation without knowledge of the operative surgeon's pre-conference plan. Changes of plan were classified as major (cancellation of surgery, extension of fusion level ≥4 levels, change from fusion to growing based technique), minor (change of fusion levels <4 levels, addition of procedure eg osteotomy), or no change.
Results: Of the 60 surgical plans included in our study, 22 were for index surgeries, 9 for revisions, and 26 for scheduled growing rod lengthenings. There were 8 total incidences of minor procedural change, 7 of which resulted in change of fusion levels ranging from 1 to 3 (mean:1.33) and 1 change resulting in the addition of an osteotomy. The rate of the change was 27% for index surgeries and 18% for revisions. Of the 6 procedural changes in the 22 index surgeries, 4 carried a diagnosis of AIS, 1 cerebral palsy, and 1 congenital scoliosis. There were no procedural changes for scheduled growing rod lengthenings. There were also no cancellations of surgery as a result of preoperative indications conference.
Conclusion: While revision scoliosis surgery is often fraught with more complexity, index AIS surgery was most subject to the influence of preoperative indications conference. This likely reflects the single most controversial aspect of scoliosis surgery which is choosing levels of fusion.

85. At What Levels are Free Hand Pedicle Screws Most Frequently Malpositioned in Children?

Mark J. Heidenreich, BS; Yaser M. Baghdadi, MD; Anthony A. Stans, MD; Mark B. Dekutoski, MD; William J. Shaughnessy, MD; Amy L. McIntosh, MD; A. Noelle Larson, MD

USA

Summary: Pedicle screws placed by the freehand technique in children were found to have the highest rate of malposition from T3 to T8 (19% vs. 6%, p=0.0001). Medial breaches and pedicle screw malposition > 2 mm were more frequent in pediatric patients with deformity than without deformity.
Introduction: On CT evaluation, pedicle screws placed by freehand technique in pediatric deformity surgery have up to a 9% rate of malposition. We sought to determine which region of the spine is associated with the greatest risk for screw malposition in pediatric patients with and without deformity.
Methods: Incidental postoperative CT exams were available in 85 pediatric patients (605 screws) treated with posterior spinal fusion using freehand pedicle screw technique. Of the screws imaged, 355 were in patients without deformity (fracture, tumor), and 250 screws in patients with deformity (scoliosis, any type). Malposition/breaches were categorized as mild (< 2 mm), moderate (2-4 mm), or severe (> 4 mm). We hypothesized that screws at the apical concavity would have a higher rate of malposition.
Results: Screws in pediatric patients with deformity had a higher rate of moderate/severe malposition compared to pediatric patients without deformity (19% vs. 27%, p=0.02). For severe malposition (> 4mm), no difference was found between patients without deformity and patients with deformity (9.6% vs. 8.6%, p=0.40). Overall, the highest rates of severe screw malposition were at T3 through T8 (Figure), which is also the region of smallest pedicle diameter in children. In patients with deformity, no higher rate of screw malposition was detected at the apical levels, or at the apical concavity. Severe medial breaches were more common in patients with deformity (8 of 19) compared to patients without deformity (6 of 34, p=0.005).
Conclusion: The clinical significance and acceptable rate of asymptomatic pedicle screw breaches in children has not yet been determined. There does not appear to be a higher rate of malposition in the apical concavity, although medial breaches were more frequent in patients with deformity. Efforts to reduce the rate of pedicle screw malposition would likely be most effective at T3 to T8, where screw malposition using the freehand technique is most frequent in children.



Percent of screws by level malpositioned as seen on incidental CT.

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86. Long-Term Effects of Thoracic Pedicle Screws with Intraoperative Undetected Invasion of the Spinal Canal at the Convexity in Scoliotic Patients

Jesús J F. Burgos, PhD; Gema De Blas, MD, PhD; Carlos Barrios, MD, PhD; Eduardo Hevia, MD; Luis Miguel Antón-Rodrigálvarez, PhD; Ignacio Sanpera, MD, PhD

Spain

Summary: SUMMARY:
The long-term impact of thoracic pedicle screws (TPS), with undetected invasion of the spinal canal at the convexity, was analyzed in 68 patients undergoing scoliosis surgery. All patients remained symptomless, with unchanged somatosensory stimulation and no evidence of screw migration at 5-year follow-up.

Introduction: There is no literature on the long-term effects TPS inadvertently invading the spinal canal at the convexity in patients with scoliosis. The aim of the study was to analyze if asymptomatic convexity TPS may bear consequences during and after skeletal growth.

Methods: A series of 68 patients undergoing surgery using TPS were studied by postoperative CT-Scan, to assess the accuracy of TPS placement. The freehand technique was used for TPS placement, and three intraoperative controls were used to confirm screw location: Screw path palpation, fluoroscopy and screw neurophysiologic monitoring. A total of 8 patients (11.5%) had convexity TPS protruding into the spinal canal by > 4 mm, all of them were asymptomatic at that time. Five patients had a single screw, and 3 patients 2 misplaced screws (11 screws). The cohort included 7 AIS and 1 congenital. The mean Cobb angle was 59.2° (range 36-73°) with a Risser 2 (0-3). All screws were located in the apical curve convexity. The patient's intraoperative data was retrospectively review. At the last examination all patients had a somatosensory evoked potentials study, and CT- Scan. Finally the SRS-22 questionnaire was completed.

Results: Patients had a median follow-up of 5 years (range 36-82 months) and all have reached skeletal maturity. The mean intraoperative EMG threshold was 12.5 mA (9.5-18 mA), well above the threshold considered of risk of screw penetration. At final review, a CT-Scan limited to the malposition screws show no changes in position. The somatosensory evoked potential remained unchanged. The SRS-22 questionnaire shows a clear improvement in all patients.

Conclusion: Patients with asymptomatic convexity TPS show no clinical, electromyography, or radiological changes in the long-term follow-up.

87. The Incidence of Neurologic Symptoms Using Free Hand Pedicle Screw Placement in Pediatric Deformity

Ozgur Dede, MD; Austin Bowles, MS; James W. Roach, MD; W. Timothy Ward, MD; Patrick Bosch, MD

USA

Summary: This study evaluated the safety of thoracic and lumbar pedicle screws, placed with a freehand technique, in idiopathic scoliosis at a major pediatric hospital over a period of 12 years. There were no permanent neural deficits and the revision rate for misplaced pedicle screws was exceedingly low.

Introduction: This study evaluated the incidence of postoperative neurological symptoms following a free hand pedicle screw insertion technique in idiopathic posterior scoliosis surgery.

Methods: Between 1/1/2000 and 10/2/2012, 1137 patients at our institution had thoracolumbar posterior instrumented spine surgery. Each patient's chart and radiographs were reviewed and only those with idiopathic scoliosis were included. Patients with neuromuscular and syndromic diagnoses were excluded as well as those with congenital or traumatic etiologies, incomplete charts, less than 3 months of follow-up and those without pedicle screws. The records were studied for complaints of radicular pain, neurological deficit, or severe headache which could be indicative of potential screw malplacement.

Results: 475 patients and 5965 pedicle screws met the inclusion criteria. 9 patients (1.9%) developed symptoms and underwent CT scanning. 6 patients were found to have pedicle screw malposition (8 screws) and 3 of these patients underwent revision surgery. Of the three revision patients, two presented with radicular symptoms (leg pain) and one with an orthostatic headache due to CSF leakage. At final follow up all revision patients had complete symptom resolution.
Three other patients presented with unilateral flank pain and were found to have medially placed thoracic screws on CT scanning but to date none of the three has elected to have revision surgery.
The remaining 3 patients had normal CT scans and their symptoms resolved without intervention.
In total, there were 8 symptomatic, misplaced pedicle screws (0.13%) in 6 patients (1.26%).

Conclusion: Over a 12 year period in a dedicated pediatric orthopaedic hospital using the free hand placement technique the incidence of symptomatic misplaced pedicle screws was exceedingly low. The use of intraoperative CT navigation for pedicle screw placement is gaining popularity. However, the cost and added radiation exposure is a concern and based on our findings, may not be warranted in pediatric posterior spinal deformity surgery.

88. Tranexamic Acid and Intrathecal Morphine are Synergistic in Reducing Transfusion Requirements in Non-Idiopathic Scoliosis Patients Undergoing Posterior Spinal Fusion

Gideon Blumstein, MS; Derek A. Seehausen, BA; Patrick Ross, MD; David L. Skaggs, MD, MMM

USA

Summary: The effect of tranexamic acid and intrathecal morphine on blood transfusion requirements during posterior spinal fusion in patients with non-idiopathic scoliosis was investigated. A retrospective review of consecutive cases at a single institution was performed. Patients who received a combination of ITM and TXA were 78% (OR: 0.22 95% CI: 0.094 - 0.497) less likely to require transfusion (p = 0.001).

Introduction: To determine whether tranexamic acid (TXA) or intrathecal morphine (ITM) reduce transfusion requirements in the peri-operative period in patients with non-idiopathic scoliosis undergoing posterior spinal fusion (PSF).

Methods: A retrospective review of consecutive cases of non-idiopathic (neuromuscular, syndromic) scoliosis patients treated with PSF at a single institution was performed. Inclusion criteria included diagnosis of neuromuscular or syndromic scoliosis, a minimum of 10 levels of fusion, and posterior spinal fusion with segmental instrumentation. Multivariate regression analysis and paired t-tests were utilized to determine significance.

Results: 342 patients with an average age 14 years (7-24) and 15 levels fused (10-19) met inclusion criteria. ITM reduced the transfusion rate 13% (p = 0.6) and TXA reduced the transfusion rate 22% (p = 0.08), neither of which reached statistical significance. However, those patients who received a combination of ITM and TXA were 78% (OR: 0.22 95% CI: 0.094 - 0.497) to require transfusion (p = 0.001).

Conclusion: While neither ITM nor TXA reached statistical significance in reducing the transfusion rate, the use of TXA and ITM together is associated with a 78% reduction in transfusion requirements in non-idiopathic scoliosis patients undergoing PSF.

89. Scoliosis Surgery in Cerebral Palsy Spastic Quadriplegic Patients: Is Fusion to the Sacrum Always Necessary? A Minimum Four-Year Follow-Up

Bruce F. Hodgson, FRACS; Nicholas deGiorgio-Miller, MBChB

New Zealand

Summary: The aim is to demonstrate that in a select group of patients, fusion to the lumbar spine rather than sacrum provides comparable long term results. This retrospective cohort study has shown that pelvic obliquity (PO) is well maintained, whilst providing peri-operative benefits.

Introduction: The incidence of scoliosis in patients with spastic quadriplegia may be as high as 80% with almost one third having progressive curves of > 40°. This case series compares two groups of patients who underwent corrective surgery either with fusion to the lumbar spine or to the sacrum. The decision was based upon pelvic obliquity measured pre-operatively. Primary outcome was 'revision procedure' and important secondary outcomes were selected to explore benefits of fusing to the lumbar spine while achieving long term follow-up.

Methods: 36 consecutive patients from 1992 to 2006 with spastic quadriplegia were reviewed, 8 were excluded. All patients were assessed and surgery performed by a single surgeon. If PO was greater than 20°, fusion was performed to the sacrum. If less than 20°, to the lumbar spine, sparing the lumbosacral junction thereby preserving mobility. Medical records and imaging from Dunedin and Christchurch Public Hospitals were reviewed and data collected.

Results: 9 patients were fused to the sacrum, 19 to the lumbar spine. The mean age at surgery was 13.5years. Mean follow up was 7.35 years. Intra-operative bleeding and operative time was increased when fusing to the sacrum. The use of Tranexamic acid improved blood loss in patients fused to the sacrum. In both groups the mean Cobb's angle had improved at final follow up compared with pre-operatively. PO was maintained in all fusions to the sacrum. In patients with fusion to the lumbar spine pelvic obliquity remained under 20° in all but 1 patient. This patient is awaiting a revision procedure. There were 2 revisions in the sacral group and 1 in lumbar spine group. 2 patients underwent removal of metalware for infection (at 2 and 8 years) and 2 others for metal irritation - all in the lumbar spine group.

Conclusion: Fusion to the sacrum in patients with spastic quadriplegia does not appear necessary if PO measures < 20°. Cobb's angle and PO are well maintained at a mean of 7.35 years. Both groups have a similar outcome if these parameters or revision surgery is used as an end point. Theoretically, sparing the lumbosacral junction should provide more mobility and therefore facilitate cares and transfers. Operative time and bleeding are reduced with fusion to the lumbar spine.

90. Proximal Junctional Kyphosis in Cerebral Palsy: Risk Factors and Guidelines

Paul D. Sponseller, MD; Suken A. Shah, MD; Burt Yaszay, MD; Peter O. Newton, MD; Mark F. Abel, MD; Tracey Bastrom, MA; Michelle C. Marks, PT, MA; Patrick J. Cahill, MD

USA

Summary: Nearly one-fifth of patients with CP develop postop PJK. Preoperative thoracic kyphosis, operative reduction in kyphosis and lower degree of MR are risk factors. Avoiding major changes in kyphosis may help. Choice of UIV and anchor does not affect the risk of PJK.

Introduction: Proximal Junctional Kyphosis (PJK) complicates surgical reconstruction of spinal deformity in some patients with cerebral palsy. Its frequency and commonly-assumed risk

factors were studied.
Methods: In a large multi-center database of patients with CP, radiographs were studied at preoperative, FE, 1 and 2 years. PJK was defined as a focal kyphosis of >15o occurring within two levels around the UIV. Proximal kyphosis was also studied as a continuous variable in order to assess causative factors. Variables studied included technical (UIV, Upper anchor type) and patient related (age, Risser, major Cobb, MR, GMFCS, pre-existing kyphosis, and hip status).
Results: 116 patients who had 2 year follow up were studied. UIV was cervical (2), T1 (26), T2 (69) and below (19). Proximal anchors were hooks (55), screws (43) and wires (23). Eighteen (15%) developed PJK. 33% of these had PJK by FE, while in the rest it developed later. Four patients had PJK of > 25o. Risk factors shown to be associated with postoperative PJK were absence of mental retardation (? for reading), pre-operative T2-12 kyphosis (45o vs 36o; p=0.03) and T2-12 kyphosis (p=0.03), and significant operative kyphosis correction (29o vs 11o; p=00.1). Post-op T5-12 kyphosis was 53o for patients who developed PJK versus 33o for those who did not. PJK did not increase pain scores. Factors not associated were anchor type, UIV, hip status, age (13.6 vs 14.3 yrs), Risser, lumbar lordosis and GMFCS. Five patients had reoperations dealing with PJK (1 Skin breakdown, 2 loss of fixation, 1 prominence).
Conclusion: PJK affects nearly one-fifth of patients undergoing long fusions for CP. It usually does not develop in the early postoperative period. Most patients do not require reoperation. Risk factors for PJK were preop thoracic kyphosis and significant reduction in kyphosis. Absence of MR was associated with increased PJK, which may be associated with neck position during reading or ADLs. UIV and proximal anchor type were not shown to be risk factors.

91. A Prospective Multi-Center Study of Neuromonitoring for Cerebral Palsy Scoliosis: The Nature and Rate of Alerts and Recovery of Changes

Suken A. Shah, MD; Paul D. Sponseller, MD; Mark F. Abel, MD; Peter O. Newton, MD; Burt Yaszay, MD; Firoz Miyanji, MD, FRCS(C); Amer F. Samdani, MD; Harms Study Group

USA

Summary: The usefulness of intraoperative neurophysiologic monitoring in scoliosis surgery for patients with CP is questioned by some. The rate, severity and outcome of neurological injuries during surgery in these patients are not well reported. Monitoring of MEP and SSEP in these patients undergoing spinal deformity is feasible and useful to detect impending neurologic deficits. The rate of neurologic monitoring alerts was 10% in this series and there were no postop neurologic deficits when corrective action was taken intraoperatively.
Introduction: The purposes of this study were 1.) to study the feasibility and reliability of intraoperative neurophysiologic monitoring (IONM) in patients with scoliosis due to CP and 2.) determine the rate, nature and outcome of neurological monitoring alerts in spinal deformity surgery in these patients.
Methods: A prospectively collected, multicenter database of 197 children with CP and scoliosis who underwent surgery was reviewed; 172 had IONM attempted, and of those with complete records, 86% had good or fair potentials that were useful during surgery, and 14% had IONM attempted and abandoned due to poor baseline signals
Results: Seventeen patients (10%) had a TcMEP alert during surgery; the most common triggering events were: traction (5), intraoperative hypotension (3), positioning of the patient (3), curve correction/placement of rods (3), placement of implant (2), tightening of wire (1). All intraoperative events were detected by IONM with a decrease from baseline MEP and 11/17 had a decrease in SSEP. The treatment was typically a surgical pause, elevation of BP, release of traction, reduction of correction, removal of screw/wire, change in patient positioning or administration of steroids. All changes were reversible with interventions from immediate to 90 minutes later. No correlation to curve size, apex or EBL could be identified with the numbers available. Patients with poor baseline signals were typically severely involved spastic quadriplegic patients with MR.
Conclusion: IONM was feasible in 86%, provided reliable information regarding an impending neurologic deficit and TcMEP was 100% specific. The rate of neurologic monitoring alerts in this population of patients with CP undergoing spinal deformity surgery was 10%. When corrective action was taken for neurologic alerts, recovery of potentials was noted in all patients. IONM should be utilized when possible in scoliosis surgery even in patients with CP to detect neurological adverse events. In view of the increased incidence of neurologic monitoring alerts, the difficulty of monitoring, patient variability, and potential for recovery similar to preoperative status, the surgeon and parents should come to explicit agreement preoperatively about a course of action if changes were to occur.

92. Intraoperative Neuromonitoring for AIS: Multimodal Motor Evoked Potential Montitoring Utilizing Simultaneous Transcranial MEP and Neurogenic MEP

Daniel J. Sucato, MD, MS; Anna M. McClung, BSN, RN; Steven Sparagana, MD; Patricia L. Rampy, MS, REPT, CNIM; Elizabeth M. Van Allen, MS

USA

Summary: A 10 year experience of monitoring posterior AIS surgery using combined transcranial MEP and neurogenic MEP together with SSEP data provided accurate monitoring especially for larger curves without permanent neurologic deficit.
Introduction: Intraoperative neuromonitoring (IONM) is

critical in the evaluation of patients undergoing AIS surgery. Although somatosensory evoked potentials (SSEP) are standard, motor evoked potentials (MEP) data can be obtained using neurogenic MEP (NMEP) or transcranial MEP (tcMEP). There are no studies which have analyzed the simultaneous use of both methods of MEP monitoring in combination with SSEP.

Methods: A retrospective review of a consecutive series of AIS patients over a 10 year period at a single institution undergoing a posterior surgery using SSEP, NMEP and tcMEP monitoring was performed. All patients had SSEP monitoring so comparisons were made between groups NMEP, tcMEP and BothMEP.

Results: There were 592 patients who were 14.9 years at surgery (483 F/109 M). The major Cobb was 59.5° and corrected to 54.1% at surgery. Overall, critical IONM changes occurred in 13 (2.2%) patients- more common with thoracic curves ($p=0.0039$) without other correlative factors. The incidence of critical IONM changes were: NMEP: 5 of 281 (1.78%), tcMEP: 4 of 283 (1.41%) and BothMEP: 4 of 28 (14.3%) ($p<0.0001$). Preoperatively, the patients in the BothMEP group had larger main curves (65.0 vs 60.5° vs 57.9°($p<0.01$) and were more likely to get an MRI preoperatively (64.3% vs 32.7% vs 39.9%)($p<0.01$) for BothMEP, NMEP and tcMEP, groups, respectively. 1of 592 (0.17%) had transient weakness associated with IONM changes identified in a patient in the BothMEP technique (tcMEP and NMEP changes were noted). The weakness resolved over 1 week and the instrumentation was performed successfully 2 weeks from the initial surgery.

Conclusion: Multimodal IONM can be successfully performed in AIS surgery to prevent neurologic deficit. A new approach with combination SSEP together with two types of MEP (neurogenic and transcranial) were used more often for challenging curves and resulted in a higher likelihood of critical changes allowing for surgeon response to prevent permanent neurologic deficit.

93. Failure of Intraoperative Monitoring to Detect Postoperative Neurologic Deficits: A 25-Year Experience in 12,375 Spinal Surgeries

Barry L. Raynor, BS; Anne M. Padberg, MS; Lawrence G. Lenke, MD; Keith H. Bridwell, MD; K. Daniel Riew, MD; Jacob M. Buchowski, MD, MS; Scott J. Luhmann, MD

USA

Summary: Intraoperative monitoring (IOM), despite appropriate utilization, failed to identify neurologic deficits occurring in 45/12,375 (0.36%) spinal surgery patients. Thirty-seven were nerve root (82.3%) and eight were spinal cord (17.7%) in origin. Eight patients had permanent deficits (0.06%), six involving nerve roots and two the spinal cord.

Introduction: The purpose of this study was to categorize and evaluate the failure of intraoperative monitoring (IOM) to detect neurologic deficits occurring during spinal surgery. This large, single institution series of operative pts involved all levels of the spinal column (occiput to sacrum). Appropriate IOM protocols were used for the pts in this series.

Methods: Multimodality IOM included somatosensory evoked potentials (SSEP), descending neurogenic evoked potentials (DNEP), transcranial motor evoked potentials (MEP), dermatomal somatosensory evoked potentials (DSEP), spontaneous and triggered EMG. IOM protocols and warning criteria were uniform throughout this series. 12,375 surgeries were performed between 1/1/1985 and 12/31/2010. 59.3% (7178) of pts were female; 40.7% (5197) were male. Procedures by spinal level: cervical 29.7 % (3671), thoracic/thoracolumbar 45.4% (5624) & lumbosacral 24.9% (3080). Age breakdown: >18 yrs 62.7% (8993), <18 yrs 33.7 (3882).

Results: 45 of the 12,375 pts (0.36%) had postoperative deficits not identified by IOM. These false negative outcomes by modality were: spEMG (n=25/55.6%), trgEMG (n=9/20.0%), DSEP (n=7, 15.6%), DNEP (n=4, 8.9%), SSEP (n=4, 8.9%). 82.3% (n=37) of IOM failures involved nerve root monitoring, while only 17.7% (n=8) involved the spinal cord. Eight pts had permanent neurologic deficits, 6 (0.048%) were nerve root and 2 (0.016%) spinal cord in origin.

Conclusion: Despite correct application and usage, IOM data failed to identify 45 (0.36%) pts with NEW postoperative neurologic deficits out of a total of 12,375 surgical pts. 8 (0.065%) of these 45 pts had permanent neurologic deficits, 6 nerve root and 2 spinal cord related. Although admittedly small, this represents the risk of undetected neurologic deficits even when properly using IOM.

94. The Recognition, Incidence and Management of Spinal Cord Monitoring Alerts in Early Onset Scoliosis

Jonathan H. Phillips, MD; Denise Lopez, MSN, ARNP; Dennis R. Knapp, MD; Jose A. Herrera-Soto, MD

USA

Summary: The incidence of spinal cord monitoring alerts in unfused instrumentation surgery for early onset scoliosis has been estimated to be extremely low suggesting that monitoring of routine implant lengthening may not be necessary. The present study shows a much higher incidence of alerts than previously reported. Non monitored lengthenings cannot be supported.

Introduction: Sankar et al, 2010 reported a very low incidence of surgical case alerts in growing rod surgery. Anecdotally this has been challenged. Guidelines for monitoring in this patient population are lacking.

Methods: An IRB approved retrospective chart review was performed of all surgical cases in early onset scoliosis from July 2003 to July 2012. All monitoring alerts were identified in the dictated monitoring note and cross referenced with the surgeon's operative note. Somatosensory evoked potentials and

Motor evoked potentials were studied.

Results: A total of 30 patients underwent 180 cases. 30 of the 180 cases were not monitored. These were implant removal, incision and drainage of infection or cases where no measurable potentials could be obtained. Over the 9 year study period there were 14 spinal cord monitoring alerts. These varied from transient loss of MEPs associated with hypotension that reversed with elevation of the blood pressure to total and non-recovered loss of SSEPs and MEPs with prone positioning alone. The incidence of alerts was thus 47% of the patient cohort or 9.3% of the cases. 27% of the patients have undergone definitive fusion. One of these had a L5 nerve root traction injury that was not detected on monitoring and evolved slowly one hour after the end of the fusion operation. Recovery was near complete. There were no permanent neurological deficits other than this. Intraoperative management of the alerts involved elevating blood pressure, lessening the distraction of the implants, removing one ploughed pedicle screw and turning two of the patients supine immediately the loss of potentials was recognized in the prone position.

Conclusion: The high incidence of monitoring alerts in this series is alarming and we cannot support the contention that any early onset scoliosis surgery can be safely done without spinal cord monitoring.

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95. The Cutoff Amplitude of Transcranial Motor Evoked Potentials for Predicting Postoperative Motor Deficis in Thoracic Spine Surgery

<u>Akio Muramoto, MD</u>; Shiro Imagama, MD; Zenya Ito; Kei Ando, PhD; Ryoji Tauchi, MD; Hiroki Matsui; Tomohiro Matsumoto, MD, PhD; Naoki Ishiguro

Japan

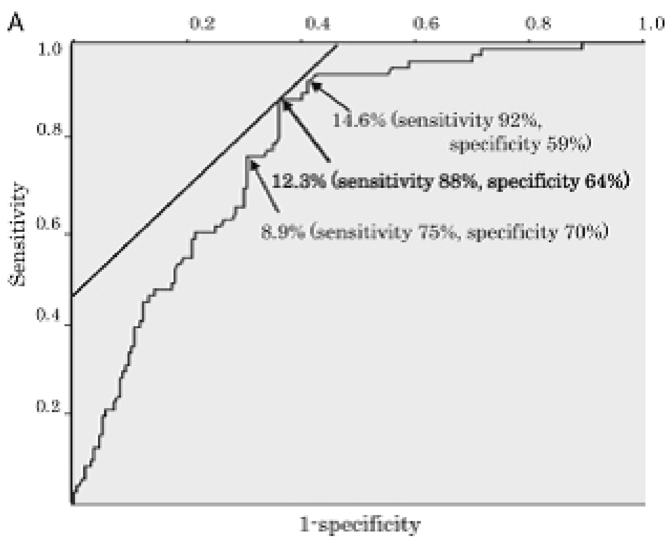
Summary: Prospective clinical study was designed to identify the cutoff amplitude of transcranial motor evoked potentials for predicting postoperative motor deficits after thoracic spine surgery. The relative and the absolute cutoff amplitudes of TcMEP at the intraoperative point of deterioration and at the end of surgery were 12% of control amplitude and 1.9μV and 25% of control amplitude and 3.6μV, respectively. The results may help establish the alarm criteria for thoracic spine surgery.

Introduction: There have been no studies presenting a scientifically established cutoff amplitude of transcranial motor evoked potentials (TcMEP) for postoperative motor deficits (PMD) in thoracic spine surgery. The purpose of this paper is to establish this cutoff amplitude.

Methods: The study includes 76 surgeries with acceptable baseline TcMEP response among 80 consecutive thoracic spine surgeries performed under TcMEP monitoring from June 2009 through January 2012. We recorded muscle action potentials from 4 upper limb muscles, and 12 lower limb muscles. We compared the mean amplitude of baseline, minimum and final amplitude between muscles with or without PMD. We also performed receiver operator characteristic (ROC) analysis to determine the cut off amplitude.

Results: 28 surgeries (37%) experienced electrophysiological deterioration(ED) defined as a 70% or greater decrease in TcMEP amplitude from baseline. In 12 surgeries (16%), PMD was found at the most immediate postoperative examination. 3 patients sustained muscle weakness 6 months postoperatively; the others recovered fully. In the 28 surgeries with ED, 330 muscles in the lower extremities had been chosen for monitoring and acceptable baseline responses were obtained from 270 (82%) muscles. Of the 270 muscles, 191 (71%) had ED during the operation, and 73 (27%) muscles had PMD. We compared the baseline, minimum and the final amplitude measurements from the 197 muscles without PMD and 73 muscles with PMD. Although, the baseline amplitude did not differ significantly, both the minimum and the final amplitude were significantly greater ($p<0.001$) in the muscles without PMD. Through the ROC analysis, the relative and the absolute cutoff amplitudes of TcMEP at the intraoperative point of deterioration and at the end of thoracic spine surgery were identified to be 12%/1.9μV and 25%/3.6μV, respectively. Sensitivity/specificity for those cutoff points are 88%/64%, 69%/83%, 90%/64%, and 70%/82% respectively.

Conclusion: In conclusion, our study identified the cutoff amplitude for TcMEP monitoring both at the intraoperative point of deterioration and at the end of thoracic spine surgery.



96. Neurophysiologic Protocol for Intraoperative Identification of the Injury Level After Spinal Cord Damage During Spine Surgery: A New Method Experimentally Tested in Pigs

Javier Cervera; Jesús J F. Burgos, PhD; Gema De Blas, MD, PhD; Lidia Cabanes; Eduardo Hevia, MD; Carlos Barrios, MD, PhD; Carlos Correa Gorospe; Gabriel Piza Vallespir, MD, PhD; Ignacio Sanpera, MD, PhD

Spain

Summary: A new neurophysiologic rationale for detection of the injury level after spinal cord injury was experimentally tested in a pig model. Cord-to-cord stimulation and recording techniques of motor evoked potentials, epidural sensory evoked potentials and the D-wave recorded at various levels permit to identify the exact location of the spinal cord injury. The pulse-train screw stimulation technique is less accurate in identifying the level of injury.

Introduction: Intraoperative spinal cord injury is a complication that may have important clinical consequences. In most instances, the intraoperative identification of the injury level might allow immediate spinal decompression, increasing the chance for later recovery. This study presents a new neurophysiologic method that was experimentally tested in a pig model.

Methods: Five industrial pigs were included in the experiment. Bilateral laminectomies were performed to expose the spinal cord at T4-T5, T7-T9 and T12-T13 segments. Pedicle screws were inserted left at T5, T7, T9 and T12. Four epidural catheters were placed sublaminar for neurophysiologic recording in T3, T6, T11 and L1. The neurophysiologic techniques performed were: a) cord-to-cord motor spinal-evoked potentials between the epidural catheters; b) recording of the sensory epidural potential after stimulation of a mixed nerve of the lower limb; c) recording of the motor D-wave in the epidural catheters after transcranial stimulation; d) Pulse-train stimulation of the four screws and recording of the responses in epidural catheters. After basal recording, the spinal cord was sectioned with a scalpel at T8 pedicle level and the neurophysiologic study was repeated for determining the level of injury.

Results: In all cases, there was a lack of caudal cord-to-cord motor potential when the spinal cord was stimulated just above the section. The epidural sensory potentials were normal in the two levels caudal to the medullar section and absent in the two segments cranial to the section. The motor D-wave was completely normal at the levels above the injury, and absent int the two caudal segments. Pulse-train stimulation of the screws craneal to the spinal cord section showed caudal response in the distal epidural catheters in three cases.

Conclusion: It is feasible to identify intraoperatively the level of an spinal cord injury by neurophysiologic methods. Cord-to-cord stimulation techniques, epidural sensory evoked potentials and the D-wave recorded at various levels permit to identify the exact location of the spinal cord injury. The pulse-train screw stimulation technique is less accurate in identifying the level of injury.

97. Pulmonary Function Changes Maintained Following Surgery for Scheuermann's Kyphosis

Baron S. Lonner, MD; Courtney Toombs, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD

USA

Summary: There has been little data on pulmonary function associated with the operative treatment of Scheuermann's Kyphosis (SK). This study demonstrates that pulmonary function is preserved in all patients with improvement noted in some with severe impairment.

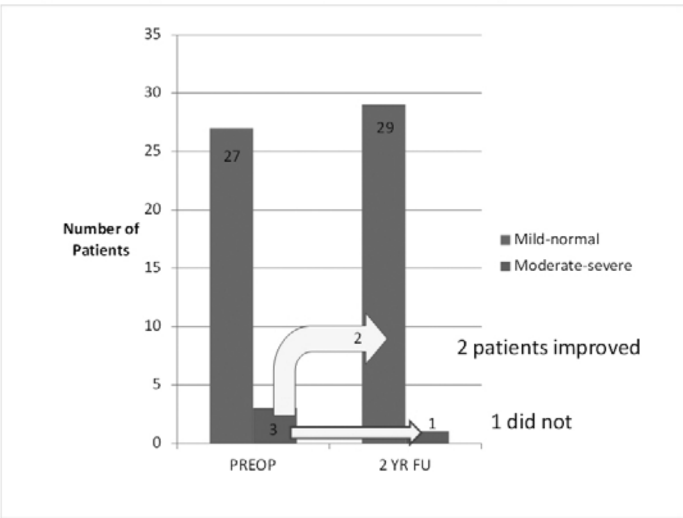
Introduction: Although previous studies on Adolescent Idiopathic Scoliosis (AIS) suggest pulmonary function may improve after surgical correction for AIS, pulmonary function changes in SK is less clear. Our objective was to evaluate the impact of surgery for SK on pulmonary function and to determine which surgical variables may predict postoperative pulmonary status.

Methods: Thirty patients undergoing posterior spinal fusion (1 anterior release) for SK were evaluated prospectively at preoperative and 2 year PO visits. Absolute and % predicted FVC, FEV1 and TLC and kyphosis apex (thoracic (T) or thoracolumbar (TL)) were collected. PFT data and sagittal measures (T2-T12 kyphosis, T5-T12 kyphosis and greatest sagittal Cobb angle) were analyzed over time via repeated measures ANOVA. Patients were also categorized based on American Thoracic Society guidelines for normal/mild and moderate/severe pulmonary function impairment at preop and postop to determine clinically meaningful improvement at 2 years.

Results: Mean age at surgery was 17.5 years (70% males). Mean kyphosis of 72.6° (56-92°) was corrected to 48.1° ($p<0.001$). No significant changes were found in FEV1 or %FEV1 after surgery (3.57 to 3.76; 90.9% to 90.7%). FVC and TLC improved (4.31 to 4.56; 6.11 to 6.82) however %FVC diminished slightly and % TLC was unchanged (96.8% to 91.8%; 108.2% to 105.6%). The location of the apex of the kyphosis did not have an impact on the % predicted PFT values. % predicted FVC and FEV1 increased in the one anterior release case (68 to 107; 76 to 102). Preoperatively, 3 patients had "moderate/severe" pulmonary impairment; and 2 years post-op, 2 improved to normal/mild and one did not change. All patients with normal/mild impairment pre-op remained so at post-op, and 90% of the final cohort was classified as normal/mild 2 years post-op.

Conclusion: Slight improvement or maintenance of pulmonary function after surgical correction for Scheuermann's Kyphosis can be expected for those with impairment, and 90% of the patients were classified as normal/mild at 2 years post operatively.

Figure 1. Changes in ATS Pulmonary Classification for Operative SK Patients



98. The Clinical Implications of Radiological Changes in Sagittal Parameters of the Cervical and Lumbar Spine Following Correction of Scheuermann's Kyphosis

Hossein Mehdian, MD, MS(Orth), FRCS(Ed); Georgios Arealis, PhD; Sherief Elsayed, FRCS(Tr&Orth)

United Kingdom

Summary: We report on 35 cases of Scheuermann's kyphosis who underwent surgical correction between 1999 and 2010. We noted the majority to have developed both neck and low back discomfort in the early postoperative course. Within a mean period of 2 years these neck and lower back symptoms had resolved. We hypothesise that ongoing changes in sagittal parameters following surgery may account for the resolution of these symptoms at 2 years.

Introduction: Scheuermann's kyphosis (SK) is the most common cause of thoracic kyphosis in adolescence. The purpose of this study was to analyze the clinical relevance of alteration in sagittal balance following correction of SK.

Methods: 35 patients with SK (26M,9F) underwent corrective surgery. Instrumentation extended from T2 to L2/L3. Radiographs were assessed for: cervical lordosis (CL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), thoracic kyphosis (TK), lumbar lordosis (LL) and the sagittal vertical axis (SVA). In addition, back and neck pain were assessed postoperatively.

Results: The mean follow up was 8 years (2-13). The mean age at surgery was 25 years. TK was reduced by surgery and was maintained at two years. Both CL and LL reduced following surgery but at two years had increased, though not to the degree noted pre-operatively. SS and PT decreased and increased respectively, with a partial reversal at two year follow up. Mean preoperative measurements were TK, LL, CL, SVA, SS, PT and PI were 83.3°, 60°, 33°, +8mm, 36°, 13° and 49° respectively. Postoperative TK, LL, CL, SVA, SS, PT and PI were 41.6°, 40°, 19°, -3.9mm, 33°, 16° and 48°. Final TK, LL, CL, SVA, SS, PT and PI were 44°, 52°, 25°, +2.8mm, 39°, 9° and 50° respectively. No major complications were noted.

Conclusion: We observed an increased incidence of neck and low back pain in the early postoperative period and approximately 2 years following surgical correction these symptoms resolved. This resolution corresponded with ongoing changes in sagittal parameters, and we believe this warrants further investigation.

99. Quality of Life Improvement Following Surgery for Scheuermann's Kyphosis Compared to Adolescent Idiopathic Scoliosis

Baron S. Lonner, MD; Courtney Toombs, BS; Suken A. Shah, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Harry L. Shufflebarger, MD; Burt Yaszay, MD; Paul D. Sponseller, MD; Peter O. Newton, MD

USA

Summary: Surgery for Scheuermann's kyphosis in the adolescent population results in significant improvements in health-related quality of life (HRQOL). SK patients have worse HRQOL globally and in self image and mental health domains before surgery compared with AIS patients. Improvement in HRQOL after surgery was greater in SK, resulting in HRQOL scores that match the scores of post-op AIS patients.

Introduction: No study to date has evaluated patient-reported health-related quality of life (HRQOL) changes with operative management of Scheuermann's kyphosis (SK). This study assessed changes in HRQOL prospectively and compared them to those occurring in adolescent idiopathic scoliosis (AIS).

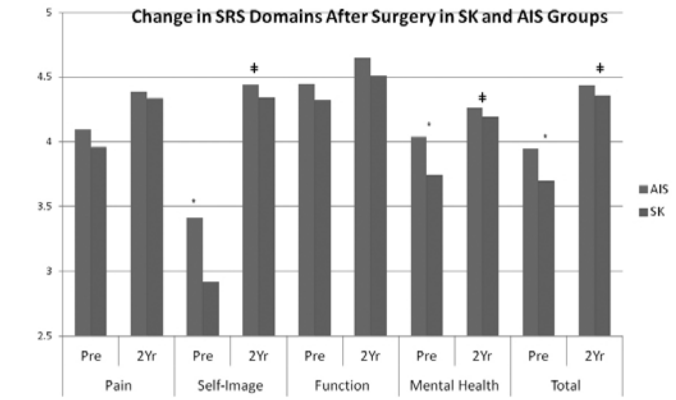
Methods: Pre-operative and 2 year follow-up HRQOL data was prospectively collected in 56 SK and 544 AIS patients using the SRS-22 outcomes instrument in a multicenter study. The SK and AIS cohorts were compared based on radiographic data, SRS and VAS scores using a repeated measures ANOVA.

Results: Kyphosis was corrected from 72.4° to 44.9° ($p<0.001$); major curve in AIS was corrected from 55.5 to 21.1 ($p<0.001$). SK SRS scores improved after surgery in all domains with the greatest change (1.42) in self-image ($p<0.001$). SK radiographic correction was not correlated with HRQOL. No changes were observed in SRS scores based on kyphosis apex. Changes in SRS pain, activity and self-image domains met the minimal clinically important difference for these domains (as determined for AIS patients). Preop kyphosis, BMI and correction of kyphosis were not correlated with SRS score change.. VAS scores improved from 3.51 to 1.51 as well, and these changes were correlated with change in the pain, mental and total score SRS domains ($p<0.001$). Baseline SK and AIS scores differed significantly in the self-image, mental health and total score domains, and SK had worse scores ($p<0.001$). At 2 yrs post-operatively, the greatest improvements were made in self image, especially in the SK group (p<0.001). Mental health and total score also improved significantly, and the SK group achieved greater gains (p<0.001). Therefore, at 2 years postop the SK group scores improved to reach values that were not different from the AIS scores in any domains.

Conclusion: Surgery for SK in the adolescent population results in significant improvements in HRQOL, which outpace those in the AIS population.

Figure 1. Differences in Baseline and Change in SRS Scores After Surgery for SK and AIS Groups

Legend: * = significant difference in pre-op baseline scores between SK and AIS (p<0.001)
ǂ = significant *change* in SRS score from preop to 2 yr in both groups (SK and AIS) (p<0.001); no significant difference in 2 yr SRS score between the two groups



100. The Routine Use of MRI Prior to Surgical Treatment for Scheuermann's Kyphosis Is Not Indicated

Daniel J. Sucato, MD, MS; Anna M. McClung, BSN, RN

USA

Summary: A consecutive series of patients with a normal neurologic examination undergoing surgical treatment for Scheuremann's kyphosis compared those patients who had an MRI with those who did not demonstrating no differences in any parameter. The data suggest that the routine use of preoperative MRI prior to SK surgery is not warranted.

Introduction: The use of preoperative MRI for Scheueremann's kyphosis (SK) is controversial with recent reports recommending routine preoperative imaging of the neural axis. However, these are small series with significant variables precluding strong conclusions.

Methods: A retrospective review of a consecutive series of patients with SK treated operatively at a single pediatric orthopedic institution from 1995 to 2011 was performed. The medical record, radiographs and the MRI were reviewed for each patient. A comparison was made between the those who had an MRI and those who did not to determine its utility in this setting.

Results: There were 85 (18F/67M), 16.4 years at surgery. All had a normal neurologic exam. A preoperative MRI was obtained in 23 (27.1%) patients primarily for persistent back pain. Two patients (8.7%) had subtle abnormalities (1 had a T12 small syrinx and 1 had mild myelomalacia at the apex) not requiring neurosurgical treatment. No differences were seen between those who had an MRI versus those who did not with respect to preoperative thoracic kyphosis (81.7 vs 77.4°, p=0.11), kyphosis flexibility (44.2% vs 39.3% p=0.403), levels fused (11.5 vs 11.9), position of LIV relative to the disc below the first lordotic disc (-0.2 vs -0.2, p=.779) and correction of kyphosis (52.5% vs 51.4% p=.306). Two patients, with normal preoperative neurologic exam and no MRI, had critical intraoperative neuromonitoring changes during correction, with return to baseline monitoring following backing off of correction. Both awoke with a normal motor exam with one of them having transient paresthesias for 6 weeks. At 2 years (n=70) both groups had maintained correction of kyphosis (47.9%, vs 50.5% p=0.644).

Conclusion: The routine use of preoperative MRI is not necessary in patients who have a normal neurologic examination prior to surgery for Scheueremann's kyphosis and does not identify patients who require neurosurgical treatment. Careful evaluation of each patient prior to surgery with a good history and physical examination and plain radiography is sufficient prior to moving forward with surgical treatment

101. Vertebral Column Decancellation (VCD) for the Management of Severe Spinal Deformity

Yan Wang, MD; Yonggang Zhang, PhD; Guoquan Zheng, MD

China

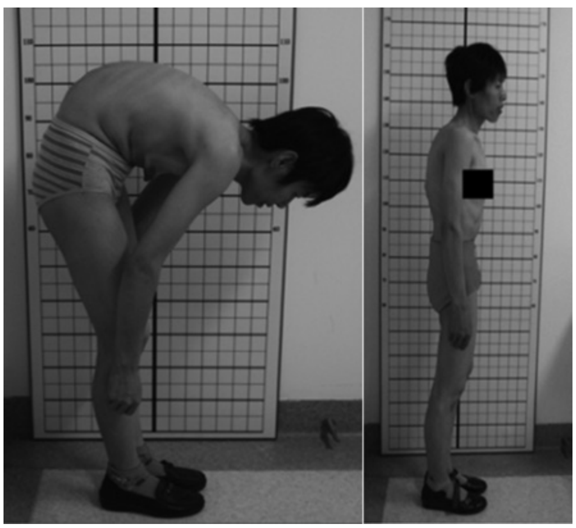
Summary: The goal of management of spinal deformity is to realign the spinal deformity and safely decompress the neurological elements. Therefore, we do not need to resect the deformed vertebrae totally like the management of spinal tumor. However, some shortcomings related to current osteotomy treatment for these deformities are still evident. Posterior vertebral column decancellation (VCD), integration of four common osteotomy techniques, is a promising technique for severe spinal deformity.

Introduction: To report the technique and results of vertebral column decancellation (VCD) for the management of Severe Spinal Deformity

Methods: From Jan 2004 to Sep 2012, 96 patients (53 males/43 females) with severe spinal deformities at our institution underwent VCD. The diagnoses included 42 congenital kyphoscoliosis, 24 Pott's deformity, 18 AS, and 12 adult scoliosis. The operative technique included multilevel VCD, disc removal, osteoclasis of the concave cortex, compression of the convex cortex accompanied by posterior instrumentation with pedicle screws. Preoperative and postoperative radiographic evaluation was performed. Intraoperative, postoperative and general complications were noted.

Results: For a kyphosis type deformity, an average of 2.3 vertebrae was decancellated (range, 1 to 4 vertebrae). The mean preoperative kyphosis was +96.3 degree (range, 81 to 138 degree), and the mean kyphosis in the immediate postoperative period was +14.2 degree(range, 4 to 30) with an average postoperative correction of +81.2 degree (range, 60 to 124). For a kyphoscoliosis type deformity, the correction rate was 64% in the coronal plane (from 83.4 to 30.0) postoperatively and 32.5 degree (61% correction) at 2 years follow-up. In the sagittal plane, the average preoperative curve of 88.5 corrected to 28.6 degree immediately after surgery and to 31.0 degree at 2 years follow-up. For scoliosis group, the correction rate was 67% (from 81.4 to 28.0). All patients had solid fusion at latest follow-up. Complications were encountered in 12 patients (12.5%) and included transient neurological deficit and complete paralysis (n=1).

Conclusion: Single stage posterior vertebral column decancellation (VCD) is an effective option to manage severe spinal deformities.



102. Preoperative Skull-Femoral Traction with Posterior Vertebral Column Resection (PVCR) to Treat Severe Rigid Spinal Deformity with Angular Curves >150°

Jingming Xie; Zhi Zhao; Tao Li; Yingsong Wang, MD; Ying Zhang; Ni Bi

China

Summary: To explore the significance of preoperative skull-femoral traction in severe rigid spinal deformity with angular curves>150°.

Introduction: Based on the angulation, rotation of the spinal cord, the extremely severe rigid spinal deformity with angular curves can be effectively corrected by PVCR, but the high risk of it has also been reached a consensus in the world. If the curves can be improved preoperatively, the safeties of PVCR and the spinal cord will be increased.

Methods: From 2004~2012, 98 consecutive cases with severe spinal deformity were successfully treated by PVCR in authors' institution, in which, 12 cases with extremely severe rigid deformities and angular curves were treated by skull-femoral traction before PVCR. For the 12 cases, the average preoperative major scoliosis curve and kyphosis was 153°(110°-168°) and 109°(61°-180°). The continuous skull-femoral traction in the supine position was started from preoperative 4 weeks. In the process of traction, the tolerance (diet, sleeping, pain, etc.), neurologic status, deformity changes, etc. were documented for analysis. The surgical correction through PVCR was performed at the end of the post-traction 4th week.

Results: For the 12 cases, the final traction force was 63% of body weight (47%-75%). After 4 weeks traction, the deformity was improved both on coronal and sagittal planes (F=64.196, P=0.000): the major scoliosis curve and kyphosis were decreased 34% and 31%. At the end of the 1st week, the major scoliosis curve and kyphosis were decreased 19% and 15%. In the 2nd week, the major scoliosis curve was decreased 11% (Fig.1), but kyphosis was unexpected increased 4%. The deformities improvement in the last 2 weeks was less obvious than the first 2 weeks (P=0.000). After PVCR, the major scoliosis curve and kyphosis were improved 69% and 66%. No spinal cord injury occurrence.

Conclusion: Preoperative skull-femoral traction is effective to decrease the risks of spinal cord displacement in PVCR. Along with the traction, the scoliosis can be improved more obviously and much earlier than kyphosis. Following the traction force exceeding 63% of the body weight, the tolerance of the patients will be obviously decreased. In the process of traction, the rigid deformity is rotated from coronal to sagittal planes so as to decrease the risks and difficulties of PVCR.

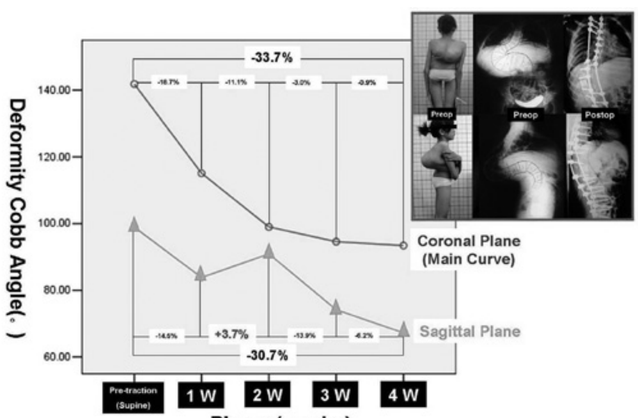


Figure 1. The changes of deformities in coronal and sagittal planes at different phases

Note: Scoliotic/kyphotic correction rate (%) = (Scoliotic/kyphotic Cobb's angle at the end of the last traction phase— Scoliotic/kyphotic Cobb's angle at the end of the this traction phase) / Pre-traction Scoliotic/kyphotic Cobb's angle × 100%

103. Posterior Vertebral Column Resection (PVCR) in Congenital Thoracic Lordoscoliosis

Meric Enercan; Cagatay Ozturk, MD; Sinan Kahraman; Bekir Y. Uçar, MD; Gurkan Gumussuyu, MD; Ahmet Alanay; Azmi Hamzaoglu, MD

Turkey

Summary: Congenital thoracic lordosis or lordoscoliosis are rare deformities which causes severe cardiopulmonary problems in early ages. PVCR is effective in restoring thoracal kyphosis in treatment of these rare deformities and avoids morbidity of combined surgeries.

Introduction: Congenital thoracic lordosis(CTL) or lordoscoliosis(LS) are rare deformities which causes severe cardiopulmonary problems in early ages. In our practice we perform PVCR for treatment of this rare deformities. The aim of this retrospective study was to evaluate the results of PVCR in treatment of CTL or LS.

Methods: 9 patients (8M,1F), mean age of 11 years (4-20) with min 2 yrs f/up were included. The surgical technique included segmenter pedicle screw fixation with long-arms for the apical and adjacent segments on concave side. Osteotomy was performed at the apex level starting from the concave side. After completion of resection, an over-kyphotic rod was placed for the first attempt of correction while a short temporary rod on convex side secured and avoided any translation. As tap screws were driven sequentially it pulled vertebral bodies backwards to the precontoured rod to create thoracal kyphosis. Over-kyphotic rod changed gradually to gain more kyphosis and in-situ benders were used for additional kyphotic effect in the final attempt (Figure 1). Preop and postop standing AP and lateral X-rays were measured for Cobb angles, sagittal parameters and diameter of thoracic cage.

Results: Av f/up was 46.3 (24-88) months. Av preop thoracic lordosis of -14.3° (-24°-11°) was restored to thoracic kyphosis of 17.6° (8°-29°). Av preop Cobb angle of 38.4° (28°-67°) was corrected to 9.8° (5°-22°) with 77% correction rate. Av. resection was 2.11 (1-4) levels. The improvement of AP diameter of thoracic cage was 31.3% (22-41). The mean postop intensive care unit period was 1.3 (1-3) days and none of patients required prolonged respiratory device support. There was no infection, implant failure or pseudoarhtrosis at the final f/up.

Conclusion: Although it is technically challenging, current study demonstrated that PVCR is effective in restoring thoracal kyphosis in treatment of CTL or LS and avoids morbidity of combined surgeries.

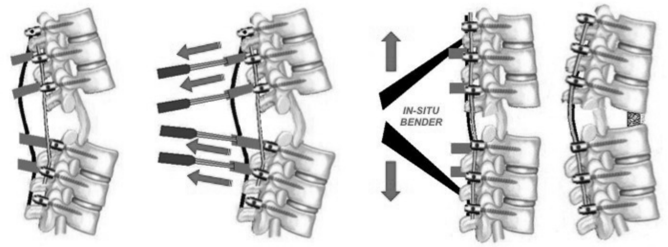


Figure 1

104. Three Column Spinal Osteotomies for Adult Spinal Deformity: Inter-Center Analysis of Variability in Technique and Alignment Impact

Pierre Devos, MS; Jamie S. Terran, BS; Richard Hostin, MD; Robert A. Hart, MD; Christopher P. Ames, MD; Oheneba Boachie-Adjei, MD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Ibrahim Obeid; Gregory M. Mundis, MD; Khaled Kebaish, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

USA

Summary: Three column osteotomies are commonly performed in the setting of spinal realignment for adult deformity. Significant variability in surgical strategy and osteotomy techniques are identified in this multicenter analysis. While deformity patterns treated were radiographically consistent amongst 8 sites in this study, fusion levels, iliac fixation and rod constructs varied. Effectiveness of realignment and junctional kyphosis rates were significantly different. Further study must examine complications and long-term outcomes of strategy and technique variability.

Introduction: Three column osteotomy (3CO), can offer dramatic sagittal plane spinal realignment. Various techniques and strategies exist to correcting adult spinal deformity (ASD). Few reports have analyzed the impact of variability on outcomes. The purpose of this study is to evaluate technique variations in 3CO across multiple centers and assess their peri-operative impact, including spinal alignment changes.

Methods: Retrospective review of 264 ASD patients from 8 sites, treated by single lumbar 3CO, minimum 3mo follow up. Demographics, radiographic parameters, surgical technique, operative time (OR) and estimated blood loss (EBL) were compared between groups. Chi-Square and ANOVA tests were performed.

Results: Preoperative radiographic parameters and SRS-Schwab Classification grades were similar across all sites. Average levels fused was 10.4, two sites differed from mean (12.5 and 8.4 levels, $p<0.001$). There was significant variation in angle of resection between sites, mean 25.2 ± 14.45 ($p<0.05$). The majority of 3CO were performed at L3 (40.2%), however, 3 sites performed most 3CO at L2, L4 and L5 ($p<0.001$). OR time and EBL varied significantly among sites. Two rods were commonly implanted at the 3CO (> 60%), however, at one site 72.2% had 4 rods at

3CO (p<0.001). At 5 sites, >60% underwent short fusions (<T10 or below), at 3 sites >50% had long fusions (>T10, p<0.001). More than 70% of the patients were fused to the ilium at all but two sites (those had poorer global alignment post op, p<0.001). At 3mo FU there was no difference between sites for modifiers PT and GA but significant variability in PI-LL (p<0.05). One site (large resection and short fusion) had a 3mo PJK rate of 54%, all other sites had PJK in <40% (p=0.037).
Conclusion: This study reveals uniform deformity indications for 3CO in ASD, however marked technique and strategy variations. By strategy, differences in fusion levels, iliac fixation and rod constructs were noted. In terms of techniques, degree of resection and variability in PI-LL were noted. There was also a significant effect in terms of PJK rates. Future analysis must include prospective evaluation of variation and the impact on patient reported outcome/satisfaction, complication and revision rates for this population.

105. Pedicle Subtraction Osteotomy (PSO) in the Revision Versus Primary Adult Spinal Deformity (ASD) Patient: Is There a Difference in Correction and Complications?

Munish C. Gupta, MD; Jamie S. Terran, BS; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Oheneba Boachie-Adjei, MD; Virginie Lafage, PhD; Shay Bess, MD; Richard Hostin, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Khaled Kebaish, MD; Eric Klineberg, MD; International Spine Study Group

USA

Summary: PSO is often performed to correct sagittal plane deformity in either the primary or revision setting for ASD. These are technically challenging operations that have potential for large blood loss and risk for intraoperative and postoperative complications. We found no significant differences in the ability of a PSO to achieve surgical correction and no difference in complication rates in the revision or primary setting. Primary PSO did however have a significant improvement in pelvic mismatch and lower pseudarthrosis rate.
Introduction: PSO is most often performed to correct sagittal plane deformity. However, these are difficult procedures that have potential for large blood loss and risk for intraoperative and postoperative complications. Our goal was to compare the amount of spinal deformity correction achieved and perioperative complication rates following PSO in the primary vs. revision surgery setting for ASD.
Methods: Multicenter, retrospective analysis of consecutive ASD pts. Inclusion criteria: age ≥ 18 years, lumbar PSO, min 6-week complication data. Pts were classified according to SRS-Schwab [L=lumbar scoliosis, T=thoracic scoliosis, D=T and L, N=no scoliosis, and modifiers PT (pelvic tilt), SVA (sagittal vertical axis) and pelvic mismatch (Pelvic incidence-lumbar lordosis)]. Patients divided into primary (P; no previous spine fusion surgery) or revision (R; previous fusion). Baseline and 1 yr demographic and radiographic parameters were analyzed. Complications and revision rates evaluated.
Results: 260 patients met inclusion criteria. Mean previous posterior spinal fusion (PSF) levels for R group=5.6. P (n=37) and R (n= 223) were similar for age, BMI, gender, mean total PSF levels (P=10.5; R=11.7), PSO level (L3), PSO angle (P=27°; R=24°) EBL (P=2.65L; R=2.69L), and OR Time (P=404min; R=455min). Distribution of SRS-Schwab ASD deformity type differed for L (P=51.4%; R=26%) and N curves (P=40.5%; R=54.3%). Sagittal modifiers were similar P vs. R. Both groups demonstrated improvement in all sagittal spinopelvic parameters from baseline to 1 year, with similar changes in sagittal modifiers, except for pelvic mismatch, which was improved to 0 more often for the P group (P=81.1%; R=58.6%; p<0.001). Complications were similar for: motor deficit (P=6.9%, R=10.7%), bowel/bladder deficit (P=10.3%, R=14.6%), deep infection (P=6.9%, R=3.9%), implant failure (P=5.4%, R=4.48%), and 1 year revision rate (P=8.1%, R=15.2%;p>0.05), but statistically different for pseudarthrosis (P=5.41%; R=3.59%; p<0.05).
Conclusion: PSO may be performed in the primary or revision ASD patient with similar sagittal deformity correction and similar complication rates. Primary PSO patients are more likely to achieve better spinopelvic realignment, and lower rate of pseudarthrosis.

106. Revision Surgery After Three Column Osteotomy (3CO) in 335 Adult Spinal Deformity (ASD) Patients: Inter-Center Variability and Risk Factors

Stephen P. Maier, BA; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Ibrahim Obeid; Gregory M. Mundis, MD; Eric Klineberg, MD; Khaled Kebaish, MD; Richard Hostin, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Oheneba Boachie-Adjei, MD; Christopher P. Ames, MD; Themistocles S. Protopsaltis, MD; Frank J. Schwab, MD; International Spine Study Group

USA

Summary: The purpose of this study was to examine the incidence and inter-center variability of revision surgery within 1year following 3CO for ASD. This multicenter study identifies indications for revisions, under-correction of alignment, and pseudoarthrosis.
Introduction: Complex spinal osteotomies including 3CO are increasingly performed to correct ASD. 3CO procedures are associated with high complication rates and revision surgery, but risk factors and variability between centers for surgical revision have not been reported.
Methods: Multicenter (n=8), retrospective review of ASD patients who underwent 3CO (n=335). The incidence and indication for revision surgery (RS) were analyzed. RS indications were classified as "Mechanical" (MR: implant

failure, pseudo, junctional failure, loss/lack of correction) or "Non Mechanical" (NMR: neurologic deficit, infection, wound dehiscence, stenosis). Risks factors for RS were analyzed using generalized linear models.
Results: 3month and 1year RS incidence were 12.3% and 17.6%. Single-level 3CO (n=311) had smaller RS rates than multi-level 3CO (n=24, 15.7% vs. 41.7%, p=0.01). Thoracic (n=63) and lumbar 3CO (n=246) demonstrated similar RS rates (12.7% vs. 16.7%, p=0.112). Rate of RS for single-level lumbar 3CO was 16.7% (MR=11.4%, NMR=5.7%). For all RS, 50% of MR and 78.6% of NMR occurred within 3mo of the index surgery. There was variation of RS between sites (range=2.5% to 32.4%, p=0.004), however low and high volume sites had similar RS rates (18.2% vs. 16.2%, p=0.503). Patients with MR were more likely to be under-corrected at 3mo (SVA=7cm vs 3.2cm, p=0.003) and had more caudal 3CO (L4 vs L3, p=0.014). SVA at 3mo and the treatment center were the only two parameters predictive of MR and for RS due to pseudarthrosis (p<0.02, Figure 1). Patients with NMR had larger 3CO resections than patients that did not have NMR (34° vs 24.5°, p=0.003).
Conclusion: 3CO procedures for ASD surgery provide deformity correction despite established complication and revision rates. There is great interest in lowering RS rates, particularly in high risk osteotomy cases, due to their impact on the patient and healthcare system. This study shows that RS associated with lower level osteotomy and higher SVA. There is significant variability in revision rates between sites which may be a reporting bias, or technique difference.

107. Morbidity of Pedicle Subtraction Osteotomy (PSO), Retrospective Multi-Centre Study: 267 Cases with Two Years Minimum Follow-Up in Nine Centers

Ibrahim Obeid; Didier Fort; Guillaume Riouallon, MD; Jean M. Vital; Stephane Wolff; Ges Ges

France

Summary: PSO is associated with a high morbidity and revision rate, over 267 patients we found 2 death and 2 complete paraplegia and revision rate of almost 30%.This technique has to be used as a last chance procedure and when other technique are not useful
In this series postoperative coronal imbalance was a risk factor for mechanical complication at least as much important as sagittal imbalance and neurological risk increases with age, dural tears and the correction angle
Introduction: PSO is an effective technique to correct sagittal imbalance. General and local complications are frequent and may be life threatening
Methods: Retrospective multicentrique of 267 adult patients undergoing a PSO in 9 centers, with at least 2 years FU. Demographic data, etiologies, full spine X rays and complications were analyzed
Results: Table1
A total of 267 patients were included in the analysis (57y, 79% F). The average FU was 36 months (24 to 86), 102 patients had an history of prior spine surgery (38%), the most common PSO level was L4 (n=154, 54%), with on average 8.6 levels fused, and 76% of fusion to the pelvis. Neuromonitoring was used in 31% of cases, mean EBL was 1990ml, and mean operative time was 272mn (100 to 660)
The risk of neurological complication increased with age (50 years), the occurrence of dural tear, and magnitude of correction (30°) (all with p<0.005). Major general complications occurred in 14 patients (5.3%), with 2 perioperative death directly related to the surgery. The overall revision rate was 29.3%; 12 patients (4.5%) had revision surgery for deep wound infection, (35%) present pseudarthrosis or rod fracture (not necessarely revised). In 55%, rod fracture and pseudarthrosis were located at the osteotomy site. A total of 8.4% of the patients developed adjacent syndrome degeneration requiring surgery. Age, rod diameters, smoker status, number of fused levels, preoperative spinopelvic parameters and etiology were not correlated to the likelihood of developing a mechanical complication. Patients who developed mechanical complications had larger sagittal and coronal C7tilt and smaller SSA Table 2
Conclusion: Our series is one of the largest published series. In addition to incomplete sagittal balance restoration, immediate postoperative coronal imbalance was a risk factor for mechanical failure. Neurological complications were correlated with age, dural tears and the magnitude of correction. With a revision rate of 29,4%.This technique has to be used as a last chance procedure and when other technique are not useful

108. Routine Use of Intraoperative Spinal Cord Monitoring is Necessary During Spinal Osteotomy for Adult Spinal Deformity

Sho Kobayashi, PhD; Tomohiko Hasegawa; Yu Yamato; Daisuke Togawa; Tatsuya Yasuda; Hideyuki Arima; Yukihiro Matsuyama, MD

Japan

Summary: Intraoperative spinal cord monitoring (IOM) could predict postoperative neurological deterioration during spinal osteotomy for adult spinal deformity. IOM provided higher sensitivity (100%) and specificity (92%).
Introduction: Recent reports showed spinal instrumentation surgery provided remarkable restoration of spinal alignment by adult spinal deformity surgery. However, there is a risk of neurological complication by excessive correction. Intraoperative spinal cord monitoring (IOM) provided respectable accuracy to predict postoperative paralysis. There were a few previous reports of IOM during spinal osteotomy for adult spinal deformity. Thus, we analyzed the efficiency of IOM for spinal osteotomy. The purpose of this study was to report IOM outcome and the neurological status following spinal osteotomy.

Methods: This is a retrospective study involving 109 consecutive patients underwent posterior thoracolumbar osteotomies from 2010 to 2012. They were classified into two groups according to the type of osteotomy, Ponte osteotomy (PO) group (n=49); 3 column osteotomy (3CO) group (n=60). We set 70% decrease of amplitude as alarm point of transcranial electrical stimulation motor evoked potentials (TcMEPs), and 50% decrease of amplitude or 10% increase of latency as alarm point of somatosensory evoked potentials (SSEP). TcMEPs and SSEP variability and the motor deficit were analyzed. Fisher's exact test was utilized to compare 3CO and PO patients.
Results: Postoperative follow up revealed 16 cases (19.8%) of IOM alerts and 7 cases (8.6%) of new neurological deficits clinically. There were 3 cases (6.7%) of neurological deterioration in 3CO group, and 4 cases (11.1%) in PO group. (p>0.05) One case in 3CO group showed anterior spinal cord syndrome due to thoracic nerve roots ligation, the others were transient paralysis of quadriceps (n=4) or tibialis anterior (n=2). IOM yielded 7 true positive cases and 5 false positive cases. Our alarm criteria provided higher sensitivity (100%) and specificity (92%). We experienced 4 cases of TcMEPs recovered by the protective procedures of spinal cord and nerve function without postoperative neurological deterioration. These indeterminate cases were very important as "rescue" cases.
Conclusion: IOM could predict postoperative neurological deterioration during spinal osteotomy for adult spinal deformity. We recommend routine use of spinal cord monitoring in the surgery of spinal osteotomy.

109. Analysis of Cervical Spine Alignment According to Roussouly Sagittal Global Spine Classification in Cervical Spondylosis Patients

Miao Yu, MD; WenKui Zhao, MD

China

Summary: Cervical spine alignments correlate with different global spine curves. The spinal and pelvic parameters may modify according to different cervical curves. Lordosis may not be the only physiological alignment in cervical spine.
Introduction: Cervical spine should correlate with global spine balance and should modify according to spinal and pelvic sagittal parameters. Lordotic alignments were probably not the only standard for all cervical curves. Appropriate range of cervical neutral angles could prevent from over-correction in surgery.
Methods: A cohort of 121 cases of cervical spondylosis was reviewed. The Roussouly Classification was utilized to categorize patients according to their spinal and pelvic parameters. The cervical alignments were classified as lordosis, straight, sigmoid or kyphosis. Other parameters, such as global cervical angles(angles between two lines parallel with posterior walls of C2 and C7), practical cervical angles(addition of endplate angles from C3 to C7, and inter-vertebral angles from C23 to C67),T1-Slope, Spinal Sacral Angles, Hip to C7/ Hip to Sacrum and C0-C2 angles were analyzed on neutral global spine lateral images.
Results: The cervical alignments correlated with different Roussouly sagittal types (P<0.05, table 1). Cervical lordosis occupied 56.5% in Roussouly Type 1. The proportions of straight alignment were 50.0% and 58.2% in Roussouly Type 2 and Type 3 respectively. The ratio of lordosis in Roussouly Type 4 arrived at 81.8%. The ratio of multiple level degenerations in straight cervical curve was 90.6% (48/53). Both the general and practical cervical angles showed significant differences between Roussouly Type 4 and Type 2, and between Type 4 and Type 3 (P<0.05, table 2). Spinal Sacral Angles and T1-Slope were significantly different between types (P<0.05, table 3)
Conclusion: The cervical spine are various according to their global spine alignment. In Roussouly Type 1, despite a large kyphosis in thoraco-lumbar spine, the cervical spine presents lordotic curves mostly. In Roussouly Type 2, straight lumbar and thoracic spines accompany straight cervical alignments. . In Roussouly Type 3, even though there are harmonious curves of global spine, straight cervical spines exist in most cases. In Roussouly Type 4, large curves of thoracic kyphosis and lumbar lordosis allow cervical lordosis in most cases. The T1-Slope and SSA are parameters, which reflect the adjustment of different cervcial spine alignment in different Roussouly types.

110. How the Neck Affects the Back: Changes in Regional Cervical Sagittal Alignment Correlate to HRQL Improvement in Adult Thoracolumbar Deformity Patients at Two-Year Follow-Up

Themistocles S. Protopsaltis, MD; Justin K. Scheer, BS; Jamie S. Terran, BS; Justin S. Smith, MD, PhD; Han Jo Kim, MD; Gregory M. Mundis, MD; Robert A. Hart, MD; Ian McCarthy, PhD; Eric Klineberg, MD; Virginie Lafage, PhD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

USA

Summary: The specific impact of regional cervical sagittal alignment on HRQL has not been studied in thoracolumbar deformity patients. Cervical alignment changes after T/L deformity correction. Changes in regional cervical sagittal alignment parameters correlate to HRQL improvements in thoracolumbar deformity patients at 2 year follow up. Regional cervical sagittal radiographic parameters are correlated with clinical measures of lumbar regional disability and health status in patients with adult thoracolumbar scoliosis. Improvements in regional cervical alignment postoperatively correlated positively with improved HRQL.
Introduction: The importance of the sagittal plane in adult thoracolumbar scoliosis has been well established. Regional

cervical sagittal alignment has been correlated with HRQL and is reciprocally affected by changes in global sagittal alignment. The specific impact of cervical sagittal alignment on lumbar regional disability and general health status has not been studied in thoracolumbar deformity patients.

Methods: Multicenter prospective data collection of consecutive patients with adult thoracolumbar spinal deformity with minimum 2 year follow up. Clinical measures of disability included ODI, SRS and SF36. Regional cervical radiographic parameters were correlated with established global sagittal parameters and HRQL. Operative patients were subanalyzed by global deformity (SVA>5 vs SVA<5).

Results: 857 patients were included. Mean age 53.5. C2C7 Plumbline (CPL) correlated with baseline ODI (r=-0.22), PCS (r=-0.22), and SRS22 (r=-0.21). Cervical lordosis (CL) correlated to postop HRQL including 1 year ODI (r=0.23), PCS (r=-0.22), SRS22 (r=-. 15); Decreases in T1S-CL correlated with better HRQL at 2 years including ODI (r=0.20) and PCS (r=-0.25).

Changes in CL correlated with HRQL: 2 year ODI (r=-0.42), SRS (r=-0.34), back pain (r=-0.44) and leg pain (r=-0.36).

For patients with SVA>5, change in T1S correlated with improvements in HRQL: two year change in ODI (r=-0.37) and back pain (r=-0.43). Decreases in T1S-CL correlated with improvements in disease specific HRQL: postoperative SRS activity (r=-0.34), SRS pain (r=-0.33).

Conclusion: Changes in regional cervical sagittal alignment parameters correlate to HRQL improvements in thoracolumbar deformity patients at 2 year follow up. Regional cervical sagittal parameters such as CL, CPL and T1S-CL are correlated with clinical measures of regional lumbar disability, health status, and disease specific disability in patients with adult thoracolumbar deformity. This effect may be direct or a reciprocal effect of the underlying global deformities on regional cervical alignment. Patients with greater global deformities (SVA>5) had larger baseline cervical lordosis, T1S and CPL and lower HRQL. Improvements in regional cervical alignment postoperatively correlated positively with improved HRQL.

111. Prevalence and Type of Cervical Deformity Among 470 Adults with Thoracolumbar Deformity

Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Themistocles S. Protopsaltis, MD; Eric Klineberg, MD; Justin K. Scheer, BS; Kai-Ming Fu, MD, PhD; Richard Hostin, MD; Vedat Deviren, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group

USA

Summary: Cervical deformity is highly prevalent (~30%) among adults presenting for surgical evaluation of thoracolumbar deformity. Its prevalence differs significantly based on SRS-Schwab curve type and sagittal spinopelvic modifier grades. Evaluation of thoracolumbar deformity should include assessment of cervical parameters to assess for evidence of concurrent cervical deformity.

Introduction: Deformity may present in multiple spinal regions in a single patient. Our objective was to assess the prevalence of cervical deformity among adults presenting for evaluation of TL deformity.

Methods: Multicenter, prospective, consecutive series. Inclusion criteria: adult spinal deformity (ASD) and age>18. Parameters included pelvic tilt (PT), pelvic incidence (PI), lumbar lordosis (LL), C2-C7 sagittal vertical axis (C2-C7 SVA), C7-S1 SVA and C2-C7 lordosis (CL). Cervical deformity was defined as CL>0° (cervical kyphosis [CK]) or C2-C7 SVA>4cm (cervical positive sagittal malalignment [CPSM]). Patients were stratified by SRS-Schwab ASD classification, including curve type (N: sagittal deformity, T: thoracic scoliosis, L: lumbar scoliosis, D: T+L scoliosis) and modifier grades: PT (0:<20°, +:20-30°, ++:>30°), C7-S1 SVA (0:<4cm, +:4-9.5cm, ++:>9.5cm), PI-LL mismatch (0:<10°, +:10-20°, ++:>20°).

Results: 470 patients met criteria (mean age=52), with mean CL=-8° (SD=15°) and mean C2-C7 SVA=3.2cm (SD=1.7cm). Prevalence of CK and CPSM was 31% and 29%, respectively. Patients with CK were younger (45 vs 55, p<0.001), but age did not differ based on presence of CPSM (p=0.12). Prevalence of CK differed by curve type: N (15%), L (27%), D (37%), T (49%) (p<0.001); prevalence of CPSM did not differ by curve type (p=0.19). Higher PT grades had lower prevalence of CK (0 [40%], + [27%], ++ [15%]; p<0.001) but greater prevalence of CPSM (0 [23%], + [28%], ++ [45%], p=0.001). Similarly, higher SVA grades had lower prevalence of CK (0 [40%], + [23%], ++ [11%]; p<0.001) but greater prevalence of CPSM (0 [24%], + [24%], ++ [48%], p<0.001). Higher PI-LL grades had lower prevalence of CK (0 [35%], + [31%], ++ [22%]; p=0.034) but no association with CPSM (p=0.46).

Conclusion: Cervical deformity is highly prevalent (~30%) among adults with TL deformity. Its prevalence and type differs significantly based on SRS-Schwab curve type and sagittal spinopelvic modifier grades. Higher SVA and PT modifiers are associated with greater cervical sagittal malalignment. Evaluation of TL deformity should include assessment of cervical parameters for evidence of concurrent cervical deformity.

112. T1 Slope Minus Cervical Lordosis (T1S-CL), the Cervical Analog of PI-LL, Defines Cervical Sagittal Deformity in Patients Undergoing Thoracolumbar Osteotomy

Themistocles S. Protopsaltis, MD; Jamie S. Terran, BS; Nicolas Bronsard, MD, PhD; Justin S. Smith, MD, PhD; Eric Klineberg, MD; Gregory M. Mundis, MD; Han Jo Kim, MD; Richard Hostin, MD; Robert A. Hart, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Christopher P. Ames, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

USA

Summary: Established parameters of cervical sagittal deformity (CSD) such as cervical kyphosis (CK) and C2-C7 plumbline (CPL) have been shown to undergo reciprocal change following correction of thoracolumbar deformity (TLD). We utilized the T1 Slope minus cervical lordosis (TS-CL), the cervical analog to PI-LL, to define cervical sagittal deformity after TLD three column osteotomy (3CO). Risk factors for the development of CSD included Instrumentation above T4 and pre-existing TS-CL mismatch as in concurrent cervical and thoracolumbar deformities.

Introduction: Cervical Kyphosis (CK) and C2-C7 plumbline (CPL) are established descriptors of cervical deformity and CPL>4cm is associated with poor HRQOL. However, reciprocal changes in these parameters of cervical alignment have been demonstrated in patients undergoing thoracolumbar 3 column osteotomy (3CO). We defined CSD with TS-CL to identify factors contributing to cervical deformity in TLD patients following 3CO.

Methods: Multicenter, retrospective, analysis of consecutive TLD patients undergoing 3CO. Preoperative and postoperative radiographic parameters of cervical sagittal balance were investigated. Since global sagittal correction decreases reciprocal cervical sagittal malalignment, postoperative values were utilized in a linear regression analysis showing CPL of 4cm corresponds to a TS-CL threshold of 17. Patients were classified into cervical sagittal deformity (CSD: TS-CL>17) or reciprocal sagittal alignment (RSA: TS-CL<17).

Results: 166 TLD patients (mean age 59.1) were identified. TS-CL correlated with CPL (preop r=.57; postop r=.48). RSA patients had a decrease in TS-CL (10.2 to 8.0) with SVA correction whereas CSD patients had an increase in TS-CL (22.3 to 26.8) with all p<0.001. Reciprocal change was demonstrated in RSA patients as CL decreased with SVA correction (r=.39) but there was no such correlation in CSD. Using linear regression analysis, UIV above T4 and preop TS-CL mismatch were identified as risk factors for postoperative cervical sagittal deformity.

Conclusion: Risk factors for developing cervical sagittal deformity in TLD patients undergoing 3CO included preop TS-CL mismatch and UIV above T4. The latter may result from disruption of the cervical paraspinal muscle attachments to the upper thoracic spine during exposure and instrumentation. While reciprocal change in cervical and thoracolumbar alignment was demonstrated in RSA patients, CSD patients had progression of their cervical deformities after 3CO.

Figure 1: Representative thoracolumbar deformity patient after PSO with UIV above T4 who developed cervical sagittal deformity. TS-CL = 62 demonstrating severe CSD.

113. Comparison of Smith Peterson (SPO) Versus Pedicle Subtraction (PSO) Versus Anterior Osteotomy (AO) Types for the Correction of Cervical Spine Deformities

Han Jo Kim, MD; Chaiwat Piyaskulkaew, MD; Lawrence G. Lenke, MD; K. Daniel Riew, MD

USA

Summary: Isolated SPOs, PSOs and AOs can be expected to provide 10°, 35° and 17° of angular correction per level performed. Although posteriorly based osteotomies provided good translational correction, an isolated AO provided only mild translational corrections. AO + SPOs provided equal or better corrections than Isolated PSOs, with equal operative times and significant less blood loss. We report the largest single surgeon series of cervical spine osteotomies with the aim of setting guidelines for planning surgery for cervical deformities (CD).

Introduction: Although the corrective power of various osteotomies in the thoracic and lumbar spine are well described, there are no reports in the literature on the corrective capabilities of osteotomies in the cervical spine to guide pre-op planning for cervical and cervicothoracic deformities.

Methods: Pts who underwent cervical osteotomies for CD were identified in a 10 yr period from 2000-2010. Demographics, surgery type, osteotomy type, operative details, radiographs and Neck Disability Index (NDI) Scores were collected for pre-op and ultimate post-op time points. Cervical lordosis (CL) and basion plumbline (BPL) were collected to assess angular and translational corrections.

Results: A total of 61 pts had surgery for CD in the study period. Diagnoses ranged from post-traumatic cervical kyphosis (22), degenerative kyphoscoliosis (15), Ankylosing Spondylitis (13), post-laminectomy kyphosis (8), Klippel-Feil (2) and muscular dystropy (1).

Isolated SPOs with posterior cervical fusions (PCF) were performed in 13 pts. The mean angular correction (MAC) generated through 1 SPO was 10.1°/level (range 1.0°-24.9° per Level) and the mean translational correction (MTC) was 1.8cm (range 0.5-4.0cm/SPO). The mean Length of Surgery (LOS) was 230min. and the estimated blood loss (EBL) was 232ml.

Isolated PSOs with PCF were performed in 10 pts. The MAC generated was 34.5° (range 28.2°- 80.0°/Level, max 1/case) per PSO and MTC of 2.5cm per PSO (range 0.2-5.6cm). The mean LOS was 344 min and EBL was 712ml.

Isolated AO w/ PCF was performed in 16 pts with a MAC of 17.1°/ osteotomy (range 3.5°-32.1°/level) and MTC was 1.0cm/ osteotomy (0.1-3.0cm/level, total 0.5-3cm total). The mean LOS was 206min and EBL was 183ml.

Combined AO & SPO w/ PCF were performed in 22 pts with a MAC of 27.8°/ osteotomy (range 3.7°-66.7°/level) the MTC was 2.6cm/osteotomy (range 0.2-7.0cm/level). The avg LOS was 321min and EBL was 325ml.

Conclusion: Posteriorly based osteotomies provided better translational correction than anterior osteotomies. The angular correction achieved by one PSO was similar to AO+SPOs. AO + SPOs provided equal or better corrections than Isolated PSOs, with equal LOS and less EBL (325ml vs. 712ml, p=0.01)

114. Cervical Scoliosis: Clinical and Radiographic Outcomes

Addisu Mesfin, MD; Wajeeh R. Bakhsh, BA; Samuel Romero-Vargas, MD; Han Jo Kim, MD; K. Daniel Riew, MD

USA

Summary: Cervical scoliosis is not a well defined condition. In our series of 12 patients with cervical scoliosis we found surgical management can result in correction of the deformity and improvement of patient outcomes. However, higher rates of complications, EBL and longer surgical time should be expected.

Introduction: Cervical scoliosis is rare and usually associated with Klippel-Feil (KFS) and Neurofibromatosis-1(NF-1). Existing studies mostly address pediatric patients and few reports address the adult patient with cervical scoliosis. Our objective was to report clinical and radiographic outcomes following surgical management of patients with cervical scoliosis.

Methods: Twelve patients with cervical scoliosis managed over a 5 year period (2005- 2010) at a single institution were identified. Scoliosis was defined as cervical Cobb angle >10°. Demographic data including: age , gender, diagnoses and primary vs. revision surgery were collected. Surgical data including: procedure (anterior vs. posterior), estimated blood loss (EBL), length of surgery (min), length of hospitalization and complications were recorded. Pre-op and post-op Cobb angle measurements were performed. Pre-op and post-op Neck Disability Index (NDI) scores were recorded.

Results: Five males and seven females with an average age of 50.9 (25-65, median 52.5) were enrolled. Diagnoses are listed in Table1. Average follow-up was 25 month (median 27, 1 - 52). Six cases were primary and six were revisions. Six cases were anterior only (Avg. 4 levels fused), four cases were posterior only (Avg. 8 levels fused) and two cases were combined anterior-posterior. Bone morphogenetic protein (BMP) - 2 was used in 11 cases, with an average dose of 14.8mg (median 12, 1 - 36). EBL was an average of 260ml (median 150, 50-900), average surgical time was 245 minutes (median 224, 136-599) and average hospital stay was 2.7 days (median 2, 1 - 7). There were seven patients with complications and two that developed adjacent segment disease (Table 1). Average pre-op coronal Cobb angle was 35.1° (median 31, 13-63) and corrected to 15.7° (median 10.5, 2-59) post -op (p <0.005, Figure1). Average pre-op NDI was 23.4 (median 26, 6 - 35) and reduced to 14.8 (median 12, 7 -23) post-op (p<0.02).

Conclusion: Surgical management of cervical scoliosis can result in correction of the deformity and improvement of patient outcomes. However, higher rates of complications , EBL and longer surgical time should be expected.

115. Spinal Hemiepiphysiodesis for Fusionless Scoliosis Treatment Using Titanium Implant Alters Biomechanical Properties

Matthew T. Coombs, MSc; David Glos, BSE; Eric Wall, MD; Donita Bylski-Austrow, PhD

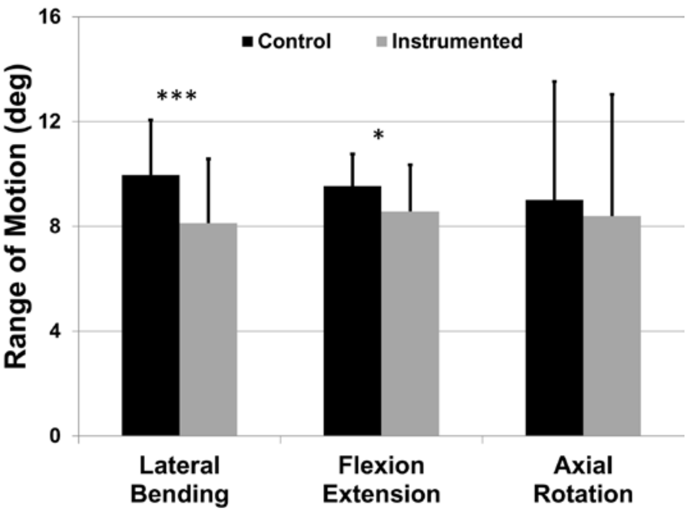
USA

Summary: Vertebral growth modification using an experimental hemiepiphyseal implant consisting of a titanium clip-screw construct is undergoing a prospective clinical safety trial for early adolescent idiopathic scoliosis. In biomechanical tests on porcine thoracic motion segments, the implant decreased intervertebral range of motion by less than one-fifth, increased stiffness by one-third or less, and decreased the neutral zone by less than one-half. Implantation of the spinal hemiepiphyseal construct preserved at least 80% of control range of motion in the immediate post-operative period.

Introduction: Growth modulation is under investigation as a treatment for early adolescent idiopathic scoliosis. A prospective clinical safety study of a titanium clip-screw construct for growth modulation is currently underway (FDA IDE, clinicaltrials.gov: NCT01465295). The purpose of this study was to determine intervertebral biomechanical properties changes due to device implantation.

Methods: In vitro biomechanical tests were conducted on single

motion segments from skeletally immature pigs. Specimens were tested before and after implantation of a construct consisting of a titanium clip and two bone screws. Pure moments were applied in lateral bending, flexion-extension, or axial rotation, with 6 specimens per loading mode. Vertebral displacements were recorded using HD video. Moment-rotation curves were determined using custom software. Range of motion (ROM), stiffness (K), and neutral zone (NZ) were measured. Statistical differences were determined by linear mixed model ($\alpha = 0.05$) with Bonferroni post-hoc corrections.
Results: The implant decreased ROM in lateral bending by 19% ($p<0.0003$), flexion-extension by 11% ($p<0.04$), and axial rotation by 8%. Mean K in lateral bending toward and away from the treated side increased 20% and 33%, respectively. In flexion and extension, K increased 10% and 16%, respectively. Treatment decreased NZ in lateral bending toward and away from the instrumented side by 30% and 47%. In flexion and extension, NZ decreased 20% and 26%. In axial rotation toward and away from the treated side, NZ decreased by 22% and 7%.
Conclusion: A titanium implant previously shown to induce asymmetrical spine growth decreased range of motion by less than 20% and neutral zone less than 50%. Stiffness increased by less than 33%. Results suggest that the device causes earlier loading to disc and growth plates in the immediate post-operative time period. Implantation of the spinal hemiepiphyseal construct preserved at least 80% of control range of motion in the immediate post-operative period. Characterization of biomechanical properties change dues to treatment is required to help define device function and efficacy, and to help assess likelihood of disc health maintenance.



Range of motion for control and instrumented specimens in lateral bending, flexion-extension, and axial rotation

116. Effect of Screw Across Vertebral Neurocentral Synchondrosis on Spinal Canal Development in an Immature Spine

Xuhui Zhou, MD; Hong Zhang, MD; Daniel J. Sucato, MD, MS; Charles E. Johnston, MD

USA

Summary: It is still controversial regarding the effect of the screw passing through the vertebral neurocentral synchondrosis (NCS) on spinal canal development in an immature spine. In an immature pig model, the screws which crossed the NCS created 71-97% NCS closure resulting in a 17-25% decrease in the spinal canal area. The screws across the NCS adversely effects on the spinal canal growth in immature pigs.
Introduction: Pedicle screws traversing the neurocentral synchondrosis (NCS) in young children may have a detrimental effect on spinal canal development. The purpose of this study was to determine the effects of placing screws across the NCS on spinal canal development by histological analysis and measurement of canal dimensions in an immature pig model.
Methods: Twenty-seven 1-month-old pigs were assigned to 2 groups based on the surgical approach used to place screws across the NCS. In the posterior approach, 16 pigs underwent unilateral pedicle screw placement from T7 to T14 and were divided into 4 subgroups: no-screw (control, n=4) without screw fixation; short-screw (sham, n=3) in which the screws did not cross the NCS; long-screw (treated, n=4) in which the screws crossed the NCS; and screw-removal (n=5) in which long screws were removed at 6 weeks postop. In the anterior approach, 11 pigs underwent vertebral body screw placement from T6 to T12 via thoracotomy and were divided into 2 subgroups: short-screw (sham, n=3) in which the screws did not cross the NCS; long-screw (n=8) in which the screws crossed the NCS. All animals were euthanized at 17 weeks. True axial CT images of the spine were obtained, on which the total area, width and depth of spinal canal were measured. A quantitative histology of the NCS was performed measuring the NCS closure rate and the hypertrophic zone height.
Results: The long-screw and the screw-removal created 97% and 20% NCS closure respectively. The canal areas in the long-screw (110.2 mm square) and screw-removal (127 mm square) were significantly smaller than the no- (137 mm square) and short-screw (137.6 mm square). The canal depth in the long-screw (9.7 mm) and screw-removal (10.4 mm) were shorter than the no- (11.4 mm) and short-screw (11.8 mm) ($p<0.05$). The vertebral body screw which crossed the NCS produced 71% NCS closure resulting in a 17% decline of the canal area and 9% shortening of the canal width.
Conclusion: Pedicle screw crossing the NCS adversely effects the spinal canal growth in immature pigs with up to a 25% decrease in canal area and 20% decline in canal depth. Pedicle screw use in the very young child should be used with caution and delay in surgical treatment until older should be considered.

117. Fusion After Vertebral Body Stapling

Elias Dakwar, MD; Amer F. Samdani, MD; Michael Auriemma; Joshua M. Pahys, MD; Randal R. Betz, MD; Patrick J. Cahill, MD

USA

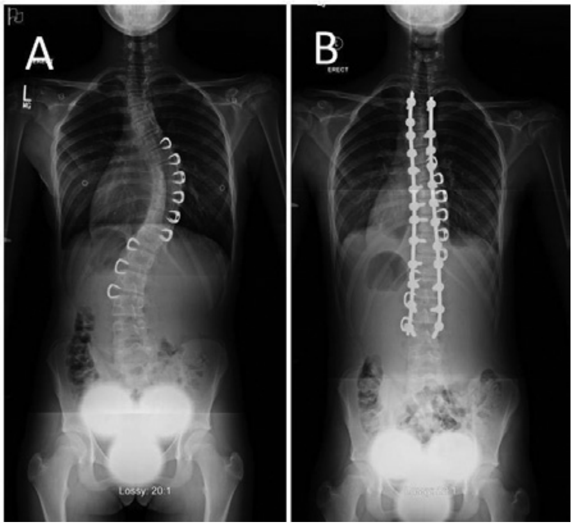
Summary: Vertebral body stapling is a fusionless treatment option for the growing spine. However, some patients continue to progress and eventually require a spinal fusion. We report that spinal fusion can be performed safely and effectively in patients who fail VBS.

Introduction: Anterior vertebral body stapling (VBS) has been shown to be a fusionless alternative treatment of scoliosis in the growing spine. However, despite undergoing VBS, some patients continue to have progression of their scoliosis and ultimately require a spinal fusion. The objective of this study is to determine the feasibility of fusion following VBS.

Methods: We conducted a retrospective study of all patients who underwent VBS for idiopathic scoliosis at our institution from 2001-2009 and were followed for a minimum of two years. We identified all patients who underwent a spinal fusion procedure after VBS. Clinical and radiographic data were analyzed.

Results: A total of 147 patients underwent anterior VBS for scoliosis from 2001 to 2009 at our institution and were followed for a minimum of two years. We identified 28 patients (19.0%) who had progression of their scoliosis and required a spinal fusion. There were a total of 38 curves (thoracic 26, lumbar 12) in this study group. 4 patients had hybrid constructs in addition to the VBS which included growing rods, short fusions, and VEPTRs. There were 24 females and 4 males. The mean age was 10.3 years (4.3-14.5 years) and the mean follow up was 5.32 years (2.2-8.9 years). The mean time from VBS to fusion was 2.9 years. The mean preoperative Cobb angle was 48.2° (thoracic 54.5°, lumbar 34.1°). The percent correction after fusion was 64.3% (thoracic 67.4, lumbar 57.5). One patient underwent an anterior fusion, while the rest had a posterior fusion. 5 patients underwent removal of the vertebral body staples for various reasons including pain, overcorrection, and loosening. The mean estimated blood loss and operative time for the spinal fusion were 1597cc and 417 minutes, respectively.

Conclusion: Despite the reported success of VBS, some patients require a spinal fusion as a definitive treatment. We report 28 patients who successfully underwent spinal fusion after VBS. The blood loss and operative time were comparable to a recent review of spinal fusion from our institution. VBS does not preclude a patient from undergoing a future spinal fusion.



Pre- and post- fusion PA images demonstrating the ability to achieve good correction and to place segmental fixation even at levels with staples present.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

118. Patient Outcomes in the Operative and Non-Operative Management of High-Grade Spondylolisthesis in Children

Kristopher Lundine, MD, MSc, FRCS(C); Stephen J. Lewis, MD; Zaid T. Al-Aubaidi, MD; Benjamin Alman, MD; Andrew Howard, MD, MSc, FRCS(C)

Canada

Summary: Paediatric patients with high-grade spondylolisthesis managed either operatively or non-operatively were identified and contacted by phone to obtain outcome scores using the SRS-30 questionnaire. Non-operative management of minimally symptomatic patients resulted in similar outcomes to operative management of more symptomatic patients.

Introduction: Ideal management of high-grade spondylolisthesis in the growing child is controversial. Some authors have advocated for surgery in all cases regardless of symptoms. Surgical intervention results in a greater than 10% risk of complications. There is a paucity of literature regarding non-operative management in this setting. This study sought to obtain quality of life outcome measures in pediatric patients with high-grade spondylolisthesis managed either operatively or non-operatively.

Methods: Database review was performed to identify patients with a Meyerding grade III-V spondylolisthesis managed either operatively or non-operatively. Patients were contacted by phone to obtain current quality of life measurements using the SRS-30 questionnaire. This is a retrospective cohort study study representing level 3 evidence.

Results: Fifty-three patients were identified for inclusion with 49 contacted for a 92% follow-up rate. Twenty-four patients were treated with operative intervention. Twenty-five patients were initially treated non-operatively, but 10 of these went on to require surgical intervention. Mean age at presentation was 12.6 years (range 8-17) and mean age at follow-up was 20.1 years (range 10-29). There were no outcome differences between groups with mean SRS-30 scores of 119 ± 22 (operative) and 121 ± 11 (non-operative). A more kyphotic slip angle was associated with worse SRS-30 outcome scores across all groups. In the non-operative group, the slip angle was significantly larger in patients who failed conservative treatment (34 ± 17 degrees) than in those who remained non-surgical at final follow-up (20 ± 14 degrees). Slip angle in the operative group was 27 ± 14 degrees. In patients who underwent surgery, an older age at surgery was associated with better SRS-30 outcome scores.
Conclusion: Non-operative management of the minimally symptomatic child with a high-grade spondylolisthesis is safe. Operative intervention for the symptomatic patient achieves similar long-term results compared with patients whose symptoms do not warrant surgery. Delayed surgical intervention does not result in worse outcomes. Regardless of treatment, patients with a more kyphotic slip angle tend to have poorer outcomes.

119. Radiographic Healing of Spondylolysis Does Not Influence Pain or Return to Sports Eight Years Later

Kent T. Yamaguchi, BA; Jerald D. Borgella; Christopher Lee, MD; Lindsay Andras, MD; Karen S. Myung, MD, PhD; Pierre A. D'Hemecourt, MD; John M. Flynn, MD; Jeffrey R. Sawyer, MD; David L. Skaggs, MD, MMM

USA

Summary: This retrospective, multi-center study shows that in adolescent spondylolysis treated conservatively, radiologic healing of the pars defect does not correspond with a patient's pain or return to sports at a mean of 8 years follow-up.
Introduction: Recent studies have suggested that brace treatment for spondylolysis is unlikely to lead to radiographic healing of the pars defect. Our goal was to determine if radiologic healing from conservative therapy corresponds with patients' pain or return to sports.
Methods: A retrospective, multi-center study of 48 subjects with inclusion criteria of: spondylolysis; age of 5-21 years; initial non-surgical care. Initial diagnostic and final follow-up X-rays, CT scans, and MRI scans were evaluated. Patients meeting inclusion criteria were contacted and asked to complete a pain and level-of-functioning survey after consent was obtained. Fisher's exact test was used to compare groups, with significance level of $p<0.05$.
Results: 48 subjects met inclusion criteria and completed the survey, with a mean time interval between diagnosis and completion of the survey of 8 years. 46 subjects (96%) underwent bracing. With a mean of 10 months between initial and final radiologic imaging, 9 subjects (19%) had evidence of radiologic healing, and 2 patients eventually went on to surgery 6 and 42 months after initial treatment. 41 subjects (85%) were able to return to sports after a mean of 6 months. At final follow-up 31 subjects (65%) were completely pain-free (indicating 0/10 pain), and 41 subjects (85%) reported pain of 2/10 or less. Fisher's exact test did not demonstrate a statistically significant relationship between radiographic healing and a patient's pain (p=1.00) or return to sports (p=0.32).
Conclusion: Our study shows that although conservative management of spondylolysis only leads to radiographic healing in 19% of cases, radiographic healing of spondylolysis does not correspond with pain or return to sports.

120. Risks and Outcomes of Corrective Spine Surgery in Chiari Malformation with Syringomyelia Versus Idiopathic Spine Deformity

Jakub Godzik; David Limbrick, MD, PhD; Lawrence G. Lenke, MD; Terrence F. Holekamp, MD, PhD; Wilson Ray, MD; Michael P. Kelly, MD

USA

Summary: In the largest study to date, we report higher rate of neurological complications compared to a matched cohort of idiopathic subjects. Outcomes are similar, however.
Introduction: Chiari Malformation, Type 1, with syringomyelia (CMS) may be associated with spinal deformity. The aims of this study were to evaluate safety and surgical outcome following spinal reconstruction for CMS-related deformities compared with Idiopathic Deformities (ID) pts.
Methods: We matched 38 CMS to ID pts (ratio, 1:1) for age, gender, degree of major deformity, and extent of spinal fusion. CMS pts underwent Chiari decompression prior to spinal reconstruction. Demographics, deformity morphology, surgical details, neuromonitoring (NM) data, and pre- and postoperative SRS-22 scores were recorded at a minimum 2 yr F/U.
Results: Mean age was 14.5 ± 5 years (CMS: 14.6 ± 5, ID: 14.4 ± 5), and 45% of pts were male. Preoperative mean major coronal Cobb measured 53 vs. 56 degrees (p = 0.6) with mean kyphosis 58 vs. 38 degrees ($p < 0.001$). An average number of 10.5 ± 2.5 vertebral levels were fused (10 vs. 10.5, p = 0.82). No significant difference existed in estimated blood loss (690 vs. 740, p = 0.39) or duration of surgery (6.2 vs. 5.7 hours, p = 0.748). Complication rates were similar between groups (32% vs. 18%, p = 0.185). CMS experienced more neurological complications (10% vs. 0%, p = 0.04), NM false negatives (6% vs. 0, p = 0.185), and NM difficulties (20% vs. 7%, p = 0.103). NM difficulties were associated with larger syrinx diameter (10 mm vs. 7 mm, p = 0.014). Mean correction was comparable between the two groups at 2 years (65% CMS vs. 66% ID, p= 0.865). At min 2 yr F/U both groups demonstrated improved SRS-22 outcome subscores: self-

image (CMS: 0.8, N=11, p = 0.012; ID: 0.6, N= 18, p = 0.002), mental health (0.4, p = 0.054; 0.2, p = 0.106) and satisfaction (1.2, p = 0.005; 0.7, p = 0.007). No difference in subscores existed between CMS and ID groups.
Conclusion: CMS patients undergoing spine reconstruction can expect similar corrections and outcomes to ID patients. They also experience higher rates of NM problems and neurological complications related to surgery. Surgeons should be prepared for these difficulties, particularly in children with larger syrinx size.

121. Scoliosis Surgery with Hybrid System in Osteogenesis Imperfecta (OI): Results of 12 Patients: Are Pedicle Screws Applicable to Weak, Tiny and Fragile Vertebrae in OI?

Masaaki Ito; Koki Uno, MD, PhD; Teppei Suzuki; Yoshihiro Inui
Japan

Summary: We reviewed 12 patients of spinal deformity in OI who were performed spinal surgery with hybrid system. Excellent bony union rate and no dislodgement and loosening of the implants were observed. However special care should be taken in placing pedicle screws in Sillence type3 patients whose medial wall of the pedicles could be easily perforated medially due to the vertebral bone quality.
Introduction: Surgical treatment of spinal deformity in OI is a challenge due to severe and rigid deformity with extreme bone fragility. Although surgery with Harrington rod or multiple hooks was reported, large series of surgery with hybrid system has not been reported. And also application of the pedicle screw to the weak, tiny and fragile vertebrae in OI was still unclear. The purpose of this study was to evaluate the result of the spinal surgery with hybrid system and the accuracy and safety of pedicle screw placement.
Methods: Of the 24 OI patients who were performed spinal surgery at our institution, 12 patients treated with hybrid system and followed at least 2-years were included in this study. There were 4 males and 8 females and 8 patients in Sillence type1 and 4 patients in Sillence type3. Average age at surgery was 23.4 years and average follow-up was 3.3 years. Surgeries performed were anterior release followed by posterior fusion in 9 patients, posterior only in 2 patients, and dual growing rod surgery in 1 patient. At least one pedicle screw was used in all cases. Radiological findings, clinical data and accuracy of the pedicle screws placement by post-operative CT scan were examined.
Results: Scoliosis was corrected from 100.4 degrees to 67.8 degrees after operation and 67.1 degrees at final FU (correction rate 31.5%). Kyphosis was corrected from 45.1 degrees to 37.3 degrees at final FU. Solid union was obtained in all patients. No implant loosening and dislodgement were observed.
Of the 148 screws inserted in 98 vertebrae, 14 screws were medially perforated more than 2mm. Perforation rates were 5.3% in type1 vs. 23.5% in type3. Complications related to spinal surgery included 2 transient neurological disturbances and 2 deep infections.
Conclusion: Pedicle screws were applicable for spinal deformity surgery in OI. Excellent bony union rate and no implant dislodgement and loosening were observed. However special care should be taken in placing pedicle screws because of the weakness of medial wall of the pedicles, which could be easily perforated especially in Sillence type3 patients.

122. Results of Surgical Correction of Scoliosis in 17 Patients with Osteogenesis Imperfecta

Zeeshan Sardar, MD, CM; Abhishek Kumar; Vincent Arlet; Neil Saran, MD, MHSc, FRCS(C); Jean A. Ouellet, MD
Canada

Summary: A retrospective case review study (Level of Evidence: IV) of 17 patients with Osteogenesis Imperfecta (OI) who underwent surgical correction for scoliosis was performed. At an average F/U of 5 yrs, postop coronal and sagittal plane alignment and correction were maintained. There was a 50% complication rate. PFTs and functional outcomes assessed by PEDI were maintained during the follow period.
Introduction: OI is the most common connective tissue disorder affecting bone and has a high prevalence of scoliosis. Progressive spinal deformity can lead to progressive restrictive pulmonary disease and functional decline. Optimal treatment, results, and expected complications of scoliosis correction in patients with OI are lacking.
Methods: We reviewed 17 OI patients that had scoliosis correction between 2002 and 2011. The mean age at surgery was 14.3 years (range: 9-21) and average follow up was 5 years. 15 patients had posterior fusion only, while 2 had posterior and anterior fusion. Preoperatively, 16 patients were on Pamidronate therapy. We evaluated demographic and standard radiographic data, PFTs, functional status and perioperative parameters.
Results: From preop to final followup, the Cobb angle of the primary curve improved from 74° to 38° while the secondary Cobb changed from 47° to 17°. The mean thoracic kyphosis changed from 31° to 37° (p = 0.064). There was no significant difference in PFTs from preop to final follow-up. Functional status, expressed by the PEDI for mobility and PEDI for self-care changed from 44.93 and 72.80 to 44.29 and 72.75 respectively. Intraoperative complications included one depressed skull fracture and three dural tears. Perioperative infection was the cause of all other complications. The patients stayed in the hospital for an average of 10.2 days with a mean of 1.4 days spent in the ICU excluding 1 outlier.
Conclusion: Surgical correction of scoliosis in OI is a feasible method to achieve a significant correction of the primary and secondary curves that is sustained in the long-term. While sagittal plane deformity is correctable and maintained statistically, there is an increase in mean kyphosis during followup suggesting the need for anterior fusion to

prevent junctional kyphosis. Despite a significant number of complications, all were without sequelae. Correction of spinal curvature stabilizes PFT results and functional outcome scores. Given the progressive nature of the spinal deformity in OI we believe that the lack of deterioration in these parameters displays the efficacy of scoliosis surgery in this patient population.

123. Scoliosis Surgery in Children with Congenital Heart Disease

Muayad Kadhim, MD; William G. Mackenzie, MD; Ellen Spurrier; Deepika Thacker; Christian Pizarro, MD; Suken A. Shah, MD

USA

Summary: With precise planning and execution, major spine surgery can be performed in patients with significant residua of CHD.

Introduction: We aimed to describe preoperative, anesthetic and peri-operative managements and complications in patients with congenital heart disease (CHD) who underwent surgery to correct a spine deformity.

Methods: This is a retrospective cohort study. There were 21 patients with spine deformity who had previous surgery for CHD. Three types of spine surgery and instrumentation were examined, posterior fusion with instrumentation (PSFI), growing rod (GR), and vertical expandable prosthetic titanium rib (VEPTR). Patients were classified into three cardiac physiologic groups: single ventricle and Fontan circulation (S), two ventricles with no residual abnormal cardiac condition (2N), and two ventricles with residual cardiac problem (2R).

Results: Subjects were 8 boys and 13 girls with mean age of 11.1 ± 5.2 years. Sixteen patients underwent surgery to correct scoliosis, and one to correct kyphosis. Total number of surgeries was 23 (16 PSFI, 5 GR and 2 VEPTR). Two patients were 2N, 11 were 2R and 8 were Group S (Table 1). Mean estimated blood loss was 1685 ml during PSFI, 512 ml during GR and 245 ml during VEPTR. Mean volume of blood transfusion was 44 ml/kg for PSFI, 19 ml/kg for GR and 0 ml during VEPTR. Mean anesthesia time was 9.9 hours for PSFI surgeries, 5.9 hours for GR surgeries, and 5.5 hours for VEPTR surgery. Mean surgery time was 5.8 hours for PSFI surgeries, 3.6 hours for GR surgeries, and 3.9 hours for VEPTR surgeries. Median ICU stay was 2 days ranging from hours to 78 days. Eight patients developed pleural effusion (one patient 2N, four patients 2R, and three patients S); 8 developed atelectasis of varying severity. Median hospital length of stay was 7 days with a range of 3-93 days. There were no deaths.

Conclusion: Patients with moderate to severe residual cardiac abnormalities and patients with single ventricle physiology need continuous participation of a pediatric cardiac anesthesiologist either as the primary provider or in collaboration with a pediatric anesthesiologist who routinely provides anesthesia for spine surgery.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

124. Adjunctive Vancomycin Powder in Pediatric Spine Surgery is Safe

Itai Gans, BS; John P. Dormans, MD; David A. Spiegel, MD; John M. Flynn, MD; Wudbhav Sankar, MD; Robert M. Campbell, MD; Keith D. Baldwin, MD, MSPT, MPH

USA

Summary: Surgical powder vancomycin is safe in pediatric spinal deformity patients >25kg.

Introduction: Spine surgeons have largely turned to vancomycin prophylaxis in an attempt to decrease the incidence of late surgical site infection (SSI) and acute SSI from methicillin resistant Staphylococcus aureus (MRSA). In adult patients the adjunctive local application of vancomycin powder (VP) with an IV cephalosporin has been shown to significantly decrease postsurgical wound infection rates; however, the safety of VP as an adjunct in pediatric spine surgery has not been reported. The purpose of this study was to evaluate the safety of adjunctive local application of VP for infection prophylaxis in posterior instrumented thoracic and lumbar spine wounds in pediatric patients >25kg.

Methods: We reviewed data collected under a systematic protocol specifically designed to monitor the safety profile of VP. We measured changes in creatinine and systemic vancomycin levels following intrawound application of 500mg of unreconstituted VP during spine deformity correction surgery in patients >25kg (patients also received routine IV cephalosporin prophylaxis). Lab values were measured preoperatively and on postoperative days (POD) 1 and 4. Any adverse reactions and infections through available follow-up (2-8 months) were recorded.

Results: 87 consecutive pediatric spinal deformity patients >25kg who received intraoperative VP over a 9 month period were identified. 63% of the patients in this series had adolescent idiopathic scoliosis, 15% congenital scoliosis, 15% neuromuscular scoliosis, and 5% spondylolisthesis. The average change in creatinine levels between the preoperative and POD 1 draw was -0.03 and between the preoperative and POD 4 draw was -0.075. The postoperative systemic vancomycin levels remained undetectable (Table 1). None of the patients experienced nephrotoxicity or red man syndrome. 3/87 patients developed a SSI.

Conclusion: Powder vancomycin acts as a local agent without appreciable systemic exposure or effect on kidney function.

Vancomycin appears to be safe to use in pediatric spinal deformity surgery patients >25kg.

	Pre-op Creatinine	POD 1 Creatinine	POD 4 Creatinine	POD 1 Vancomycin Level	POD 4 Vancomycin Level
Median	0.5	0.5	0.5	BDT	BDT
Maximum	1.1	1	0.9	BDT	BDT
Interquartile Range	0.2	0.2	0.15	0	0

Median, maximum, and interquartile range for preoperative creatinine, postoperative creatinine, and vancomycin. (POD = postoperative day; BDT = below detection threshold)

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

125. Cost Savings Analysis of Intra-Wound Vancomycin Powder in Posterior Spinal Surgery

Osa Emohare, MBBS, PhD; Brian W. Hill, MD; Charles Gerald T. Ledonio, MD; Bowei Song; Eva Enns, PhD; Rick A. Davis, MD; Robert A. Morgan, MD; David W. Polly, MD; Matthew Kang, MD

USA

Summary: Recent literature has shown that using intra-wound vancomycin prophylactically in posterior instrumented spine surgery decreases the incidence of post-operative wound infection. Our study evaluated the clinical efficacy and costs savings associated with the use of vancomycin in a matched cohort of 300 patients. No patients treated with vancomycin required repeat surgery, whereas the untreated group required 13 additional procedures, at a mean additional cost of $41,251 each. The use of vancomycin in this study shows the potential for significant savings.

Introduction: Recent literature has shown that using intra-wound vancomycin prophylactically in posterior instrumented spine surgery substantially decreases the incidence of post-operative wound infection requiring revision surgery. One recent article of 110 patients stated cost savings of over $900,000 per patient who avoids revision spine surgery for wound infection. The purpose of this study was to evaluate the clinical efficacy of intra-wound vancomycin powder in all posterior spinal surgeries and elucidate the cost savings for the hospital via a budget impact model.

Methods: A matched cohort of 300 patients, 150 with prophylactic vancomycin and 150 without, who underwent posterior spinal surgery (instrumented and non-instrumented), over an approximately one-year period were analyzed. We then retrospectively reviewed the cost of a return surgery for surgical site infection. The total insurance payment received by the healthcare facility was used to model the costs associated with a repeat surgery. This cost was offset against the cost of a single local application of vancomycin costing approximately $12.

Results: Of the 150 patients in the treatment group, the return to surgery rate, for surgical site infection, was zero. In the group without vancomycin, 6 patients required a total of 13 procedures. The mean cost per episode of surgery based on the actual reimbursement received by the healthcare facility was $41,251 (range $14,459.21-$114,763.39). A total of $536,267 was spent on 4% of the 150 patient cohort without vancomycin, whereas a total of $1800 ($12x150 patients) was spent on the cohort treated with vancomycin. Not only was there a statistically significant reduction in the incidence of operative wound infections, but there was a cost savings of $536,267.

Conclusion: This study shows a significant reduction in surgical site infections requiring a return to surgery with tremendous cost savings by using intra-wound vancomycin powder. In our study population, the cost savings totaled over half a million dollars.

126. Does a Kaolin Impregnated Hemostatic Dressing Reduce Intraoperative Blood Loss and the Blood Transfusions in Pediatric Spinal Deformity Surgery?

Emily Abbott, BS; Richard M. Schwend, MD; Sreeharsha V. Nandyala, BA

USA

Summary: In this retrospective study of scoliosis deformity surgery, pediatric patients who received perioperative packing with an FDA approved kaolin impregnated haemostatic dressing experienced both 39% less blood loss and total blood transfusion volume than patients who did not receive this treatment.

Introduction: Minimizing blood loss and transfusions are clear benefits for patient safety. Wound packing with hemostatic dressings, a common technique in severe trauma and combat medicine, has not been reported in the spine literature. The purpose of this study was to evaluate the hemostatic benefits of using a kaolin impregnated trauma pad during pediatric spinal deformity correction surgery.

Methods: Level 3 retrospective case controlled, IRB approved, single surgeon study of children who underwent posterior spinal deformity surgery. The control group included 67 patients (46F, 21M, 12.8±4.4 yrs, 10.8±4.7 levels fused) who received standard operative care with gauze packing between June 2007 and March 2010. The treatment group included 48 patients (29F, 19M, 13.7±3.2 yrs, 10.6±4.3 levels fused) who underwent intraoperative packing with Quik Clot Trauma Pads (QCTP, Z-Medica Corporation) for all surgeries after July 2010. No other major changes in the use of antifibrinolytics or perioperative, surgical, or anesthesia technique were noted. Statistical differences were analyzed using ANCOVA in R with $p<.01$. The statistical model included sex, age, weight, scoliosis type, the number of vertebral levels fused, and surgery duration as covariates.

Results: The treatment group had significantly ($p<.001$) 39% less intraoperative estimated blood loss than the control group (822±152cc (marginal mean ± SE) vs 1357±130cc). Patients who received the QCTP treatment had significantly (p<.01) 39% less total perioperative transfusion volumes (660±112cc vs 1080±96cc)(figure 1).

Conclusion: The use of a kaolin impregnated intraoperative trauma pad appears to be an effective and inexpensive method to reduce intraoperative blood loss and transfusion volume in pediatric spinal deformity surgery.

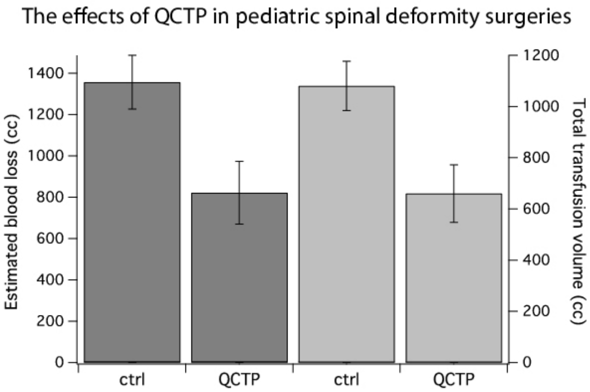


FIGURE 1: Using intraoperative Quik Clot Trauma Pad (QCTP) in pediatric spinal deformity surgeries significantly reduced both the estimated blood loss volume (dark grey) and total perioperative transfusion volume (light grey).

127. Before Diagnosis the SRS-22 Questionnaire Discriminates Populations but Does Not Correlate with Deformity: A Cross-Sectional Study of 1354 Adolescent Idiopathic Scoliosis (AIS) Patients

Laura Rainoldi; Francesco Negrini; Fabio Zaina; Stefano Negrini, MD

Italy

Summary: The SRS-22 Questionnaire was completed by 1354 adolescents neither treated nor diagnosed, divided into 5 groups (normals <10° Cobb; AIS: 11-20°; 21-30°; 31-40°; >40°). Significant differences between groups and negligible correlations between deformity and SRS-22 domains emerged. Unlike previous studies, the SRS-22 showed discriminative validity among AIS populations. High scores reported suggested that at the first visit no domain appeared really compromised. Before diagnosis, Self-Image appears compromised also in normals, Pain is not a real issue also in curves >40°.

Introduction: The Scoliosis Research Society Questionnaire (SRS-22) is the actual standard to measure psychological well-being and quality of life in Adolescent Idiopathic Scoliosis (AIS) patients. Its psychometric properties have been checked, but not in large populations, mainly in high-degree curves and usually in patients already diagnosed and/or treated: all these situations may interfere with reported results. Our aim was to check the discriminative validity and correlation with deformity of the SRS-22 in a large sample of consecutive patients neither treated nor diagnosed.

Methods: 1354 adolescents (75% female) completed the SRS-22 before their first evaluation. 5 groups were created: normals <10° Cobb - AIS: 11-20°; 21-30°; 31-40°; >40°). To prevent sample size effect, ANOVA with Hochberg's GT2 post-hoc correction was performed. The two genders were analyzed separately to control sex differences among groups. Pearson correlations with Cobb degrees have been calculated.

Results: In females, statistically significant differences among groups were found for all the domains and the total score; in males, Pain and Mental Health did not show statistically significant differences among groups. In all domains, AIS patients with curves >40° reported significant lower scores compared to normals. Even if statistically significant, the existing negative correlations between Cobb degrees and all domains scores were negligible (Rho<0.2). All groups showed the highest scores (median 4.80, range 1.40 - 5.00) for Pain and the lowest scores for Self-Image (median 3.60, range 1.20 - 5.00).

Conclusion: Before diagnosis, significant differences between groups were found, but with negligible correlations between deformity and SRS-22 domains. The SRS-22 showed a discriminative validity to study AIS populations: this was not found previously and can be explained either by the large sample studied or by the absence of first diagnosis in our population. The high scores found showed that at the first visit no domain appeared really compromised, with a ceiling effect. Before diagnosis, Self-Image appears compromised also in normals, while Pain is not a real issue also in curves >40°. To monitor potential variations in the scores, a longitudinal study should be designed.

128. Impact of BMI and Depression on Scoliosis Research Society (SRS-22) Questionnaire After Major Spine Surgery

Sara E. Thompson, BA; Jamal McClendon, MD; Frank L. Acosta, MD; Tyler Koski, MD

USA

Summary: We investigated the effect of depression and obesity on SRS-22 sub-scores.

Introduction: Depression and obesity can have a significant impact a person's quality of life. To date, no study as examined the impact of these conditions on SRS-22 sub-scores.

Methods: We retrospectively reviewed consecutive adult elective spinal fusions ≥4 levels (2004-2011) with available SRS-22 questionnaires and follow-up ≥1 year. One way ANOVA examined SRS-22 sub-scores based on BMI category (Ideal 18.5-24.99, Overweight 25-29.99, Obese ≥30). Linear regression analysis evaluated BMI, history of depression, and presence of spinal malalignment at 1 and 2 years, controlling for confounders. Mean follow-up was 18.6 months.

Results: 110 patients (24M:86F) with mean age of 60.5 years and mean BMI of 28.7 were analyzed. Patients with depression

(N=35) had lower pre-op Pain (p=0.011), Function (p=0.001), Self Image (p=0.02), and Mental Health (p=0.005) scores. Patients with depression had lower Mental Health scores (p=0.019) at 1 year and lower Function (p=0.008) and Mental Health (p=0.002) scores at 2 years. Both groups showed significant improvement in all sub-scores at 1 and 2 years. The results of the regression analysis for depression are shown in Table 1. Obese patients had lower pre-op and 1 year Function scores than ideal weight patients (p=0.008 and 0.011). There were no significant differences between BMI categories at 2 years. Regression analysis showed that BMI influenced pre-op Function (p=0.001) and Self Image (p=0.039), and 1 year Function (p=0.036) scores. Regression analysis showed that spinal malalignment influenced pre-op and 1 year post-op Self Image scores (p=0.020 and 0.016).
Conclusion: Depression is an independent predictor of Mental Health, Pain, and Function scores. BMI is an independent predictor of pre-op Function and Self-Image scores and of Function scores at 1 year. Spinal malalignment is an independent predictor of pre- and post-op Self-Image scores.

Table 1. Regression Analysis-Depression

SRS Sub-Score	Pre-Op	1 Year	2 Year
Pain	S (0.025)	NS	NS
Function	S (0.007)	NS	S (0.02)
Mental Health	S (0.013)	S (0.013)	S (0.019)

S=Significant, NS=Not-Significant, (p-value)

129. The SRS-7: An Unidimensional Rasch-Developed Short Form of the SRS-22 Questionnaire for Measuring Health-Related Quality of Life in Adolescent Idiopathic Scoliosis

Antonio Caronni, MD, PhD; Fabio Zaina; Stefano Negrini, MD

Italy

Summary: SRS-22, the Scoliosis Research Society questionnaire for assessing health-related quality of life in idiopathic scoliosis, was subjected to Rasch Analysis (RA) statistics. When tested on adolescents with mild idiopathic scoliosis, RA shows SRS-22 suffering poor clinometric properties (e.g. multidimensionality and ceiling effect). Thus, SRS-22 raw score does not satisfy measurement requirements, possibly leading to erroneous patients evaluation. RA was further used to develop a SRS-22 short form questionnaire (SRS-7) which provides a better measure of subjects with mild idiopathic scoliosis.
Introduction: Scoliosis Research Society-22 questionnaire (SRS-22) was developed for evaluating health-related quality of life (HRQL) in idiopathic scoliosis (IS) patients. Rasch analysis (RA) is a statistical procedure which turns questionnaire ordinal scores into interval measures. Measures from Rasch-compatible questionnaires can be used, the same as body temperature or blood pressure, to quantify disease severity, progression and treatment efficacy. In the current work, SRS-22 RA is presented and SRS-22 raw score is eventually converted into an interval measure.
Methods: Three hundred SRS-22 were randomly collected from a database including 1354 SRS-22 of consecutive IS adolescents at their first evaluation (229 females; 13.9±1.9 years; 26.9±14.7° Cobb). Winsteps software (3.69.1) was used for RA (partial credit model).
Results: RA showed both disordered thresholds and overall misfit of the SRS-22. Sixteen items were thus re-scored and two misfitting items (6 and 14) removed to obtain a Rasch-compatible questionnaire. Subjects HRQL measured too high with the rearranged questionnaire, indicating a severe SRS-22 ceiling effect. RA also highlighted SRS-22 multidimensionality, with pain/function not merging with self-image/mental health items. In addition, item 3 showed differential item functioning (DIF) for both curve and hump amplitude. A 7 items questionnaire (SRS-7) was prepared by selecting single items from the original SRS-22. SRS-7 showed fit to the model, unidimensionality and no DIF. Finally, compared with the SRS-22, the short form scale shows better targeting on the subjects population.
Conclusion: According to Rasch theory, SRS-22 does not satisfy fundamental measure requirements, i.e. additivity, generalizability and unidimensionality. Moreover, when used with mild IS adolescents, SRS-22 is affected by a severe ceiling effect. SRS-7, a 7 items short form questionnaire, provides an HRQL measure better tailored to subjects with mild idiopathic scoliosis, with the advantage of being an interval scale.

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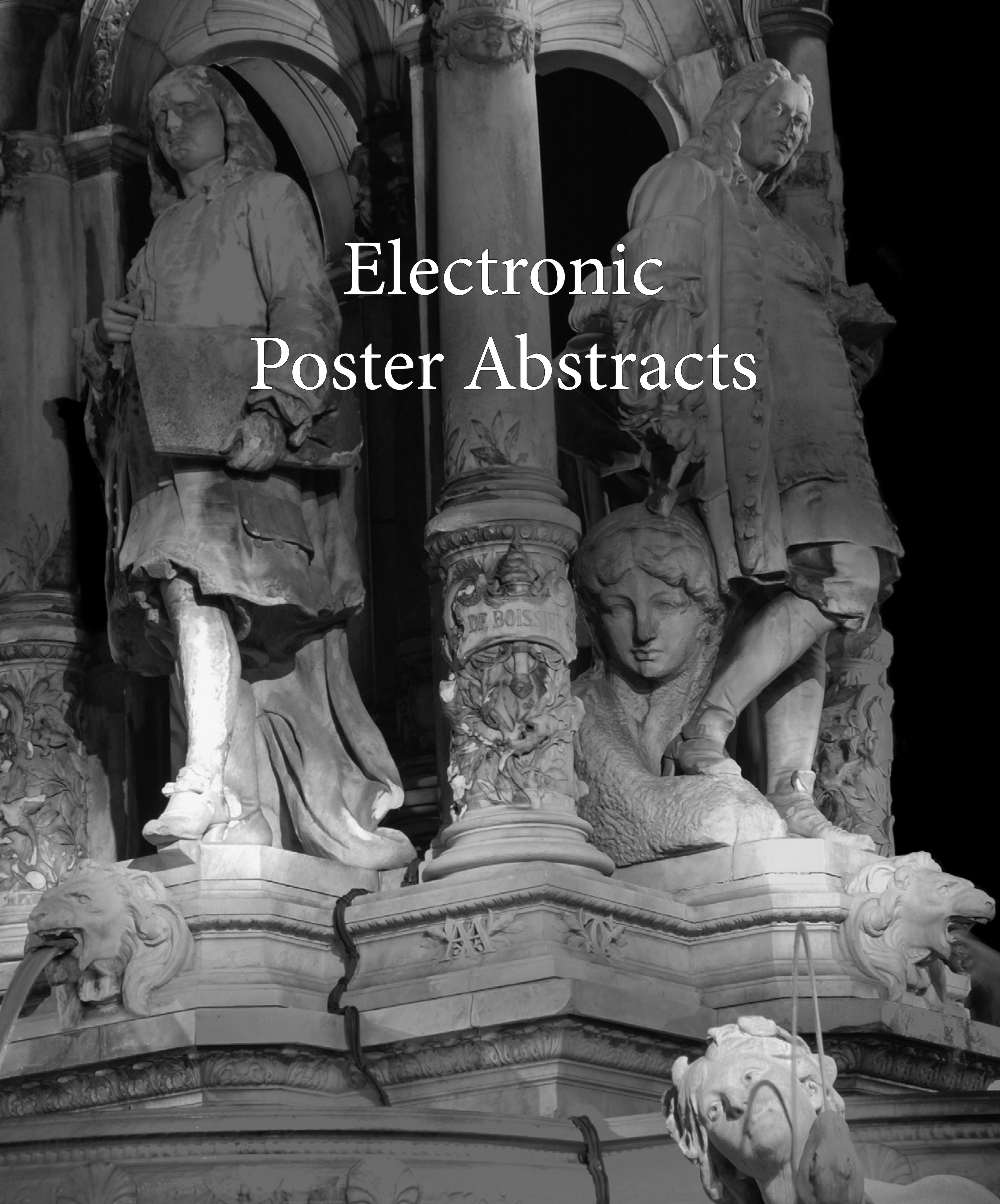

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201. Peak Height Velocity as a New Predictive Factor for Curve Progression in Patients with Late-Onset Idiopathic Scoliosis

Masaaki Chazono, MD, PhD

Japan

Summary: The sensitivity, specificity, and area under the curve (AUC) of the receiver -operating -characteristic (ROC) analysis were calculated to predict spinal curve progression for various Cobb-angle cutoff values at PHV.As a result, these findings indicate that 32 degrees of spinal curvature when patients are at PHV is a significant predictive indicator for progression of the curve to a magnitude requiring surgery.

Introduction: Academic societies in the United States, Singapore, and Hong -Kong have recommended that scoliosis screening began at the age of 10 years, or 11 years at the latest, however Japan has not yet integrated the timing of a mass nationwide screening program. Therefore, we can not detect the individual PHV values in patients with LIS during clinical visit. The aim of this study was to analyze the relationship between the magnitude of the Cobb angle at PHV and the most recent treatment method before maturity in female patients with LIS.

Methods: A retrospective review identified 56 skeletally immature female LIS patients with a mean age of 10 years. These patients were followed until maturity and assigned to 1 of 3 groups: observation (O-group), brace treatment (B-group), and surgery (S-group), depending on the treatment method in use at the final follow-up visit. Height measurements were recorded at each visit; height velocity was calculated as the height change, in cm, divided by the time interval, in years. The PHV, age at PHV (APHV), height at PHV (HPHV), and final height (FH) were determined for each group. The sensitivity, specificity, and area under the curve (AUC) of the receiver -operating -characteristic (ROC) analysis were calculated to predict spinal curve progression for various Cobb-angle cutoff values at PHV.

Results: The PHV had a mean value of 7.84, 8.61, and 8.94 cm/year in the O-group, the B-group, and S-group, respectively. The APHV was 11.7, 12, and 11 years, the HPHV was 153.2, 152.8, and 149.3 cm, and the FH was 161.5, 159.5, and 159.3 cm, respectively. When a Cobb angle of 32 degrees was used as the cutoff for determining which patients underwent surgery, ROC analysis revealed 78% sensitivity, 82% specificity, and an AUC of 0.925, acceptable values for curve progression in patients with LIS.

Conclusion: These findings indicate that 32 degrees of spinal curvature when patients are at PHV is a significant predictive indicator for progression of the curve to a magnitude requiring surgery. We suggest that the curve-progression risk assessment in patients with LIS should include PHV, along with measures of skeletal and/or non-skeletal maturity.

Ω 202. NF1 and Idiopathic Scoliosis: Shared Genomic Regions

Nancy Hadley-Miller; Kandice Swindle; Heejong Sung, PhD; Cristina M. Justice, PhD; Douglas Stewart

USA

Summary: Linkage regions from a genome-wide analysis of familial idiopathic scoliosis (FIS) were compared to genome-wide association analysis results of NF1 patients with scoliosis (≥30 degrees spinal curvature) to identify common genomic regions that may contain genetic variants related to the scoliosis phenotype.

Introduction: The study of genetic variation in diseases that share phenotypic features can aid us in our understanding of pathogenesis. The main objective of this study was to determine if individuals with FIS and those with NF1 and scoliosis share significant linkage or association signals to common chromosomal regions.

Methods: Model-independent linkage analyses of a genomic screen on a group of Caucasian families in which male probands had ≥30 degrees spinal curvature (23 families) identified multiple loci significantly linked to FIS including 17q11, upstream of the NF1 locus. Initial and fine-mapping data were analyzed by model-independent linkage analyses using SIBPAL (SAGE, v6.0.1) to identify regions significantly linked to the scoliosis phenotype.

GWAS data (1M Illumina panel) from 80 unrelated Caucasians with NF1 was reviewed. Spinal curvature measurements determined through MRIs indicated scoliosis of ≥30° in 7/80 NF1 individuals. Fisher's Exact Test was performed on 605,630 SNPs in the 80 patients (calling rate >99%; MAF≥10%; individual genotyping rate >98%).

Results: Fisher's Exact Test of the NF1 populations identified significant loci potentially related to the scoliosis phenotype containing multiple genes (Table 1). Three genes are also found within significant loci linked to FIS within our familial idiopathic population: TIAM2 (6q24.3-25.3), CAMKID (10p13) and ZNF423 (16q12).

Conclusion: Multiple genes have been identified to be significantly related to the scoliosis phenotype within these populations. CAMK1D (Ca2+/calmodulin-dependent-protein-kinase 1; 10p13) plays a role in spinal cord, neural crest, and

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skeletal development, and thus is of particular interest. The finding of shared genetic regions by two disorders marked by scoliosis will allow us in finding genetic variants involved in the pathogenesis of scoliosis.

203. Association of Body Composition with Curve Severity in Children and Adolescents with Idiopathic Scoliosis (IS)

Edyta A. Matusik; Jacek Durmala, PhD; Pawel Matusik; Karol Wadolowski, MS

Poland

Summary: The first study comparing relationship between body composition parameters (assessed by bioelectrical impedance methodology and standard measurements) and scoliotic curve severity in pediatric population with idiopathic scoliosis.

Introduction: Body composition changes during the developmental period and differs in children with idiopathic scoliosis (IS). No large-scale study has been performed to reveal the link between scoliotic deformity and body composition assessed by bioimpedance method (BIA). The study objective was to correlate the extent of scoliotic-curve severity with nutritional status of patients with IS based on standard anthropometrical analysis and BIA.

Methods: 279 patients (224 girls/ 55 boys) in mean age of 14.21 ± 2.75 years, with IS were qualified into the study. Scoliotic curve was assessed by Cobb's angle and angle vertebra rotation (AVR). Curve severity was categorized into a mild (10-19), a moderate (20-39) and a severe group (≥40) based on Cobb's angle. Height, weight, waist and hip circumferences were measured and body mass index (BMI), BMI Z-score, waist/height ratio (WHtR) and waist/hip ratio (WHR) were calculated in the entire group. Body composition parameters as: fat mass (FAT), fat-free mass (FMM), predicted muscle mass (PMM) and total body water (TBW) were evaluated using bioelectrical impedance analyzer.

Results: Mean Cobb angle of the mild, moderate and severe groups were 13.69 ± 2.95, 26.74 ± 5.67 and 52.36 ± 12.43 respectively. Cobb's angle and AVR were positively correlated ($p < 0.01$) with FAT% and BMI, but inversely ($p<0.01$) with FFM%, TBW% and PMM% in the study group. Subgroups analysis revealed the same relationship only in the group of severe spinal deformity, also for BMI Z-score and WHtR. Body fatness expressed as FAT% was significantly higher ($p<0.05$) in the severe vs. mild group, but FFM%, TBW% and PMM% were significantly ($p<0.05$) lower.

Conclusion: 1. Body composition parameters assessed by BIA are associated with scoliotic curve severity, mainly in severe spinal deformity patients. 2. Fatness degree (FAT% and BMI Z-score) and fat tissue distribution (WHtR) seems to have significant relation with clinical grade of IS. 3. Further investigations concerning relation between body composition and curve severity in of children and adolescent with IS are indicated.

Ω 204. Dynamic Fast Breath-Hold MRI Based Pre- and Post-Spinal Fusion Lung Volume Analysis in Patients with Adolescent Idiopathic Scoliosis (AIS)

Defeng Wang, PhD; Lin Shi, PhD; Winnie C. Chu, FRCR, FHKAM, MD; Bobby K. Ng, MD; Tsz Ping Lam, MBBS; Jack C. Cheng, MD

Hong Kong

Summary: The proposed study aims to develop a novel segmentation algorithm to perform lung segmentation. Dynamic fast breath-hold MRI data of 15 patients with Adolescent Idiopathic Scoliosis were used to test this algorithm and the lung volume of AIS was measured before and after operation. The lung segmentation process was significantly speed-up.

Introduction: Patients with AIS commonly suffer from restrictive pulmonary impairment. To evaluate and measure the pulmonary function and lung volume, dynamic fast breath-hold MRI (BH-MRI) is applied to capture MR images for analysis. The traditional method for lung assessment was time-consuming and labour intensive. To improve the efficiency, we aim to develop a computer program to assist physicians and researchers to perform lung segmentation on MR images.

Methods: Subjects involve 15 patients with AIS. Their pre- and post-operation lung volume in inspiration and expiration states was capture by BH-MRI. The lung regions on MR data were automatically delineated using image thresholding followed by morphological operations. Then they were refined to measure the lung volume before and after operations. To validate the results calculated by the proposed program, results obtained automatically were compared to those obtained manually by an experienced radiologist.

Results: After validation, results obtained from the program were comparable with high correlation (R= 0.92) to those measured manually. While the measurement remained accurate, the processing time was significantly reduced by one-fifth from an average of 60 minutes to 12 minutes for one dataset. The computer analysis was highly reproducible (Intraclass

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coefficient = 0.99). The lung volume was increased from 2.74L before operation to 3.04L after operation.

Conclusion: The proposed algorithm demonstrated an accurate, efficient and reproducible lung segmentation and volume measurement for patients with AIS. It is a potential program that could be adopted by physicians for long-term follow-up of pulmonary function.

205. Are Routine Post-Operative Radiographs Required During the First Year Following Surgery for Idiopathic Scoliosis?

Sumeet Garg, MD; Emily A. Kipper; Jaren LaGreca; Patrick M. Carry, BA; Mark A. Erickson, MD

USA

Summary: Clinical notes and radiographs for 227 consecutive adolescent patients having surgery for idiopathic scoliosis were reviewed to determine if clinically useful information is obtained by routine radiographs during the first year after surgery. 169/227 patients (74%) had no symptoms, and only one had revision surgery for a dislodged set plug. After obtaining baseline post-operative standing radiographs, routine radiographs during the first year after surgery for IS may not be required in the absence of clinical symptoms.

Introduction: Radiographs are routinely taken at almost every post-operative visit following surgery for idiopathic scoliosis (IS). The goal of this study was to determine if clinically useful information is obtained by this practice.

Methods: 227 consecutive patients between the ages of 10-21 having surgery for IS at our institution from 2004-2010 were identified. Charts were reviewed to determine patient reported clinical symptoms: pain greater than expected, implant prominence, and sensory/motor disturbance. Radiographs were reviewed to identify implant failure and curve change.

Results: Patients had an average of 3 visits (range 2-10) and 6 radiographs (range 2-12) during the first year after surgery. 75% had pedicle screw and 25% had hybrid constructs. Pain was the most common symptom, occurring in 14% of patients. Neurologic symptoms (13%) and implant prominence (4%) were less common. Implant failure was identified in 4 subjects (2%), 3 had revision surgery. Curve progression >10° occurred in the un-instrumented curve 2 patients (1%). No patient had change in treatment due to curve progression. Pain was the only clinical symptom associated with implant failure in univariate logistic regression analysis (p=0.0047). Presence of any one symptom of pain, neurologic symptoms, or implant prominence was also associated with implant failure (p<0.0365). 169/227 patients did not have any symptoms and only one of these had revision surgery. The incidence of need for revision surgery was 2.85/1000 radiographs [95% CI 0.57 to 8.33]. Sensitivity of pain for implant failure was 75%, specificity 87%, positive predictive value 10%, negative predictive value 99.5%.

Conclusion: Reducing the number of radiographs taken during the first year after surgery for IS in patients without symptoms can reduce radiation exposure to patients and health care costs without affecting treatment.

206. Anxiety in Adolescents with Idiopathic Scoliosis Undergoing Posterior Spinal Fusion: A Prospective Study to Identify Effective Intervention Strategies

Leslie Rhodes, MSN; Donna C. Scott, MSN; Cassie Nash; Kaku Barkoh, MD; Derek M. Kelly, MD; William C. Warner, MD; Jeffrey R. Sawyer, MD; Robert F. Murphy, MD

USA

Summary: Anxiety is a significant issue in adolescents undergoing PSF. Preoperative orientation and hospital tour before PSF were associated with increased anxiety in adolescents. This study indicates that adolescents need information closely correlated to their age and developmental level using different interventional strategies for the caregiver and the adolescent.

Introduction: A prospective randomized study examined the effect of an interventional preoperative orientation on anxiety levels of adolescents undergoing posterior spinal fusion (PSF). Secondary outcomes analyzed were caregiver anxiety, length of inpatient stay, analgesic consumption of morphine equivalents, and patient/caregiver satisfaction.

Methods: Adolescents undergoing PSF were randomly assigned to either the control group (N= 39) or interventional group (N=26). All subjects and caregivers completed the State-Trait Anxiety Inventory (STAI) at four intervals: preoperative appointment, preoperative holding area, postoperative orthopaedic unit, and discharge. Patients and caregivers completed a hospital satisfaction survey at discharge.

Results: Both adolescent groups had significantly higher state anxiety scores than trait anxiety scores at all intervals (control p=0.003) (interventional p=0.010). A significant difference in patient anxiety was found at the postoperative interval: the orientation group scored higher on state anxiety than the control group (p=0.024). There were no significant differences in the caregiver state anxiety scores. In the orientation group,

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anxiety was strongly correlated between caregiver and patients ≤ 14 years old at the postoperative interval (r=0.520) and at discharge (r=0.636). In the control group, anxiety was strongly correlated between caregiver and patients ≥15 years old at the preoperative appointment (r=0.709), postoperatively (r=0.469) and at discharge (r=0.544). Trait anxiety scores for both groups remained stable over time. No significant differences were found in length of stay or morphine equivalent use. Patient satisfaction scores were higher in the intervention group than in the control group (p=0.0005).

Conclusion: This study indicates that anxiety is a significant issue in adolescents undergoing PSF. Preoperative orientation and hospital tour before PSF were associated with increased anxiety in adolescents. Adolescents need information closely correlated to their age and developmental level using different interventional strategies for the caregiver and the adolescent.

207. Scoliosis Progression in Male Patients with Adolescent Idiopathic Scoliosis: Correlation with Digital Skeletal Age Score

Pooya Hosseinzadeh, MD; Ryan D. Muchow, MD; Russell M. Odono, MD; Crystal Norgren; Janet L. Walker, MD; Vishwas R. Talwalkar, MD; Todd A. Milbrandt, MD, MS; Henry J. Iwinski, MD

USA

Summary: Retrospective review of 69 adolescent male patients with scoliosis was performed and curve progression based on DSA was studied. We showed a bimodal pattern of curve progression in male patients with high predictability of DSA on final curve outcome.

Introduction: Recently, Sanders et al. introduced a modified digital skeletal age (DSA) score that correlates well with the behavior of idiopathic scoliosis (IS) in female patients. It is known that curve progression in male IS patients behaves differently than female patients related to the Risser stage, but it has not been correlated with the DSA in male patients. Therefore, we aimed to identify an association between the DSA and curve progression in male IS patients.

Methods: A retrospective review of male patients with AIS was performed. Inclusion criteria were: AIS, male, PA hand and spine radiographs at the same visit, and greater than one clinic visit. Major curve Cobb angle, Risser sign, triradiate cartilage status, DSA, and treatment were reviewed for each clinical visit and the monthly curve progression (MCP) was calculated. An operative curve was defined as any major curve >50 degrees at skeletal maturity or having undergone spinal arthrodesis. We correlated the MCP with the DSA score and Risser sign and assessed the ability of the DSA score to predict progression to an operative curve.

Results: 69 patients met inclusion criteria, with 16 patients being defined as operative. MCP correlated with the DSA score for both operative and non-operative curves in a bimodal pattern of curve progression with the highest values at digital skeletal stage 2 and 3 followed by a smaller peak at stage 6 and 7 (Chart 1).The average MCP was higher for operative curves compared to the non-operative curves. Highest values of MCP correlated with Risser stage 0 with open trirdiate cartilage. We also studied the predictability of a surgical outcome for curves with different Cobb angles at various stages of DSA.Curves that presented between 30-40 degrees with a DSA score of 2 or 3 progressed to a surgical magnitude 100% (6/6 patients) and 60% (3/5 patients) of the time, respectively. No curves less than 40 degrees at presentation progressed to surgery when the initial DSA score was 4 or greater.

Conclusion: The DSA score correlates with curve progression in male AIS patients and demonstrates the potential for progression in later stages of skeletal maturity, particularly in those patients whose curves advance to an operative level.

208. Amount of Coronal Correction in AIS Patients Following Posterior Column Osteotomies: An Intraoperative Radiographic Study

Yang Xu, MD, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD; Linda Koester, BS; Brenda A. Sides, MA

China

Summary: We reviewed 23 AIS patients undergoing PCOs with a minimum 2-year follow-up. Intraoperative radiographic analysis showed an average of 22% of the total coronal Cobb correction was from the PCOs, 31% from prone positioning, and 47% from actual instrumentation placement.

Introduction: Posterior column osteotomies (PCOs—Smith-Petersen or Ponté) were originally designed for correction of spinal kyphosis. However, PCOs performed at the apex of a rigid major curve may allow greater coronal correction for adolescent idiopathic scoliosis (AIS) patients. The goal of this study was to determine the amount of correction obtained in coronal alignment through PCOs vs. that obtained from prone positioning and instrumentation as well.

Methods: 23 AIS patients that underwent PSF with PCOs having a minimum 2-year follow-up were reviewed. 20 were primary and 3 were revisions surgeries. We excluded those with

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a concomitant PSO, VCR or anterior release/fusion at the PCO levels. Routine pre and postop as well as intraoperative prone radiographs were obtained before and after PCOs (to check screw placement). Percent coronal correction obtained from prone positioning, PCOs and instrumentation were evaluated.

Results: 23 patients aged 15.0±2.1 years underwent 113 PCOs (avg 4.9±1.9) with 12.7±1.5 average levels of screw instrumentation, with 3.9 years (range 2-6.8) average follow-up. Mean coronal Cobb of the major curve was 71.6°±16.04. On side bending, the major curve measured 56.8°±15.9 (Δ20.7%). With prone positioning and anesthesia, the major curve measured 54.2°±9.9 (Δ20.7%, p=0.003). After PCO, the major curve measured 45.1°±9.7 (Δ15.1%, p=0.003). After instrumentation with active correction, the major curve measured 23.1°±9.2 (Δ31.5%, p<0.001). Thus, of the 3 contributions to the overall coronal correction, prone positioning provided 31%, PCOs provided 22%, and the actual instrumentation provided 47%.

Conclusion: Although instrumentation with correction maneuvers play the most important role in providing coronal correction (47%), together both prone positioning (31%) and PCOs (22%) provide >50% of the correction prior to rod placement/correction. PCOs do contribute to coronal correction averaging 22% in AIS patients.

209. Spinal Penetration Index Assessment in Adolescent Idiopathic Scoliosis Using EOS Low-Dose Biplanar Stereoradiography

Brice Ilharreborde, MD; Jean Dubousset; Wafa Skalli, PhD; Keyvan Mazda

France

Summary: With little radiation exposure, EOS stereoradiography permits routine imaging in a functional standing position and morphological assessment of the rib cage. The spinal penetration index (SPI) is a new 3D parameter quantifying the portion of the rib cage occupied by vertebrae, and therefore reflecting the global trunk deformity in AIS. The goal of this study was to assess the correlation between EOS 3D parameters and pulmonary function tests in 80 thoracic AIS patients.

Introduction: The spinal penetration index (SPI) quantifies the portion of the rib cage occupied by vertebrae, and therefore reflects the global trunk deformity in AIS. When measured by computed tomography (CT) or magnetic resonance imaging, SPI can only be determined in the reclining position, which modifies spinal and thoracic morphology. In addition, CT results in high radiation exposure. The authors studied rib cage and spinal morphology using low-dose stereoradiography and their impact on respiratory function in adolescent idiopathic scoliosis (AIS).

Methods: In eighty thoracic AIS patients, a slot-scanning radiologic device allowing simultaneous acquisition of orthogonal images and 3D reconstructions with low exposure to radiation (EOS) was used to determine thoracic volume, mean spinal penetration index (SPIm), apical spinal penetration index (SPIa), Main Thoracic (MT) curve Cobb angle, T4-T12 kyphosis, and apical vertebral rotation (AVR).

Results: Thoracic volume calculated with EOS was correlated with functional total lung capacity, but also with T4T12 kyphosis (r=0.31, p=0.006). SPIm and SPIa were significantly increased in hypokyphotic patients. Forced vital capacity and forced expiratory volume in 1 second were also significantly lower in the hypokyphotic population (p=0.04 and p=0.03, respectively) and correlated with thoracic volume and T4-T12 kyphosis. No correlation was found between spinal penetration indices and pulmonary function tests, but SPIm was significantly greater in patients with obstructive syndrome (p=0.01).

Conclusion: With little radiation exposure, EOS biplanar stereoradiography permits routine imaging in a functional standing position and morphological assessment of the rib cage. Spinal penetration indices reflect the global trunk deformity in AIS, and are significantly increased in hypokyphotic patients and in case of obstructive syndrome. This new parameter should be included in the postoperative assessment of surgical procedures.

210. Sagittal Balance and Compensatory Mechanism After Segmental Instrumentation for Adolescent Idiopathic Scoliosis

Per D. Trobisch, MD; Patrick J. Cahill, MD; Amer F. Samdani, MD; Harms Study Group; Randal R. Betz, MD; Jahangir Asghar, MD

Germany

Summary: Patients with AIS tend to adjust lumbar sagittal alignment rather than the pelvis to achieve sagittal alignment long-term following fusion for AIS.

Introduction: Modern instrumentation decreases the incidence of sagittal imbalance following surgery for AIS compared to early instrumentation such as the Harrington rod. However, patients may be compensating for inadequate correction of

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their thoracic sagittal alignment by altering their lumbar sagittal alignment or their spinopelvic balance. The purpose of this study is to analyze global sagittal balance and to identify potential compensatory mechanisms for achieving sagittal balance after segmental instrumentation for AIS.

Methods: This is a radiographic analysis of a prospectively collected multicenter database. Patients with segmental instrumentation for AIS type 1&2 and a minimum follow-up of 2 years were included. Changes in lumbar lordosis (LL) were analyzed for correlations to changes in pelvic tilt (PT) and sagittal vertical axis (SVA) as quantified by the distance between the C7 plumb line and the posterior sacral vertical line.

Results: 91 patients (63 girls, 28 boys, mean age at surgery 14.5 years) were included. The lowest instrumented vertebra was at or above L2 in 81% of the patients. On the first erect x-ray, LL significantly decreased 7.9° from pre-op ($p<0.001$) but the SVA remained stable (pre-op: -1.6 cm vs. first erect: -1 cm; $p>0.05$) due to a significant increase of PT (pre-op 10.9°, first erect 14.9°, $p<0.001$). At two years follow-up, PT returned to pre-op values, accompanied by a compensatory hyperlordosis below the instrumentation (3.3°, $p=0.01$). The temporary increase of PT on the first erect was significantly correlated (r -0.46, $p<0.001$) to an iatrogenic decrease of LL. An iatrogenic decrease of LL was also significantly correlated to an increase of SVA on the first erect (r -0.38, $p<0.001$) and at 2 years follow-up (r -0.47, $p<0.001$).

Conclusion: The long-term compensatory mechanism for the inability to restore sagittal alignment in a thoracic fusion for AIS is to decrease LL (not increasing PT), perhaps increasing the risk of long-term degeneration.

211. Extending the Fusion Level to the Lumbar Spine in Lenke 1 and 2 Curves Can Reduce the Risk of Distal Adding-On?

Takuto Kurakawa; Koki Uno, MD, PhD; Teppei Suzuki; Yoshihiro Inui; Kenichiro Kakutani, MD, PhD

Japan

Summary: Ninety Lenke type 1 or 2 curves in which the fusion level was extended to the lumbar spine were evaluated. Comparing Lenke type 1 curves, distal adding-on (DAO) was more likely to occur in Lenke type 2 curves. In Lenke type 2 curves, postoperative change of C7-CSVL might affect the development of DAO.

Introduction: Distal Adding-on (DAO) in Lenke type 1 or 2 patients who underwent selective thoracic fusion has been reported. However, it is still unclear whether extending the fusion level to the lumbar spine is effective to prevent the DAO or not. The aim of this study was to evaluate the incidence of DAO and associated risk factors in Lenke type 1 and 2 scoliosis, in which the fusion level was extended to the lumbar spine.

Methods: Of the 198 AIS patients surgically treated between 2007 and 2010, Lenke 1 and 2 curves which segmentally fused including the lumbar spine and followed up at least 2 years were involved in this study. The 9 radiographic parameters were assessed; 1) magnitude and correction of PT (proximal-thoracic), MT, and TL/L curves, 2) C7 plumb line to CSVL distance (C7-CSVL), 3) segmental difference of the lowest instrumented vertebra from the thoracic end vertebra (LIV-EV), 4) angulation of distal junctional disc (DJD) below the LIV. DAO was defined as a postoperative increase of more than 5° in the angulation of DJD. The incidence of DAO was evaluated by X-square test, and the parameters were compared between curve types using one-way ANOVA.

Results: Ninety patients met inclusion criteria (Lenke 1; 47, Lenke 2; 43), and 21 patients met the definition for DAO (Lenke 1; 6, Lenke 2; 15). The incidence of DAO in Lenke 2 curve (34.9%) was significantly higher ($P<0.05$) than in Lenke 1 (12.8%). The median LIV level was both L2 ($P>0.05$), and the mean LIV-EV (Lenke 1=1.9, Lenke 2=1.6) was not significantly different between curve types. The UIV levels were T4 and T2 ($P<0.05$) in Lenke 1 and 2 curves respectively. The average of PT in Lenke 2 (21.4°) was significantly larger ($P<0.05$) than in Lenke 1 (11.9°) at the last follow-up. The mean C7-CSVL was significantly smaller in Lenke 1 (-5.7mm) than in Lenke 2 (0.3mm) at 1-week after surgery, whereas it did not appear any difference between curve types (Lenke 1; -6.1mm, Lenke 2; -3.1mm) at the last follow-up.

Conclusion: The results of this study suggested that DAO was more likely to occur in Lenke type 2 patients, even if the fusion level was extended to the lumbar spine. Particularly in Lenke type 2 curves, postoperative change of C7-CSVL might affect the development of DAO.

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212. Is Neck Tilt and Shoulder Imbalance the Same Phenomenon? A Radiological Correlation Study of 89 Adolescent Idiopathic Scoliosis (Lenke 1 and 2) Patients

Mun Keong Kwan, MS(Orth); Kai Ann Wong, MBBS(MALAYA); Chris Yin Wei Chan, MS(Orth); Chee Kean Lee, MS(Orth); Lim Beng Saw, MS(Orth)

Malaysia

Summary: Shoulder imbalance and neck tilt are common in AIS. Confusion exists regarding the true meaning of these two clinical entities. We hypothesize that shoulder height inequality/ imbalance and neck tilt are separate clinical problems. This study reveals that clinical neck tilt and shoulder height inequality/ imbalance are different clinical entities that need to be distinguished. T1 tilt and CA correlate with neck tilt, whereas CHD, CRD, CLA and RSH correlate with shoulder height inequality/ imbalance.

Introduction: Shoulder imbalance and neck tilt are common in AIS. Confusion exists regarding the true meaning of these two clinical entities. We hypothesize that shoulder height inequality/ imbalance and neck tilt are separate clinical problems.

Methods: This prospective clinical radiological study involved 89 AIS (Lenke 1 and 2) patients. Shoulder height inequality/ imbalance is graded according to side-to-side acromioclavicular height difference - Grade 0: <1cm, Grade 1: 1-2 cm, Grade 2: 2-3 cm, Grade 3: >3 cm. Neck tilt is graded as: Grade 0: No neck tilt, Grade 1: Neck tilt but can be corrected actively, Grade 2: Neck tilt that cannot be corrected and Grade 3: Neck tilt with trapezius asymmetry. Patients underwent anteroposterior radiograph including the cervical spine and shoulder joint. Coracoid Height Difference (CHD), Clavicle Rib Intersection Distance (CRID), Clavicle Angle (CLA), Radiographic Shoulder Height (RSH), T1 tilt and Cervical Axis (CA) were measured.

Results: The average age was 17.2 (11-32) years. 48.3% (43) had not undergone surgery while 51.7% (46) were post-operative patients. 66.3% (59) were Lenke 1 and 33.7% (30) were Lenke 2 cases. The clinical neck grading showed strong inter-observer reliability with a Kappa coefficient of 0.71. There was no significant correlation between clinical neck tilt and shoulder imbalance grading ($p = 0.936$). T1 tilt and CA had significant correlation with the clinical neck tilt grading ($p=0.000$) but not with clinical shoulder imbalance grading ($p=0.984$, $p=0.528$). T1 tilt angle could discriminate between Grade 0 & 2, Grade 0 &3 and Grade 1 & 3 neck tilt. Cervical axis showed significant difference between Grade 0 & 1, Grade 0 & 2, Grade 0 & 3 and Grade 1 & 3 neck tilt. CHD, CRID, CLA and RSH could significantly differentiate Grade 0 & 2 shoulder imbalance but CHD can differentiate Grade 0 & 1 shoulder imbalance ($p<0.05$).

Conclusion: Clinical neck tilt and shoulder height inequality/ imbalance are different clinical entities that need to be distinguished. T1 tilt and CA correlate with neck tilt whereas CHD, CRD, CLA and RSH correlate with shoulder height inequality/ imbalance.

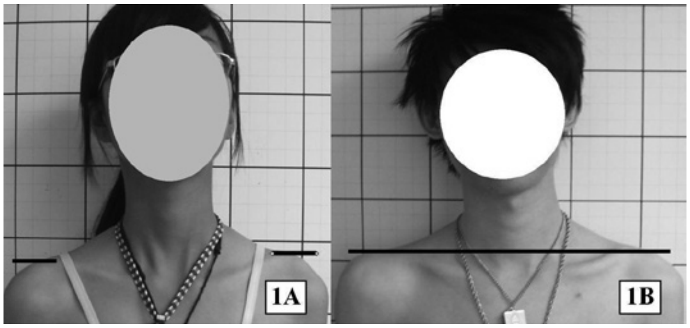

Figure 1A shows a case with shoulder imbalance with no neck tilt. Figure 1B shows a case of neck tilt with no shoulder imbalance.

213. The Importance of Sagittal Stable Vertebrae in Adolescent Idiopathic Scoliosis (AIS) Surgery

Woojin Cho, MD, PhD; David Essig, MD; Michael Faloon, MD; Gbolabo Sokunbi, MD; Akilah B. King, BA; Matthew E. Cunningham, MD, PhD; Oheneba Boachie-Adjei, MD

USA

Summary: Consecutive AIS patients (Posterior fusion, all pedicle screws, one surgeon, x-ray measurement in PACS, a single investigator) were reviewed for among PJK, DJK and control (C) groups. If the LIVs is located too anterior to the SSVL, the chance of PJK increases whereas if it is too posterior, the chance of DJK increases. Thus postoperative distance between LIV and SSVL can assist in predicting the possibility of PJK or DJK at follow-up.

Introduction: Ths Sagittal stable vertebra (SSV) has been advocated to be included in posterior spinal fusions for correction of hyperkyphosis. However, there are no studies regarding the importance of the SSV in AIS pts.

Methods: This retrospective review included 380 consecutive AIS pts who underwent the corrective surgery by a single surgeon using all pedicle screw constructs. 135 Pts were identified who had complete radiographic images stored in PACS. After excluding Lenke 5 curve patterns, ant. or combined surgeries, and hybrid constructs, 91 pts were selected. 3 groups

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were identified: Proximal Junctional Kyphosis(PJK), Distal Junctional Kyphosis(DJK), and Control(C). PJK was defined as > 10° angular change between the sup. endplate of UIV-2 to the inf. endplate of UIV between postop and the final f/u. DJK was defined as > 5° angular change between the sup. endplate of the LIV to the inf. endplate of LIV+1 between postop and final f/u. Regardless of whether or not PJK/DJK occurred before or after 2 yrs, all pts were included. In C, a subset of AIS pts with 2 yr f/u without complications was selected. Various anatomic parameters were measured and compared between the PJK, DJK and C to identify risk factors.

Results: After excluding other complication and short f/u less than 2yrs for C, 7 Pts in PJK (8%), 5 Pt in DJK (5%) and 21 in C remained. First notice of PJK was avg. 0.74 ± 0.56 yr, DJK was avg. 0.47 ± 0.44 yr. Younger age, lower Risser stage, smaller PT and MT curves had significantly more PJK, but not DJK. There was no significant difference among PJK, DJK and C in terms of preop thoracic kyphosis or its correction. However, the distance between LIV and Sagittal Sacral Vertical Line (SSVL) in postop and final f/u was significantly different in both PJK and DJK compared to C. In contrast to hyperkyphotic pts, SSV was poorly defined in AIS because many pts had hypokyphosis preoperatively.

Conclusion: If LIV is located too anterior than SSVL, the chance of PJK increases. In contrast, if it is too posterior, the chance of DJK increases. The concept of SSV is difficult to apply to AIS. However, the postop distance between LIV and SSVL can predict the possibility of PJK or DJK during f/u.

	C (n=21)	PJK (n=7)	P-value	C (n=21)	DJK (n=5)	P-value
Sex (male=1, female=0)	0.29 ± 0.46	0.14 ± 0.38	0.23	0.29 ± 0.46	0.2 ± 0.45	0.36
Age at Surgery	**15.86 ± 2.06**	**13.71 ± 1.79**	**0.01**	15.86 ± 2.06	15.42 ± 3.01	0.35
Risser	**3.83 ± 1.10**	**2.21 ± 1.68**	**0.00**	3.83 ± 1.10	3.60 ± 1.52	0.35
PT Preop	**27.86 ± 12.32**	**15.00 ± 11.46**	**0.01**	27.86 ± 12.32	32.60 ± 5.73	0.21
MT Preop	**56.57 ± 15.70**	**37.71 ± 11.50**	**0.00**	56.57 ± 15.70	54.40 ± 3.78	0.38
T5-12 Preop	23.95 ± 12.11	29.14 ± 17.26	0.19	23.95 ± 12.11	24.20 ± 3.96	0.48
T5-12 Postop	23.24 ± 7.11	28.43 ± 8.75	0.06	23.24 ± 7.11	24.40 ± 2.07	0.36
T5-12 Final	24.14 ± 8.96	25.43 ± 10.37	0.38	24.14 ± 8.96	29.20 ± 8.29	0.13
T5- 12 Postop-Preop	-0.71 ± 7.60	-0.71 ± 13.09	0.50	-0.71 ± 7.60	0.20 ± 4.76	0.40
T5- 12 Final -Postop	0.90 ± 5.34	-3 ± 3.37	0.04	0.90 ± 5.34	4.80 ± 6.98	0.09
T5- 12 Final-Preop	0.19 ± 8.82	-3.71 ± 14.19	0.20	0.19 ± 8.82	5.00 ± 7.42	0.14
LIV-SSVL Distance Preop	16.48 ± 17.37	22.86 ± 6.67	0.18	16.48 ± 17.37	5.8	0.11
LIV-SSVL Distance Postop	**14.90 ± 19.87**	**29.43 ± 7.50**	**0.04**	**14.90 ± 19.87**	**-2.60 ± 16.79**	**0.04**
LIV-SSVL Distance Final	**10.10 ± 18.19**	**26.29 ± 10.11**	**0.02**	**10.10 ± 18.19**	**-11.6 ± 18.85**	**0.01**

Ω 214. 3-D Reconstruction of the Rib Cage Geometric Properties from Biplanar Radiographs

Benjamin Aubert, MSc; Claudio Vergari, PhD; Brice Ilharreborde, MD; Wafa Skalli, PhD

France

Summary: Rib cage three-dimensional model completes the spine analysis, particularly for the deformed thorax in adolescent idiopathic scoliosis, by providing clinical measurements such as rib cage volume, spinal penetration index, rib hump and morphological parameters. A new method of rib cage 3D reconstruction from biplanar radiographs was developed and assessed in terms of accuracy by comparison versus CT-scans and in terms of intra and inter-observers reproducibility of clinical measurements. The proposed method showed promising results which could improve the clinical evaluation.

Introduction: Three-dimensional (3D) subject-specific modeling of the spine and the rib cage in standing position is important for the analysis of adolescent idiopathic scoliosis (AIS), which is a global 3D deformity of the trunk. Clinical measurements (CM) computed from 3D model of rib cage complete the deformed spine analysis by providing essential clinical data when analyzing, for instance, pulmonary restrictive disease. A new method of rib cage 3D reconstruction from biplanar radiographs was developed and assessed regarding scoliosis cases.

Methods: First, a database of 86 trunk 3D reconstructions was built and parametric models of rib cage surface, ribs midline and ribs surface were defined. Statistical parametric models were used to quickly provide a first estimation of rib cage 3D shape from manual digitization of few anatomical landmarks in both radiographs. This first model was then projected on the X-Rays and manually adjusted in order to optimize matching between model projections and X-Rays information. Clinical measurements (CM) were then computed, including rib cage volume, spinal penetration index, rib hump and rib cage maximal dimensions. Accuracy was assessed by comparison with 29 rib cages reconstructed from CT-scan. Intra and inter-observers reproducibility was determined on twenty AIS patients (mean Cobb angle 37°, range [7.7 57]) reconstructed twice by three operators, yielding 95% confidence interval (95%CI).

Results: Line-to-line distance computed between rib midlines from biplanar radiographs and CT-scans presented a mean distance of 3.6 mm. 95% CI was lower than 7% for rib cage volume, and lower than 5°, 7%, 1.4% and 1.2% for maximum rib hump, maximum antero-posterior and lateral diameters,

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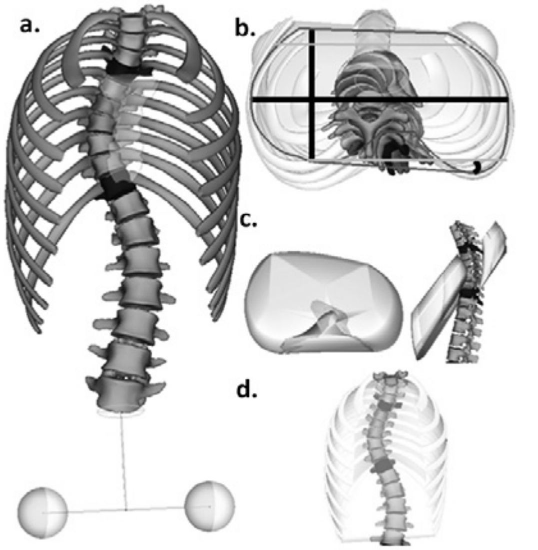
and volumetric spinal penetration index, respectively. Average reconstruction time was 6 minutes (max 10mn).

Conclusion: This study provided a relevant rib cage 3D reconstruction method from low-dose stereoradiography. Proposed method was quick, accurate and reliable, and will improve clinical evaluation outcome in AIS.



(a) Rib cage and spine 3D reconstruction ; (b) Lateral and postero-anterior diameters and rib hump angle ; (c) Volumetric spinal penetration index ; (d) Global rib cage volume

215. The Use of a Subcuatneous Pain Pump Lowers Narcotic Use and Length-of-Stay in Patients Undergoing Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

M. W. Shrader, MD; John Jones, MD; Sean Nabar; Lee S. Segal, MD; Gregory R. White, MD

USA

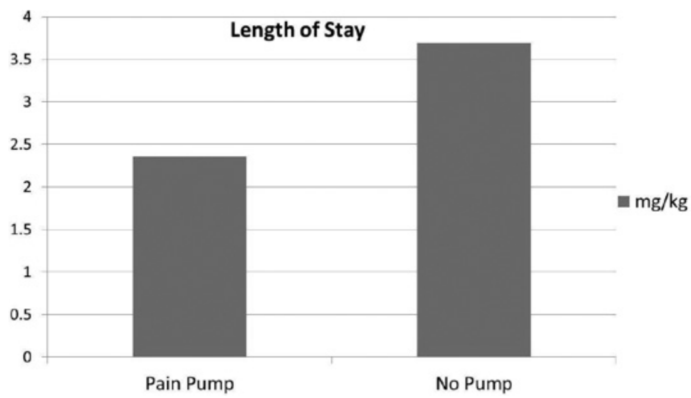
Summary: This retrospective study demonstrated that the use of a subcutaneous pain pump lowered narcotic use and length-of-stay in patients with adolescent idiopathic scoliosis undergoing posterior spinal fusion.

Introduction: Posterior spinal fusion (PSF) and instrumentation for adolescent idiopathic scoliosis (AIS) can cause significant postoperative pain. Appropriate pain control for these patients is crucial. Modern techniques of using adjunctive pain control modalities, such as a local pain pump, have been shown to be safe in this patient population. The purpose of this study is to investigate the use of subcutaneous pain pumps in patients with AIS undergoing PSF.

Methods: This is a retrospective review of patients with AIS over a five year period undergoing PSF. The total narcotic used (TNU) was determined by summing all narcotics given during the hospital stay (oral and intravenous), and converting them to morphine equivalent units (mg of morphine-equivalents, normalized by body weight). Patients who had a subcutaneous bupivacaine pain pump placed intraoperatively and used for three days postoperatively were identified and compared to the group without the pump. The data from these two groups were then analyzed to determine changes in LOS and TNU. All patients were followed for two years.

Results: 197 patients (mean age 14.5) were included in the study. 74 patients received the bupivacaine pain pump, compared to 123 who did not. In the group with the pump, the mean LOS was 4.4 days and the TNU was 2.36 mg/kg, compared to values of 4.8 days (p=0.007) and 3.69 mg/kg (p<0.00001) in the non pump group. There were no adverse reactions to the use of the pain pump.

Conclusion: The use of a subcutaneous pain pump significantly lowered the LOS and the TNU of patients with AIS undergoing PSF. This adjunctive modality offered safe and effective pain control. Further study is needed for detailed analyses of this method to further demonstrate the clinical and cost effectiveness of a subcutaneous pain pump.



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ǂ 216. Comparison of Long-Term (5 YR) Reoperation Rates and Outcomes for Long Fusions to the Sacrum for Adult Deformity: Primary Versus Revision Surgery

David Essig, MD; Michael Faloon, MD; Woojin Cho, MD, PhD; Gbolabo Sokunbi, MD; Thomas Ross, MS, RN; Matthew E. Cunningham, MD, PhD; Bernard A. Rawlins, MD; Oheneba Boachie-Adjei, MD

USA

Summary: This review compares reoperation rates (RO) between primary (PS) and revision (RS)surgery for adult spinal deformity (ASD) at a minimum 5 yr f/u. Despite better patient reported outcomes, no difference was seen in the RO between groups.

Introduction: Long fusions to the sacro-pelvis for adult deformity have significant rates of associated complications which may require reoperation. This study aims to compare the RO and patient reported outcomes between primary and revision surgeries performed at a single institution.

Methods: This is a retrospective review of patients who underwent anterior-posterior spinal fusion from the thoracic spine to the lumbo-sacral pelvis for adult spinal deformity that had a minimum of 5 years follow-up. Pts were separated into two groups 1) PS & 2) RS surgeries. RO complications were grouped according to categories relating to 1. infection 2. neurologic 3. fusion status 4.hardware & 5. global alignment and stratified by early (< 6months), late (>6 months and <2 years), and long term (>2 years). 5 yr SRS-22 & ODI scores were compared.

Results: 134 consecutive pts, 71 PS & 63 RS were included in the analysis. 50 PS & 41 RS cases had complete HRQL and ODI scores with 5 yr minimum f/u; 13 males & 121 females; mean age 56.2(37-74). Mean follow up was 5.5 years (4.8-12.8 years). RO rates were 23.5% & 35.4% respectively for PS and RS (p=0.16). 36.8% of patients requiring reoperation did so on multiple occasions. In the PS group RO rates were for 1. infection (37.5, 33.3, 0%) 2. neurologic (37.5, 16.7, 9%) 3. fusion status (0, 16.7, 9%) 4. hardware (25, 16.7, 72.7%) & 5. global alignment (0, 16.7, 9%) at 6 months, <2 yrs, > 2years. For RS, RO rates were for 1. infection (45, 0, 16.7%) 2. neurologic (30, 25, 0%) 3. fusion status (0, 25, 50%) 4. hardware (15, 25, 16.7%) & 5. global alignment (10, 25, 16.7%) at 6 months, <2 yrs, > 2years respectively. Total SRS-22 & ODI scores were (3.74 & 3.41) (p=.022) & (12.7 & 17.0)(p=.02) at a minimum of 5 yr f/u respectively for PS& RS.

Conclusion: Pts with long fusions to the sacrum had a significant number of revision surgeries performed by 5 yr f/u. In both groups, complications treated at less than 5 yrs tended to be related to infection or neurologic issues, those requiring reoperation at greater than 5 yrs tended to be related to fusion & alignment. Despite better patient reported outcomes, no difference was seen in the reoperation rates between groups.

ǂ 217. Comparison of Pulmonary Function in Adults Younger and Older than Age 60 Undergoing Spinal Deformity Surgery

Ronald A. Lehman, MD; Daniel G. Kang, MD; Lawrence G. Lenke, MD; Jeremy J. Stallbaumer, MD; Brenda A. Sides, MA

USA

Summary: We evaluated the impact of adult spinal deformity surgery on pulmonary function for patients younger and older than age 60, with minimum two year follow-up. We found older patients have no significant difference in %predicted PFTs compared to younger patients postoperatively and no differences in the rate of clinically significant PFT decline (≥10% predicted FEV1). However, older patients more frequently (23% v 12%) experience PFT impairment (<65%predicted FEV1) after spinal deformity surgery.

Introduction: The objective of this study was to determine differences in pulmonary function in adult patients who are either younger (Y) or older (O) than age 60 following spinal deformity surgery. We hypothesize that older age may further exacerbate impairment of pulmonary function following spinal deformity surgery.

Methods: 128 consecutive adult deformity patients with idiopathic scoliosis undergoing surgical treatment were evaluated at a single institution with minimum two year follow-up. Prospectively collected PFTs, clinical records and radiographs were analyzed.

Results: There were 102 patients in Y group (avg age 39.3±14.1 yrs) and 26 in O group (avg age 63.7±2.7 yrs), with similar follow-up (Y=2.9 v O=2.6 yrs, p=0.27). There were no differences in average preop main thoracic (MT) curve magnitude (Y=50.0deg, O=54.8deg, p=0.27); however O patients had significantly greater # of lumbar (5.9 versus 4.2, p=0.00), thoracic (9.1 versus 7.3, p=0.00), and total (15.0 versus 11.5, p=0.00) levels fused. We also found O patients had significantly lower absolute pre-op FEV1 (2.1 versus 2.6L, p=0.02) and FVC (2.7 versus 3.3L, p=0.05), but no differences in %predicted PFTs. This relationship remained at two yrs, with lower absolute FEV1 (1.9 versus 2.5L, p=0.00) and FVC (2.5 versus 3.1L, p=0.00). A clinically significant decline in PFTs (greater than 10% predicted FEV1) occurred

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in 8 (31%) O patients and 26 (25%) Y patients which was not statistically different (p=0.63). We also observed pre-op PFT impairment (less than 65%predicted FEV1) in 1 (4%) O patient, which significantly increased to 6 (23%, p=0.02) O patients postoperatively, compared to Y group experiencing no change in the number of patients (n=12, 12%) with PFT impairment postoperatively.

Conclusion: This is the largest study to date evaluating age related reduction in PFTs. We found older patients have no significant difference in %pred PFTs compared to younger patients postoperatively and no differences in the rate of clinically significant PFT decline (≥10% pred FEV1). However, older patients more frequently (23% v 12%) experience PFT impairment (<65%pred FEV1) after spinal deformity surgery.

218. Is Direct Decompression Essential in the Surgical Treatment of Degenerative Scoliosis with Radicular and/or Claudication Pain?

Dilip K. Sengupta, MD; Huang Peng, MD, PhD

USA

Summary: In degenerative scoliosis no significant difference was found in leg pain relief (radicular/claudication) with laminectomy (55 cases) vs. indirect decompression (30 cases) after deformity correction with posterior instrumentation.

Introduction: Adult degenerative scoliosis may present with mechanical back pain and claudication/radicular leg pain. Conventional surgical treatment involves long spinal fusion with correction of deformity and direct decompression with laminectomy. Deformity correction itself may achieve significant indirect decompression and may obviate the need for laminectomy.

Purpose: Whether direct vs. indirect decompression are equally effective in relief of leg pain following posterior instrumented correction of deformity.

Methods: 85 consecutive cases of degenerative scoliosis with lumbar curve ≥25° (2005-2009) treated with posterior instrumented fusion (≥3 segments) and direct/indirect decompression, were reviewed at 2+ year follow-up. Curve size, ODI, VAS, SF-36 and pain drawing data were prospectively collected at 0, 3, 6, 12, 24 months.

Results: 55 cases (M18, F37, age 62.2yr+/-10.02SD), with mean Cobb 31°, had laminectomy and fusion at 7.13 (+/- 3.49 SD) segments. 30 cases (M-10, F-20) (age 61.6yr+/-10.85 SD) with mean Cobb 35.7°, had indirect decompression by posterior instrumented fusion at 9.7(+/-3.09 SD) segments. The baseline data between these two groups was not different for age (p=0.81), sex (p=0.95), Cobb (p=0.09), VAS leg pain (p=0.09), ODI (p=0.75), PCS (p=0.06) and MCS (p=0.11); but indirect decompression group had a longer fusion (p=0.00).

Outcome: Both the groups improved after surgery. No significant difference found in VAS leg pain relief (p=0.7), ODI (p=0.297), MCS (p=0.089), but direct decompression group had greater improvement in PCS (p=0.018). Operation time, EBL and complication rate was greater in direct decompression group but not significant.

Conclusion: In degenerative scoliosis, indirect decompression of spinal stenosis may require a longer segment fusion, but equally effective in improvement of leg pain due to stenosis, compared to direct decompression. Greater PCS improvement in the direct decompression group may represent shorter segment fusion.

219. Mechanical Complications of Lumbosacral Fixation in Surgical Treatment of Adult Deformities and the Relationship with L5-S1 Disc Space

Gabriel Gutman; Clément Silvestre; Pierre Roussouly, MD

Israel

Summary: Several previous studies have shown a relatively high complication rate for this select group of patients

Introduction: Historical cohort study of mechanical complications of sacral fixation in adult deformities with long fusion constructs. The objectives were to investigate the perioperative and short-term mechanical complications related to pelvis fixation in adult deformities, to determine risk factors and to propose a solution.

Methods: 176 consecutive patients who underwent combined posterior followed by anterior surgical reconstruction for adult (mean age 56.9±9.8 years; range 23- 82) spine deformity with long (5-17 vertebrae; mean 8.74±3.38) spinal instrumentation and fusion to the sacrum or ileum at a single institution between January 2007 to January 2011, with mean follow up 33.6±10.35 months; range 24- 72.

Results: Mechanical complications directly related to sacral fixation were seen in 27 patients (15.3%). Pseudoarthrosis (PA) was seen in 10 patients (5.68%). L5-S1 PA was seen in 9 of the patients (5.11%) at a mean time of 15.4±6.8 months (range 8-24). Sacral screw loosening was seen in 8 patients (4.54%). Painful implants requiring removal were noted in 2 patients. 1 patient had a sacral fracture after the instrumentation. 2 patients developed a juntional kyphosis

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(JK) due to insufficient lumbar lordosis (LL) and remained slightly unbalanced. Other 2 patients that were initially with high pelvic incidence and anteverted pelvis remained slightly unbalanced also due to inadequate LL. Cox regression results showed a positive association between disc space (DS, in mm) and L5-S1 PA (HR=1.274 95%CI 1.009-1.608 p=0.042). Patients with DS higher than 10 mm had HR=6.8 (95%CI 1.47-31.48 p=0.014) compared to patients with DS ≤ 10 mm. No statistical significant difference was found between patients who were treated with or without cage. Among 57 patients with a disc space > 10 mm, 2/21 (9.5%) and 6/36 (16.7%) patients developed PA in the patients with and without cage respectively (p=0.697)

Conclusion: L5-S1 PA and an unbalance sagittal profile are the most common mechanical complications. High L5-S1DS should be considered a high risk for PA and be treated by a combine posterior and anterior reconstruction. Appropriate LL should be provided to this group of patients. Further large-scale studies are necessary to obtain more overwhelming results.

Ω 220. Targeting the Genomic Locus of Familial Idiopathic Scoliosis

Mitsuru Yagi, MD, PhD; Shinjiro Kaneko, MD, PhD; Takashi Asazuma, MD, PhD; Masafumi Machida, MD

Japan

Summary: Linkage analyses have identified several candidate genes, a significant step in defining the genetic etiology of this disorder. To identify the familial scoliosis causing locus will guide both surgeon and patients for the appropriate clinical planning and treatment.

Introduction: The high prevalence of familial idiopathic scolisos is indicative of genetic heterogeneity. To localize genes related to scoliosis, identification of groups of families with common clinical characteristics is a strategy that reduces genetic heterogeneity. Recent work provides evidence for linkage at several different chromosome sites while the limited number of microsatellite makers makes the linkage analysis less efficient. The aim of this study is to identify the genomic locus of familial idiopathic scoliosis and to relate it to the progression of the curve.

Methods: Pedigrees having clinically relevant idiopathic scoliosis and their non scoliotic parents were identified. Radiographic confirmation was required for a positive diagnosis. Linkage analysis was performed with 610,000 microsatellite markers for genome wide screening. A total of 7 families with at least 2 pedigrees with idiopathic scoliosis was ascertained and examined by a single orthopedic surgeon. In addition to the degree of lateral curvature, variables measured included type of curve, degree of curvature, age at diagnosis, ethnic background, awareness of condition, presence of pain, and type of treatment. Blood samples were obtained from all participants and genomic DNA was extracted with standard purification protocols. The stratification for mode of inheritance was determined by calculating the likelihood of each family under X-linked dominant/recessive (XLD/XLR) and autosomal dominant/recessive (AD/AR) modes of inheritance. In the AD/AR model, the sex-dependant penetrance values were incorporated into the model as liabilities. Families were then ranked based on the ratio of the likelihood of the XLD/XLR model relative to that of the AD/AR model. Families were ranked by increasing value of their L(XLD)/L(AD) ratio. Candidate regions were determined by the presence of at least two adjacent markers significant at the 0.02.

Results: Candidate 3 genes were considered to have the strongest evidence for linkage across all subsets considered. All of them have been identified as an essential gene for skeletal growth and axonal growth.

Conclusion: Linkage analyses have identified several candidate genes, a significant step in defining the genetic etiology of this disorder.

Ω 222. Optimization of Spine Deformity Surgery Training: A National Survey of Residency and Spine Fellowship Program Directors

Alan H. Daniels, MD; J. M. DePasse, MD; Stephen T. Magill, PhD; Staci A. Fischer, MD; Christopher P. Ames, MD; Robert A. Hart, MD

USA

Summary: This study examined the opinions of residency and spine fellowship program directors regarding current spine deformity surgery training in the United States. Orthopaedic and neurosurgical residents perform few adult spinal deformity cases during residency. A large majority of respondents felt that both orthopedic and neurosurgical trainees should complete an advanced fellowship if they desire to perform spine deformity surgery in practice.

Introduction: Current training for spine surgeons in the United States consists of a neurological surgery or orthopaedic surgery residency program followed by an optional spinal surgery fellowship. The goal of this study was to collect data on spine deformity surgery exposure during residency and to assess the opinions of orthopaedic and neurological surgery residency

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and spine fellowship program directors (PDs) regarding current spine deformity surgery training in the United States.

Methods: An anonymous questionnaire was distributed to all of the PDs of orthopaedic and neurological surgery residencies and spine fellowships in the United States (N=382). A 5-point Likert scale was used to assess attitudinal questions.

Results: One-hundred and four program directors completed the survey, including 37 orthopaedic surgery residency PDs, 32 neurological surgery residency PDs, and 35 spine fellowship PDs (response rate 27%). When asked how many adult spinal deformity surgery cases their residents log at the completion of residency, the most common answer for both orthopaedic surgery and neurological surgery PDs was 0-10. When asked how many pediatric spinal deformity surgery cases their residents log at the completion of residency, orthopaedic PDs most commonly chose 11-20 cases, while 80% of neurosurgical PDs chose 0-10 cases ($p<0.001$). 100% of the orthopaedic PDs and 90.6% of neurological surgery PDs recommended a fellowship for their trainees wishing to perform spine deformity surgery. Over 90% of PDs agreed that orthopaedic trainees should complete a spine surgery fellowship before practicing spine deformity surgery, while over 80% agreed that neurological surgery trainees should complete a spine surgery fellowship before practicing spine deformity surgery.

Conclusion: This study examined the opinions of residency and spine fellowship PDs regarding current spine deformity training in the United States. Orthopaedic and neurosurgical residents from many training programs perform <20 spinal deformity cases during residency. A large majority of respondents felt that both orthopedic and neurosurgical trainees should complete an advanced spine surgery fellowship if they desire to perform spine deformity surgery in practice.

223. Ligamentous Stabilizers of the Occipitocervical Junction

Kristen E. Radcliff, MD; Mir Hussain; Mark Moldavsky, MS; Noelle Klocke, MS; Alexander R. Vaccaro, MD, PhD; Todd J. Albert, MD; Saif Khalil, PhD; Brandon Bucklen, PhD

USA

Summary: Traumatic occipitocervical (OC) dislocations which may cause destruction of stabilizing ligaments are often associated with pathological cranial-caudal and anterior-posterior translations. An in vitro biomechanical study was used to identify the key contributions of each major ligament and joint capsule by incremental dissection. The vertical structures on the clivus, namely the tectorial membrane, were the main stabilizers of anterior-posterior translation, while the OC junction was the main stabilizer of cranial-caudal translation. Transverse ligaments acted as secondary stabilizers.

Introduction: The relative contributions of the ligaments of the OC junction to overall stability and the effects of the occipitoatlantal (OA) joint capsules on pathological translation are unknown. The purpose of this study is to determine which stabilizing ligaments at the craniocervical junction are most important in restraining pathological translation.

Methods: Seven human cadaveric specimens were tested with a custom six degrees of freedom spine simulator under the conditions: intact; clivus removal (CR), alar/transverse ligament destruction (TL), and OA capsule sectioning (OAS). Motion was applied with a load of 2.5 N-m. Flexion-extension (FE) and lateral bending (LB) was applied to a C0-C2 segment while anterior-posterior (AP), and cranial-caudal (CC) translations were recorded. Translations are presented as a percent of intact (Intact = 100%) for each joint.

Results: C0-C1 AP translation during LB increased significantly following CR (362% intact). C0-C1 CC translation during FE increased significantly following CR (146%), TL (188%), and OAS (361%).

C1-C2 AP translation increased significantly following CR (610%). C1-C2 CC translation increased significantly following CR (710%) and TL (882%).

Overall C0-C2 AP translation increased most in LB following CR (545%, decreased after TL (411%) and increased after OAS (521%). C0-C2 CC translation during LB increased most following CR (313%), TL (418%) and OAS (498%) in LB.

Conclusion: The vertical structures attached to the clivus are the main stabilizer of AP, while the OA joint is the main stabilizer of CC translation. The transverse ligaments and OA capsules are secondary stabilizers. Future models of occipitocervical injury should evaluate the interplay of all three ligamentous structures.

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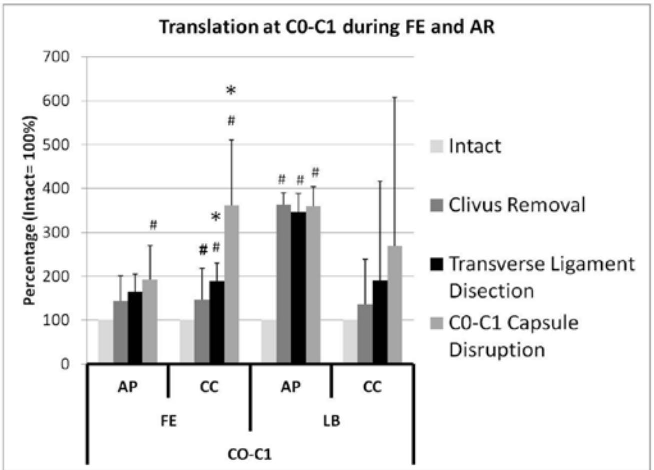

Figure 1: An example of translation during rotation: The AP and CC coupled translation during FE and LB for intact and injuries at each C0-C1.

225. Impact of Pelvic Incidence/Lumbar Lordosis Mismatch in the Surgical Treatment for Adult Spinal Deformity

Satoshi Inami; Hiroshi Taneichi, MD; Takashi Namikawa, MD, PhD; Daisaku Takeuchi; Chizuo Iwai; Yo Shiba, MD; Yutaka Nohara, MD

Japan

Summary: Aim was to determine key factor leading to sagittal vertical axis (SVA) < 50mm, in surgical treatment for adult spinal deformity (ASD). Spino-pelvic parameters were compared between SVA<50 and SVA≦50 groups, on post-op radiographs of 49 ASD patients. Only pelvic incidence/lumbar lordosis mismatch (PI-LL) was significantly different, and SVA<50 group had smaller PI-LL (8.4° vs. 16.5°). This result implicate that enough LL which reflects PI is necessary to obtain stable sagittal balance.

Introduction: Sagittal spinal malalignment is commonly defined by increased sagittal vertical axis (SVA). Generally, surgical treatment for adult spinal deformity (ASD) should attempt to obtain a postoperative SVA < 50mm. However, little is known about key factor leading to SVA < 50, in surgical treatment for ASD.

Methods: Fourty-nine consecutive patients (13 male and 36 female, mean age 60.2 years, SD 10) who underwent surgery for ASD between 2007 and 2011 were included. Pre- and immediate post-op radiographic measurement included thoracic kyphosis (TK: T5-12), thoracolumbar kyphosis (TL: T10-L2), lumbar lordosis (LL: T12-S1), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and SVA on standing lateral radiograph. The difference between PI and LL (PI-LL) was also assessed as indicator of spino-pelvic balance. Postoperative parameters were compared between SVA<50 and SVA≦50 groups. The average of pre-op parameters were TK: 15.8°, TL: 22.4°, LL: 6.7°, PT: 32.5°, SS: 17°, PI: 49.5°, SVA: 99.6mm, PI-LL: 42.8°.

Results: The average of post-op parameters were TK: 26.7°, TL: 7.5°, LL: 39.4°, PT: 23.1°, SS: 26.7°, PI: 49.8°, SVA: 27.1mm, PI-LL: 10.4°. SVA<50 group was 37 pts and SVA≦50 group was 12 pts. Only PI-LL was significantly different factor between the two groups, and patients in SVA<50 group had smaller PI-LL (8.4° vs. 16.5°, p<0.05). In SVA<50 group, 20 pts had PI-LL below 10° (<50&<10 group) and 17 pts had over 10° (<50&>10 group). Comparison of this two groups showed that patients in <50&>10 group had smaller LL (34.3° vs. 44.3°, p<0.05), greater PT (27.9° vs. 17°, p<0.05), greater PI (53.1° vs. 43.7°, p<0.05).

Conclusion: We measured sagittal balance at early post-op stage to know key factor itself in surgical treatment, without influence of PJK. Our findings show that PI-LL in SVA<50 group was significantly smaller than that in SVA>50 group, and this result implicate that enough LL which reflect PI is necessary to obtain stable sagittal balance. Whereas, patients with PI/LL mismatch need pelvic retroversion to maintain sagittal balance.

226. The Utility of Cultures in the Treatment of Osteomyelitis of the Spine

Sina Pourtaheri, MD; Arash Emami, MD; Mark J. Ruoff, MD; Eiman Shafa, MD; Kimona Issa, MD; Tyler Stewart, BS; Kumar Sinha, MD; Ki S. Hwang, MD

USA

Summary: Obtaining blood or tissue cultures prior to administration of antibiotics has been the standard of care in the treatment of osteomyelitis of the spine. In this retrospective study on vertebral osteomyelitis, the clearance rate of osteomyelitis was similar in the positive culture group and the group with continually negative cultures. In the culture negative group, an ESR > 48 on initial presentation was associated with clearance of the infection.

Introduction: The purpose of this study was to evaluate the short and long-term outcomes of spinal osteomyelitis in patients where the infecting organism was identified through cultures in contrast to cases where the cultures continued to be negative.

Methods: A retrospective review of 920 patients who had spinal osteomyelitis from 2001 to 2011 from a single institution was performed. Inclusion criteria included appropriate initial

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imaging, lab results, and no treatment prior to admission at an outside institution. Chi-squared statistics, Fisher's exact, and single sample t-tests were used to examine the data. Clearance of the infection was defined as normalizing of serum markers and resolution of osteomyelitis on MRI after 6 months of treatment.

Results: One-hundred and six patients met the inclusion criteria: 75% had positive cultures (C+ group) and 25% had negative cultures (C- group); 62 men (58%), 44 women (42%), mean age 54 years, mean follow-up 38 months. The distribution of cultures preformed: 58 open biopsy, 60 percutaneous biopsy, 148 blood cultures. In regard to clearance of the osteomyelitis, the C+ group cleared the infection in 69 (61%) of the admissions and the C- group cleared the infection in 26 (70%) of the admissions [OR: 0.65, 95% CI: 0.29 to 1.44; p=0.28]. The Oswestry scores on presentation to the latest following was respectively 63 (SD± 19.5) and 49 (SD±16) in the C+ group and 56 (SD±18) and 37 (SD±18) in the C- group. The mean cost of hospital admission: C+=$275,144, C-=$133,405, p=0.01. CBC, ESR, CRP were significantly higher in the C+ group [p=0.02]. Some of the increased cost is attributable to the biopsy procedure and increased LOS to obtain the biopsy as an inpatient. In the C- group, a CRP > 48 on presentation had a higher likelihood of osteomyelitis clearance [OR: 6, p = 0.03].

Conclusion: The rate of clearance of the infection and Oswestry score was similar in the C+ and C- groups, except with a higher cost of hospital admission in the C+ group. In patients who present with an elevated CRP and continued negative blood cultures, consider empiric antibiotics over invasive procedures.

227. Is In-Vivo Manual Palpation for Thoracic Pedicle Screw Instrumentation Reliable?

Ross R. Moquin, MD; Blair Calancie, PhD; Miriam Donohue, PhD

USA

Summary: This is the first study to assess in vivo accuracy of manual palpation of thoracic pedicle screw tracks. 526 pedicle track/screw placements were compared. Ball point tipped probe palpation of pedicle breaches has an error rate of 89.8% while 100% reliable in verifying the absence of a breach

The accuracy of manual palpation for detecting breaches was disturbingly low. These findings are consistent with cadaveric studies and point to the need for alternative methods to assess pedicle integrity during surgery.

Introduction: Previous reports on the accuracy of manual palpation for thoracic pedicle screw placement have been restricted to cadaveric studies. This prospective study assesses the in vivo accuracy of manual palpation for detection of pedicle breaches in the thoracic spine during human surgery.

Methods: In 526 consecutive thoracic pedicle screw placements, a pilot hole using the free-hand method was made then palpated with a ball-tipped probe. Pedicle breach was announced and compared to both neuromonitoring and CT evaluations of screw position.

Screw position was assessed via CT scans. Two blinded evaluators reviewed each scan twice, with 4 weeks between viewings on Osirix Dicom viewer. Screw position was evaluated to identify pedicle breaches >2 mm in the medial, lateral, and foraminal directions. Screws intentionally placed with in-out-in approach were still counted as lateral breaches.

Results: 257 of 526 screws met criteria for a breach without any neurologic or vascular complications. There were 166 breaches ≥ 2 mm (32 medial, 134 lateral) out of 257 total. Of these,149 (30 medial, 119 lateral) were inaccurately identified as acceptable by the surgeon's manual palpation, giving an overall error rate of 89.8%. Of the 91 placements with no breach, the surgeon correctly identified 100% as having no breach. For medial breaches, the average intra-observer reliability Kappa was 0.67 and inter-rater reliability Kappa was 0.53. For lateral breaches, the average intra-observer Kappa was 0.72 and inter-observer Kappa was 0.67.

Conclusion: Ball-tipped probe manual palpation is grossly insufficient for identifying pedicle tracks that would result in malplaced screws.

229. Does Intraoperative Cell Salvage System Effectively Decrease the Need for Allogeneic Transfusions in Scoliotic Patients Undergoing Posterior Spinal Fusion? A Prospective Randomized Study

Jianxiong Shen; Jinqian Liang; Soo Yong Chua

China

Summary: This prospective, randomized study was designed to determine the safety and efficacy of intraoperative cell salvage system in decreasing the need for allogeneic transfusions in a cohort of scoliosis patients undergoing primary posterior spinal fusion with segmental spinal instrumentation.

Introduction: Scoliosis patients undergoing posterior spinal fusion can experience significant intraoperative blood loss and often require perioperative blood transfusions. Intraoperative

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cell salvage and reinfusion can reduce or obviate perioperative allogeneic blood transfusion. Despite these benefits, their efficacy in pediatric PSF is unclear. Reported complications include transient hematuria, altered hemostasis, and electrolyte imbalance

Methods: A total of 92 consecutive scoliosis patients undergoing posterior instrumented spinal fusion were randomized into 2 groups according to whether a Cell Saver machine for intra-operative blood salvage was used or not. Data included age, body mass index, perioperative hemoglobin levels, surgical time, levels fused, perioperative estimated blood loss, perioperative transfusions and incidence of transfusion related complications. A chi square test and t tests were performed for intraoperative and perioperative allogeneic transfusion between groups. A regression analysis was performed between selected covariates to investigate the predictive factors of perioperative transfusion.

Results: Perioperative allogenic blood transfusion rate were lower in the cell saver group (10% vs. 28.6%, P =0.022). Mean intraoperative red blood cell transfusion requirement were also lower (0.16 U/pt vs. 0.52 U/pt, P =0.041). The mean Hb and hematocrit levels in the cell saver group were significantly higher in the first three days ($P < 0.05$). No marked differences were observed in transfusion related complications between both groups (p =0.292). A multivariate analysis demonstrated that preoperative hemoglobin value (OR: 0.849; p = 0.008), surgical time (OR: 1.041; p = 0.019), intraoperative estimated blood loss (OR: 1.011; p = 0.001) and the use of cell saver system (OR: 0.007; p = 0.003) had a trend toward significance in predicting likelihood of transfusion.

Conclusion: Cell saver use significantly reduces the need for allogeneic blood in spine deformity surgery, particularly in patients with low preoperative hemoglobin or longer operation time. This study confirms the utility of routine cell saver use during PSF with segmental spinal instrumentation for scoliosis patients.

ǂ 230. The Current State of Evidence Regarding Pediatric Spondylolysis: A Report from the SRS Evidence-Based Medicine Committee

Charles H. Crawford, MD; Charles Gerald T. Ledonio, MD; Shay Bess, MD; Jacob M. Buchowski, MD, MS; Douglas C. Burton, MD; Serena S. Hu, MD; Baron S. Lonner; David W. Polly, MD; Justin S. Smith, MD, PhD; James O. Sanders, MD

USA

Summary: A structured literature review was performed by the SRS Evidence Based Medicine Committee to answer clinically relevant questions regarding pediatric spondylolysis. The evidence was stronger for the clinical questions of etiology, prevalence, natural history and diagnostic methods. The evidence was weaker for clinical questions regarding treatment (both non-operative and operative). This review will provide a foundation for future research and will help guide current clinical decisions with a summary of the best available evidence.

Introduction: The evolution of medical knowledge, changes in societal expectations, and health care economics have lead medical organizations to undertake practice guideline development. The initial steps of practice guideline development include a structured literature review to assess the current state of peer-reviewed, published evidence. The Evidence Based Medicine Committee of the Scoliosis Research Society recently undertook a structured literature review of Pediatric Lumbar Spondylolysis. Here we present our preliminary findings.

Methods: A literature search was performed with the assistance of a trained medical librarian. Citations and abstracts were retrieved. Abstracts were reviewed for obvious exclusions. Full text articles were then distributed for review. During full text review, articles were included if they provided evidence for one of the clinical questions formulated by the committee. Clinical questions were grouped into Foreground (etiology, prevalence, natural history), Diagnostic, Non-Operative Treatment, and Operative Treatment. Levels of evidence were assigned.

Results: From 947 initial citations with abstract, 301 articles were included in the full text review. An additional 149 articles were recommended for exclusion, leaving 152 articles for inclusion in the evidence assessment. 54 (36%) of the articles addressed etiology, prevalence, natural history - 32% of these were graded as Level of Evidence III or better. 53 articles (35%) addressed Diagnostic methods - 30% of these were Level of Evidence III or better. 21 (14%) articles addressed non-operative treatment - only 10% of these were graded as Level of Evidence III or better. 34 (22%) of the articles addressed surgical treatment - only 9% of these were graded as Level of Evidence III or better.

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Conclusion: The Level of Evidence in the current literature for pediatric spondylolysis is higher for the clinical questions of etiology, prevalence, natural history and diagnostic methods. The number of studies and the Level of Evidence is lower for clinical questions regarding treatment (both non-operative and operative).

ǂ 231. Incremental Cost-Effectiveness of Adult Spinal Deformity Surgery: Observed QALYs with Surgery Compared to Predicted QALYs Without Surgery

Ian McCarthy, PhD; Michael F. Obrien, MD; Christopher P. Ames, MD; Thomas J. Errico; Han Jo Kim, MD; Justin S. Smith, MD, PhD; Frank J. Schwab, MD; Eric Klineberg, MD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; David W. Polly, MD; Richard Hostin, MD; International Spine Study Group

USA

Summary: The incremental cost-effectiveness ratio (ICER) of surgical versus nonsurgical treatment for adult spinal deformity (ASD) has eluded the literature due in-part to inherent self-selection into surgery. Using observed pre-operative HRQOL for patients who later underwent surgery, the study builds a statistical model to predict hypothetical QALYs without surgical treatment. Projected 10-year follow-up reveals an average of $105,600 per incremental QALY gained from surgical treatment, with costs of treatment based on total payments received by the hospital for surgery.

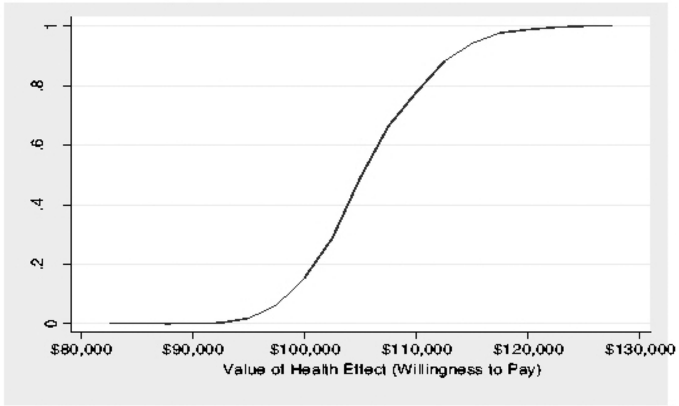
Introduction: The incremental cost-effectiveness ratio (ICER) of surgery for adult spinal deformity (ASD) has eluded the literature due in-part to inherent self-selection into surgical treatment. Using observed pre-operative HRQOL outcomes for patients who later underwent surgery, the study builds a statistical model to predict hypothetical QALYs without surgical treatment. The analysis compares predicted QALYs to observed post-operative QALYs and forms the resulting ICER.

Methods: Single-center, retrospective analysis of consecutive patients undergoing primary surgery for ASD. Payments (expressed in 2010 dollars) to the hospital were collected from administrative data and QALYs calculated from the SF-6D, each discounted at 3.5% per year. Regression analysis was used to predict hypothetical QALYs without surgery based on pre-operative longitudinal data for 141 crossover surgical patients with similar diagnosis, baseline HRQOL, age, and gender compared to the study cohort.

Results: Three-year follow-up was available for 239 of 278 eligible patients (86%), which were predominantly female (n=203, 85%) with average age of 49 (range 18 to 82). With discounting, total payments to the hospital averaged $211,529, including readmissions, with average QALYs of 1.9 at three-year follow-up. Average QALYs without surgery were predicted to be 1.5 after three years. At three and five-year follow-up, the ICER was $570,000 and $278,000, respectively. Projecting through 10-year follow-up, the ICER was $105,600, with the cost-effectiveness acceptability curve (CEAC) presented in Figure 1.

Conclusion: Based on the World Health Organization's (WHO) suggested upper threshold for cost-effectiveness (3 times per capita GDP, or $140,000 in 2010 dollars), the analysis reveals that surgical treatment for ASD is cost-effective after a 10-year period. At earlier follow-up intervals, the ICER well exceeds the WHO threshold, highlighting the importance of extended follow-up in the appropriate economic evaluation of surgical treatment for ASD.

Figure 1. CEAC for ASD Surgery: Projected 10-year Follow-up



232. Quantifying the Role of Baseline HRQOL and Readmissions on the Cost-Effectiveness of Surgical Treatment for Adult Spinal Deformity (ASD)

Ian McCarthy, PhD; Michael F. Obrien, MD; Christopher P. Ames, MD; Thomas J. Errico; Han Jo Kim, MD; Gregory M. Mundis, MD; Frank J. Schwab, MD; Eric Klineberg, MD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; David W. Polly, MD; Richard Hostin, MD; International Spine Study Group

USA

Summary: Little is known regarding the determining factors of the incremental cost-effectiveness ratio (ICER) of surgical versus non-surgical treatment for ASD. Using regression-based methods, this analysis calculates the incremental improvement in QALYs due to surgical treatment, and quantifies the effect of baseline HRQOL and readmissions on the resulting ICER. Projected through 10-year follow-up, cost-effectiveness of

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surgical treatment improved over time and was most cost-effective for patients with poorer baseline HRQOL who were never readmitted to the hospital (ICER=$139,893).

Introduction: Little is known regarding the determining factors of the incremental cost-effectiveness ratio (ICER) of surgical versus non-surgical treatment for ASD. This analysis uses regression-based methods to estimate the incremental effect of surgical treatment on QALYs.

Methods: Single-center, retrospective analysis of consecutive patients undergoing primary surgery for ASD. Payments (in 2010 dollars) to the hospital were collected from administrative data and QALYs calculated from the SF-6D, each discounted at 3.5% per year. The effect of surgery on QALYs was estimated using a multivariable regression specifying QALYs after three-years as the dependent variable and baseline characteristics, along with an indicator for surgical versus non-surgical treatment, as independent variables.

Results: Three-year follow-up was available for 352 patients (239 surgical and 113 non-surgical), predominantly female (n=297, or 84%) with average age of 48 (range from 18 to 82). Total payments to the hospital averaged $211,529 for surgery, including readmissions. Controlling for baseline characteristics, surgery was estimated to increase QALYs by 0.12 (p=0.00) over 3-year follow-up. Projected through 10-year follow-up, the ICER for a patient with average baseline HRQOL was estimated to be $578,740 (95% CI: $328,000 to $1.1 mm), reducing to $220,908 (95% CI: $133,000 to $387,000) for patients with baseline HRQOL in the bottom quintile, and $139,893 (95% CI: $94,000 to $219,000) for patients with baseline HRQOL in the bottom quintile and no readmission.

Conclusion: Based on the World Health Organization's (WHO) suggested upper threshold for cost-effectiveness (3 times per capita GDP, or $140,000 in 2010 dollars), ASD surgery is borderline cost-effective after a 10-year period, but only for patients without a readmission and with lower baseline HRQOL. While this analysis controls for baseline patient differences in estimating the incremental benefit of surgery, future research should also consider the degradation in HRQOL had surgical treatment not been pursued.

233. Complication Rates are Reduced for Revision Adult Spine Deformity Surgery Among High-Volume Hospitals and Surgeons

Justin C. Paul, MD, PhD; Baron S. Lonner, MD; Vadim Goz, BA; Jeffrey H. Weinreb, BS; Raj Karia, MPH; Courtney Toombs, BS; Thomas J. Errico

USA

Summary: Previous studies have shown improved outcomes associated with higher volume surgeons and hospitals, but this relationship has not been shown in revision adult spinal deformity surgery, an intervention with a high complication rate. Using relevant in-hospital patient records from the National Inpatient Sample, we found an improvement in major complications among higher volume hospitals and surgeons for complex revision cases of adult spine deformity.

Introduction: Previous studies have shown improved outcomes associated with higher volume surgeons and hospitals. Revision adult spinal deformity surgery (RASDS) is a particularly high-risk intervention. We aimed to assess complication rates in RASDS by surgeon and hospital operative volume for this entity.

Methods: The 2003-2009 National Inpatient Sample was queried the database using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes for patients age >50 with in-hospital stays including a spine arthrodesis for a diagnosis of scoliosis. Annual surgeon and hospital identifiers were used to allocate records into volume quartiles by number of surgeries performed in that year. Hospitals and surgeons were assigned to a quartile based on the annual volume of ASDS cases. In 2003, hospitals with ≤5 procedures and surgeons with <2 were assigned to the first quartile (low-volume), whereas hospitals with ≥30 and surgeons with ≥11 procedures were assigned to the fourth quartile (high-volume). In 2009, the first quartile included hospitals ≤10, and surgeons ≤3, and the fourth quartile included hospitals ≥44 and surgeons ≥18 (see Table for overall averages). The primary endpoint was morbidity during the hospital stay. One-way analysis of variance was used to assess continuous measures, chi-square for categorical measures.

Results: A total of 9,321 (8774 primaries and 247 revisions) patients in the NIS database met our inclusion criteria. High-volume surgeons and hospitals performed a greater percentage of revision surgery (see Table). The highest volume surgeons and hospitals showed significant decreases in the rate major complication for RASDS.

Conclusion: Morbidity associated with RASDS is lower when patients are treated by high-volume surgeons at high-volume centers. The sharp rise in morbidity from third to fourth

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quartiles may represent a concurrent increase in the complexity of cases for the highest volume surgeons and hospitals.

234. Perioperative Complications and Mortality After Spinal Fusions: Analysis of Trends and Risk Factors

Vadim Goz, BA; Jeffrey H. Weinreb, BS; Virginie Lafage, PhD; Thomas J. Errico

USA

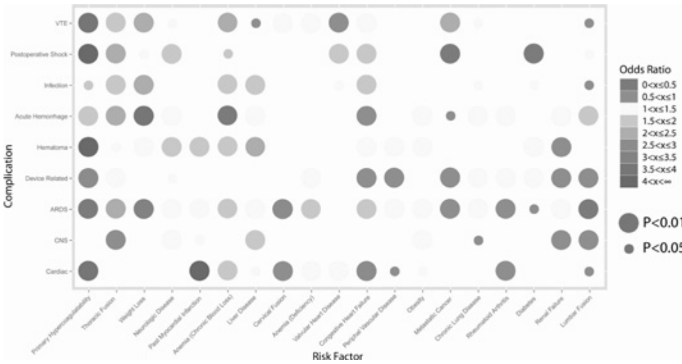
Summary: This study uses a national database to analyze trends in complications and mortality after spinal fusions. The study also identifies independent predictors of postoperative complications.

Introduction: Over 413,000 fusions were performed in the United States in 2008 accounting for $33.9 billion in cost. It is essential to critically evaluate surgical outcomes in order to better identify patients who benefit most from surgery. Significant volumes of clinical evidence are accruing from implementation of electronic medical records and compilation of administrative databases. Integration of this empiric evidence into clinical practice is instrumental in providing higher quality, evidence based, patient centered care.

Methods: This study used national inpatient sample (NIS) data from 2001 to 2010. Patients that underwent spinal fusions were identified using ICD-9 codes. Data on patient comorbidities, primary diagnosis, and postoperative complications was obtained via ICD-9 diagnosis codes. National estimates were calculated using weights provided as part of the database. Time trend analysis for average length of stay, total charges, mortality, and comorbidity burden was performed. Univariate and multivariate models were constructed to identify predictors of mortality as well as postoperative complications.

Results: An estimated 3,552,873 spinal fusions were performed during the study period. The national bill for spinal fusions increased from $10 billion in 2001 to $46.8 billion in 2010. On average patients today are older and have a more comorbidities than ten years ago. Mortality remained relatively constant at .46%, 1.2%, and .14% for cervical, thoracic, and lumbar fusions respectively. Morbidity rates increased at all levels. A multivariate analysis of 19 procedure and patient related risk factors and 9 perioperative complications identified 85 statistically significant (p<.01) interactions (Figure 1).

Conclusion: The data on risks of spinal fusions presented in this study is pivotal to appropriate surgical patient selection and well-informed risk benefit evaluation of surgical intervention. This analysis of patient comorbidities that predispose to specific postoperative complications will allow for a patient centered evidence based approach to selection of surgical candidates.



235. A Comprehensive Evaluation of the Utility of Routine Post-Operative Radiographs Following Pediatric Scoliosis Surgery

David Shau; Jesse E. Bible, MD; Stephen P. Gadomski, BA; Richard Samade, PhD; Sheyan Armaghani; Clinton J. Devin, MD; Gregory Mencio, MD

USA

Summary: The purpose of this study is to comprehensively evaluate the utility of obtaining routine post-operative radiographs in pediatric scoliosis patients.

Introduction: Post-operative radiographs are routinely obtained following pediatric scoliosis surgery despite lack of evidence supporting such practice.

Methods: A total of 1969 clinic notes from 451 consecutive scoliosis patients (ages 10-18) that underwent surgery correction over a 10-year period at a single institution were retrospectively reviewed. Curve pathology (adolescent idiopathic scoliosis, neuromuscular, or other), pre-operative curve characteristics, and surgical procedures performed were recorded. All post-operative clinic notes and radiographs were reviewed for abnormalities and changes in treatment course. It was then determined if clinical signs/symptoms and/or an abnormal radiograph led to a change in treatment course, which was defined as a therapeutic intervention or further diagnostic testing.

Results: Of the 451 scoliosis patients in this study (average age of 14.7±2.4 years), 73% had adolescent idiopathic curves, 23% neuromuscular curves, and 4% other underlying pathology. Overall, a change in treatment course occurred in 42 patients (2.1% follow-up visits) with all having symptomatic findings

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on history and physical exam but only 15 (0.8%) having supportive abnormal radiographs. A statistically significant increase in utility was seen in radiographs obtained at visits ≥1 year compared to <1 year post-operatively (1.7% vs. 0.3%, p=0.001). Curve etiology and surgical approach yielded no impact on radiographic utility (p=0.115 to p=1.000). The overall sensitivity, specificity, positive and negative predictive values of routine post-operative radiographs in determining treatment course were 35.7%, 98.1%, 28.9%, and 98.6%, respectively.

Conclusion: Routine radiographs provide low utility in guiding treatment course in asymptomatic patients following pediatric scoliosis surgery, regardless of the curve pathology. Factors such as worsening symptoms and time since surgery should be considered prior to obtaining radiographs. Thorough evaluation of patient/caregiver complaints, exam findings, and clinical suspicion at post-operative visits could minimize unnecessary radiation exposures and reduce medical costs without compromising care.

236. Complications in Spinal Surgery: A Comparison of Patient and Surgeon Reporting Systems

Mohammed N. Yasin, FRCSEd (Tr&Orth); Irfan Siddique, MBChB, FRCS(Orth); Rajat Verma, MSc, FRCS, FRCS(Orth); Saeed Mohammad, MBChB(Glas), FRCS(Glas), FRCS(Tr&Orth)

United Kingdom

Summary: Differences exits between patient and surgeon reporting of complications, We compared the two mechanisms to the true rate for 921 spinal patients. Results show patients over-report all negative outcomes and surgeons under-report. However, improved pre-operative counselling may reduce patient reporting and surgeon reporting remains the best tool for auditing purposes.

Introduction: Complication rates are increasingly used to compare procedures, surgeons and units. It is also accepted that surgeon reporting may under-appreciate the true complication rate. This has led to an increased drive in patient reported complications. Our aim was to compare and correlate complication rates between patient and surgeon reporting systems in spinal surgery.

Methods: A complication was defined as any event/s, which may have occurred postoperatively that, were not expected or were a deviation from the normal post-operative course. Data was collected prospectively over a 6 month period using the SPINE TANGO Core Outcome Measure Index. Analyses was made between patient and surgeon reported complications at point of discharge from our institution. This data was cross-referenced with the true complication rate using the electronic patient recording system. Matched surgeon and patient reported complication measures were analysed. Complications were further graded using the Clavien-Dindo Classification System to allow a comparison between the two reporting mechanisms.

Results: Complete data for 921 patients was analysed. The overall surgeon reported complication rate at discharge was 4.6% compared with 25.0% at discharge for patient reporting (p<0.001). The correlation coefficient was 0.17 demonstrating poor correlation. The true complication rate was 15.2% with both methods showing a significant difference (p<0.001) and poor correlation. Classification of complications showed surgeons reported type 3 & 4 complications better, whilst patients over-reported types 1 & 2.

Conclusion: There is poor correlation between surgeon and patient reported complications, compared to the true complication rate. Surgeons under-report and patients over-report. However, despite this, surgeon reporting correlates more closely to types of complications which are significant for monitoring and auditing. Patient reporting reflects all negative outcomes not just complications and thus matching surgeon and patient expectations may reduce this rate.

237. Deep Venous Thromboembolism Following Pediatric Spinal Surgery

Natasha O'Malley; George H. Thompson, MD; Jochen P. Son-Hing; Christina Hardesty, MD; Connie Poe-Kochert, BSN

USA

Summary: We performed a 20 year retrospective review from our Pediatric Orthopaedic Spine database to evaluate the incidence of deep venous thromboembolism (DVT) in those who had spine surgery, including growing rods and VEPTRs. There was a 0.3% incidence among 1264 patients, corresponding to a 0.19% incidence in 2062 procedures. DVT is a rare occurrence in children undergoing spine surgery, and thus, thromboembolic prophylaxis is not indicated.

Introduction: With a recognized increase in the incidence of (DVT) in young patients, especially in those with complex chronic conditions, it is important for patient safety and risk management to identify subgroups that would benefit from prophylactic treatment. The aim of our study was to assess whether spine surgery in children was associated with an increased incidence of DVT, and if prophylaxis is warranted.

Methods: A prospectively approved, Institutional Review Board approved Pediatric Orthopedic Spine database (1992-2012) was reviewed to identify patients who had a DVT post operatively.

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Results: 1264 patients (856 female, 408 male) with a mean age at surgery of 12 ±3.54 years (range 0.75 - 18 years) who underwent spinal surgery (2062 procedures) were reviewed. Four patients had clinical DVT (0.3%) within 10 weeks of their procedure (range 31 to 76 days). All were lower limb DVTs. There were no upper limb thromboses or pulmonary emboli. The affected children were 9 to17 years old; 3 with a diagnosis of neuromuscular scoliois (1 post-polio and 2 with myelomeningocoele) who underwent posterior spinal fusion with segmental spinal instrumentation, and one who had in-situ fusion of a grade 3 spondylolisthesis. Two of these patients had central venous lines inserted peri-operatively, a known risk factor for thromboembolism, and one had a prior history of a popliteal thrombus. All were treated with injectable anticoagulants until oral Coumadin had reached a therapeutic dose.

Conclusion: Despite extensive surgical procedures, our spinal surgery patients have a low rate of clinical DVT, which has diminished over time, with no events since 2005. The decrease in use of sub-clavian/internal jugular or femoral lines, secondary to the increase of peripherally inserted central catheters (PICCs) may be one contributing factor, as is earlier mobilization and implementation of a strict 2 hour turning and leg-exercise protocol in the immediate post-operative period. We conclude that there is no evidence to routinely treat pediatric patients undergoing spinal surgery with thromboproplylaxis.

238. Does Curve Magnitude/Deformity Correction Correlate with Pulmonary Function After Adult Deformity Surgery?

Ronald A. Lehman, MD; Daniel G. Kang, MD; Lawrence G. Lenke, MD; Jeremy J. Stallbaumer, MD; Brenda A. Sides, MA

USA

Summary: We evaluated the relationship of pre-op curve magnitude and deformity correction with pulmonary function in 76 adult patients following spinal deformity surgery. Pre-op main thoracic (MT) curve magnitude correlated negatively with pre-op pulmonary function, and MT deformity correction correlated negatively with %pred PFTs. This suggests that a greater MT deformity correction may result in significantly less decline in pulmonary function than smaller curve corrections. Sagittal curve magnitude and deformity correction as well as pulmonary function did not demonstrate a significant relationship.

Introduction: The effect of surgical correction on pulmonary function of adult spinal deformity patients is unknown. The purpose of this study was to determine if a correlation exists between curve magnitude, deformity correction and postoperative pulmonary function (PFTs) following adult spinal deformity surgery.

Methods: We prospectively collected PFTs on 76 adult deformity patients (70F, 6M, avg age 41.2) undergoing primary surgical treatment for idiopathic scoliosis at a single institution and followed them for 2 years (avg 2.93). Radiographs for all pts were analyzed for main thoracic (MT) and sagittal T5-T12 (Sag) curve magnitude and correction.

Results: For all patients, there was a significant change in MT Cobb correction from 53.2 to 20.8 deg (avg -32.5 deg, p=0.00), Sag Cobb from 35.3 to 28.8 deg (avg -6.50 deg, p=0.00), and a significant decline in absolute and %pred PFTs after surgery, with %pred FEV1 and %pred FVC decreasing 5.86% (p=0.00) and 3.54% (p=0.01), respectively. We found pre-op MT curve magnitude significantly correlated (moderate, negative) with pre-op absolute and %predicted PFTs (r=0.364 to 0.506; p=0.001) respectively. The amount of MT deformity correction was also significantly correlated (weak, negative) with changes in %pred FEV1 and %pred FVC [change%pred FEV (r=-0.238, p=0.04); change%pred FVC (r=-0.249, p=0.03)], and there was no significant relationship between Sag deformity correction and PFTs.

Conclusion: In this large study on adult deformity surgery, Pre-op MT curve magnitude negatively correlated with pre-op pulmonary function (PFTs). There was also a negative correlation between MT deformity correction and %pred PFT change. We found that greater MT curve correction may result in significantly less decline in pulmonary function (PFTs) than smaller curve corrections.

239. In the World of Pay-for-Performance, How Do We Evaluate Baseline Risk? An Innovative Risk Assessment Tool for Spine Surgery

Nathan L. Hartin, MD; Kedar Deogaonkar, MD, FRCS; Siddharth B. Joglekar; Amir A. Mehbod, MD; Ensor E. Transfeldt, MD

USA

Summary: The Fusion Risk Score is introduced to objectively assess baseline risk of spine surgery preoperatively. The score is the sum of two components - one arises from risks unique to the individual patient (Patient Score) and the other from the planned surgery (Procedure Score). With knowledge of the

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Patient Score, the surgeon may plan intervention (Procedure Score) that appropriately controls risk.

Introduction: The specter of outcomes monitoring influences surgeon decision-making. The benefits of surgical intervention are under threat for those who possess a high baseline risk of adverse events. An objective method of stratifying risk preoperatively allows the surgeon to both control risk through tailoring intervention and explain differences in complication profile in high-complexity practice.

Methods: A retrospective review of 364 fusion surgeries in the year 2009 in patients over age 65 was conducted and patients followed for 2 years. A logistic regression analysis was performed to identify factors predictive for the occurrence of perioperative events. The predictive variables were incorporated in a weighted fashion into the Fusion Risk Score scaled from 1 to 20. Patient demographics and co-morbidities were incorporated into the Patient Score (max 10) and surgical approach, levels and osteotomies into the Procedure Score (max 10).

Results: Multivariate analysis demonstrated ischemic heart disease, levels of fusion, obstructive pulmonary disease, open anterior approach, revision surgery and diabetes to be predictors of perioperative events. Univariate analysis additionally demonstrated spinal osteotomy and renal impairment to be predictive. When applied, the Fusion Risk Score was highly predictive of perioperative events, ICU admission, operative time, blood loss and length of stay (all p<0.001). A score over threshold 10 carries a very high risk (>50%) of perioperative events.

Conclusion: An easy-to-use and highly predictive Fusion Risk Score is introduced to objectively assess baseline risk. By balancing the Procedure Score to the individual Patient Score, the surgeon can appropriately control perioperative risk.

240. Factors Associated with the Use of BMP During Pediatric Spinal Fusion Surgery: An Analysis of 4817 Children

Amit Jain, MD; Khaled Kebaish, MD; Paul D. Sponseller, MD

USA

Summary: Our goal was to investigate the trends in use of recombinant human bone morphogenetic protein (BMP) during pediatric spinal fusion surgery. From 2003 through 2009, the use of BMP during pediatric spinal fusion increased significantly from 2.7 to 9.3%. Factors associated with increased BMP use include: older age, diagnoses of congenital scoliosis, thoracolumbar fractures and spondylolisthesis, private insurance status, non-teaching hospital status, large bed capacity, and hospital location in the Western and Southern United States.

Introduction: Our goal was to investigate the trends in the use of recombinant human bone morphogenetic protein (BMP) during pediatric spinal fusion surgery, and to analyze how patient, surgical, and hospital characteristics influence BMP use.

Methods: Using the Nationwide Inpatient Sample database, we identified 4817 children eighteen years old or younger who underwent spinal fusion surgery with the use of BMP from 2003 through 2009. Multivariate logistic regression model, Z-test of proportions and simple linear regression were used for statistical analysis; significance was set at $p < 0.05$.

Results: There was a 3.4-fold increase in BMP -- from 2.7% in 2003 to 9.3% in 2009 -- an average 16% per year increase ($p < 0.01$). For each additional year of age, BMP use increased 1.09-fold (OR: 1.05 to 1.13, $p < 0.01$). Compared with adolescent idiopathic scoliosis, adjusted odds of BMP use were: 1.3-fold in congenital scoliosis (OR: 1.02 to 1.76, $p = 0.04$), 2.8-fold in thoracolumbar fractures (OR: 2.1 to 3.8, $p < 0.01$), and 5.0-fold in spondylolisthesis (OR: 3.9 to 6.3, $p < 0.01$). Patients with private insurance were 1.5-fold more likely to receive BMP (OR: 1.2 to 1.9, $p < 0.01$). Patients with autograft bone use intraoperatively were 0.63-fold less likely to receive BMP (OR: 0.52 to 0.77, $p < 0.01$). The rate of BMP use was 0.39-fold in teaching hospitals (OR: 0.31 to 0.48, $p < 0.01$) and 1.7-fold in hospitals with large bed capacity (OR: 1.3 to 2.2, $p < 0.01$). Compared to hospitals located in the Northeast, those in the West had 1.7-fold (OR: 1.3 to 2.4, $p < 0.01$) and those in the South had 2.0-fold (OR: 1.5 to 2.7, $p < 0.01$) odds of BMP use.

Conclusion: Use of BMP during pediatric spinal fusion has increased significantly. Patient factors (age, diagnosis, insurance), surgical factors (autograft use), and hospital factors (teaching status, bed capacity, geographic location) influenced the variation in BMP use.

241. Analysis of Unplanned Hospital Readmissions Following Pediatric Spinal Fusion Surgery

Amit Jain, MD; Jared M. Wohlgemut, BSc; Paul D. Sponseller, MD

USA

Summary: The aim of our study was to investigate the incidence and causes of unplanned readmissions after pediatric spinal fusion surgery, and to analyze factors associated with

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readmission. We found that the rate of 90-day unplanned readmission after pediatric spinal fusion surgery exceeds 7%, with wound healing complications predominating. Patient diagnosis, number of levels fused and intraoperative blood loss are independent predictors of readmission. These factors may be of consideration in the postoperative management of children receiving spinal fusion.

Introduction: The aim of our study was to investigate the incidence and causes of unplanned hospital readmissions after spinal fusion surgery in children.

Methods: Records of all children (≤18 years) with spinal fusion surgeries performed by a single surgeon from 2000-2009 were reviewed. Unplanned readmission was defined as: rehospitalization within 90 days of the index surgery. Patients readmitted for staged procedures, growing rod distractions, or unrelated medical problems were excluded. 861 patients (average age: 14±2.7 years) met the inclusion criteria. Univariate and multivariate logistic regression analyses were performed.

Results: The rate of 90-day unplanned readmission after pediatric spinal fusion surgery was 7.7%. Mean time elapsed between initial discharge and readmission was 28±18 days.

Causes of readmission were: wound breakdown/superficial infections in 30 patients (3.5%), deep wound infections in 8 patients (0.9%), fixation failure in 8 patients (0.9%), medical complications in 8 patients (0.9%), neurological complications in 6 patients (0.7%), and pulmonary complications in 6 patients (0.7%). Of the 66 unplanned readmissions, 58% required further operative management.

On univariate analysis, patient diagnosis, levels fused, and blood loss were found to be significantly associated with readmission. Compared to idiopathic scoliosis, the odds of readmission with Schuermann's kyphosis were 1.8-fold (P=0.45), genetic and syndromic scoliosis were 2.5-fold (P=0.01), cerebral palsy were 3.9-fold (P<0.01), and other neuromuscular causes of scoliosis were 4.4-fold (P<0.01). Readmission rate increased 1.13-fold for each additional level fused (P<0.01), and 1.38-fold for each additional liter of blood loss (P<0.01). There was no significant difference in readmission rate by age, race, gender or surgical approach. Stepwise multivariate logistic regression analysis revealed that only patient diagnosis and blood loss were independent predictors of readmission.

Conclusion: The rate of 90-day unplanned readmission after pediatric spinal fusion surgery exceeds 7%, with wound healing complications predominating. The readmission rate varies with patient diagnosis, levels fused and blood loss.

242. Adult Spinal Deformity (ASD) Patients Have Distinct Baseline Characteristics Based on Idiopathic Versus Degenerative Scoliosis Types

Han Jo Kim, MD; Christopher I. Shaffrey, MD; Oheneba Boachie-Adjei, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Vedat Deviren, MD; Justin S. Smith, MD, PhD; Matthew E. Cunningham, MD, PhD; Shay Bess, MD; Richard Hostin, MD; Khaled Kebaish, MD; Christopher P. Ames, MD; International Spine Study Group

USA

Summary: ASD pts are different based on having a diagnosis of idiopathic (IS) vs degenerative scoliosis (DS). Specifically, DS patients experience more back and leg pain which translated into worse baseline SRS and ODI scores compared to patients with IS.

Introduction: No studies have delineated the differences between patients with adult IS and DS. The purpose of this study was to compare those patients with either diagnosis with respect to demographics, curve magnitude, pain presentation, operative details and outcomes.

Methods: A prospective database of ASD pts was reviewed. Operative pts with a diagnosis of adult DS or IS were included. Revisions and pts with insufficient data were excluded. Age, BMI, Charlson Comorbidity Index (CCI), OR details, radiographic measurements, back and leg pain quantification via numeric rating scale (NRS), Oswestry Disability Index (ODI) and SRS Outcome Scores were collected.

Results: Of the 357 pts in the prospective operative database, 187 pts underwent primary surgery and 161 of them had sufficient data for inclusion into the study. There were 54 pts with a diagnosis of adult DS and 107 with Adult IS. The average age, BMI and CCI was larger in Group DS (Table 1). No significant differences were noted in operative details (Table 1), except for a higher number of decompressions and three column osteotomies performed in DS. (79%vs46%;p<0.01, 25%vs7%;p=0.02) However, patients with IS had deformities of greater magnitude evidenced by a larger pre-op thoracic and thoracolumbar scoliosis (Table 1). In addition, DS patients had significantly more back pain and leg pain compared to IS patients (Table 1). Although both groups improved with respect to the NRS back and leg pain scores, the amount of improvement seen with operative intervention was seen more in DS as well. With respect to SRS Outcomes, DS patients also demonstrated lower baseline SRS Activity, Pain and Appearance subscores and higher ODIs, however, these outcome measures equalized with surgery. (Table 1)

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Conclusion: Adult IS and DS patients appear to be different patient subsets in the ASD population. Patients with Adult DS are older and have more back and leg pain at baseline compared to their IS counterparts. Both groups demonstrated good outcomes with operative intervention.

243. The Classification for Early Onset Scoliosis (C-EOS) Predicts Timing of VEPTR Anchor Failure

Michael G. Vitale, MD, MPH; Hiroko Matsumoto, MA; Howard Y. Park, BA; Daren J. McCalla, BS; David P. Roye, MD; Wajdi W. Kanj, MD; Randal R. Betz, MD; Patrick J. Cahill, MD; Michael Glotzbecker, MD; Scott J. Luhmann, MD; Sumeet Garg, MD; Jeffrey R. Sawyer, MD; John T. Smith, MD; John M. Flynn, MD

USA

Summary: The Classification for Early Onset Scoliosis (C-EOS) is a consensus-based classification developed by pediatric spine surgeons with expertise in the treatment of EOS. This study aims to examine the predictive ability of the C-EOS with respect to time to anchor failure in surgically treated EOS patients who experienced this complication. The results show that the C-EOS is able to discriminate risk of rapid failure between classes of the C-EOS, and more significantly, may guide decision making for pediatric spine surgeons.

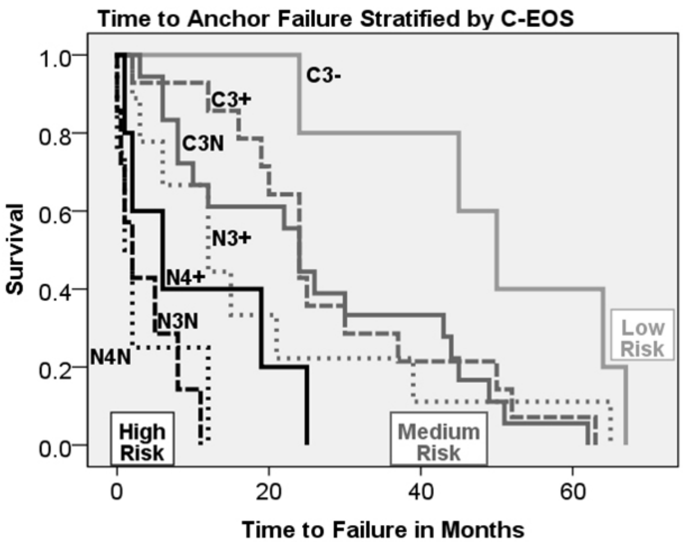
Introduction: Gaps in the literature and related variability in management of Early Onset Scoliosis (EOS) have driven research within the field. One research initiative is the consensus-based Classification for Early Onset Scoliosis which was developed by a consortium of EOS surgeons. This study aims to examine C-EOS's ability to predict timing of proximal anchor failure in EOS surgery patients.

Methods: 105 EOS patients were retrospectively queried from an EOS database, all of whom were treated with Vertical Expandable Prosthetic Titanium Rib and experienced proximal anchor failure. Patients were classified by the C-EOS, which includes a term for etiology (C:Congenital (52.8%), N:Neuromuscular (32.1%), S:Syndromic (7.5%), I:Idiopathic (7.5%)), Cobb (1:≤20 (0%), 2:21-50 (16.0%), 3:51-90 (67.0%), 4:>90 (16.0%)), and kyphosis ("-"≤20 (12.3%), "N"; 21-50 (39.6%), "+" >50 (39.6%)). Outcome was measured by time and number of lengthenings to failure.

Results: Including C-EOS classes with more than three subjects, survival analysis demonstrates that the C-EOS discriminates low, medium, and high risk of rapid failure (Figure 1). The low risk of rapid failure group consisted of Congenital/51-90/Hypokyphosis (C3-) class. The medium risk group consisted of Congenital/51-90/Normal&Hyperkyphosis (C3N, C3+) and Neuromuscular/51-90/Hyperkyphosis (N3+) classes. The high risk group consisted of Neuromuscular/51-90/Normalkyphosis (N3N) and Neuromuscular/>90/Normal&Hyperkyphosis (N4N, N4+) classes. Significant differences were found in time (p<.05) and number of expansions (p<.05) before failure between Congenital and Neuromuscular classes.

As isolated variables, Neuromuscular etiology experienced a significantly faster time to failure compared to patients with idiopathic (p<.001) and congenital (p=0.026) etiology. Patients with a Cobb >90 demonstrated significantly faster time to failure compared to patients with Cobb 21-50 (p=0.011).

Conclusion: The ability of the C-EOS to discriminate among various classification subgroups supports its validity and demonstrates its potential use in guiding decision making. Further experience with the C-EOS may allow more tailored treatment, and perhaps better outcomes for patients with EOS.



The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

244. Treatment of Spina Bifida with Spinal Fusion Surgery: Demographics, Complications and Mortality

Amit Jain, MD; Emmanuel N. Menga, MD; Hamid Hassanzadeh, MD; Surbhi Jain, MBBS; Addisu Mesfin, MD

USA

Summary: The aim of this study was to report the national trends in use of spinal fusion surgery in this group, and

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to analyze patient and hospitalization characteristics, and complications and mortality. We found that from 2000 through 2010, 13,316 spinal fusion surgeries were performed in patients with spina bifida in the United States; 47% were performed in children. The overall complication rate was 10.7% and mortality rate was 0.3%.

Introduction: There is limited data in the literature on the epidemiology of patients with spina bifida treated with spinal fusion. The aim of this study was to report the national trends in use of spinal fusion surgery in this group, and to analyze patient and hospitalization characteristics, and complications and mortality.

Methods: The Nationwide Inpatient Sample database (NIS) was queried from 2000 through 2010 to identify all patients who received spinal fusion surgery (procedural code "158") with a diagnosis of spina bifida (ICD9 code "741: Spina Bifida"). The data was converted into national estimates using stratified sampling weights. Trends over time were analyzed using simple linear regression models, and statistical significance was set at $P<0.05$.

Results: From 2000 through 2010, 13,316 patients with spina bifida (mean age 26.1±19.3 years) received spinal fusion surgery in the United States. 6,276 patients (47.1%) were ≤18 years of age; mean age at surgery in this group was 9.4±5.3 years. There was no significant increase in the total number of surgeries performed during the study period ($P=0.24$).

58.3% patients were female. By race, 72.0% were Caucasian, 9.5% were African American, 13.0% were Hispanic, and 1.5% were Asian. 38.5% patients had a public insurance, and 61.5% were privately insured.

38.2% were treated at small sized hospitals, 25.2% were treated at medium sized hospitals, and 36.6% were treated at large hospitals. 73.9% were treated at non-teaching facilities, and 26.1% were treated at teaching facilities. Mean length of hospitalization was 6.7±10.0 days (no significant change over the study period; $P=0.87$). Mean total charges were $66,858±$79,742 (significant increase over the study period; $P<0.01$).

Overall complication rate after surgery was 10.7%. Complications were as follows: pulmonary 4.6%, infectious 3.5%, cardiac 0.91%, renal 0.86%, neurological 0.65% and thromboembolic 0.19%. Overall in-hospital mortality was 0.31%.

Conclusion: Over the last decade, 13,316 spinal fusion surgeries have been performed in patients with spina bifida; 47% performed in children. Overall complication rate was 10.7% and mortality rate was 0.3%.

245. Expectations and Health Outcomes in the Surgical Treatment of Adult Spinal Deformity (ASD)

Ian McCarthy, PhD; Michael F. Obrien, MD; Christopher P. Ames, MD; Vedat Deviren, MD; Gregory M. Mundis, MD; Oheneba Boachie-Adjei, MD; Frank J. Schwab, MD; Eric Klineberg, MD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Richard Hostin, MD; International Spine Study Group

USA

Summary: There is a general perception that a patient's pre-operative expectations may impact their post-operative self-reported quality of life. The purpose of this study is to analyze the relationship between HRQOL outcomes following ASD surgery and patients' general pre-operative health expectations. Results reveal a negative but statistically insignificant relationship between HRQOL improvement and pre-operative expectations.

Introduction: There is general consensus in favor of the management of pre-operative expectations for surgical ASD patients, despite little empirical evidence as to whether future health expectations actually impact HRQOL outcomes. The purpose of this study is to analyze the relationship between HRQOL outcomes following ASD surgery and patients' general pre-operative health expectations.

Methods: Retrospective analysis of a multi-center, prospective database of surgical ASD patients. General health expectations were measured using question 11c of the SF-36, which asks patients to choose the best of five responses (definitely true to definitely false) to the statement: "I expect my health to get worse." Responses were grouped into three categories (worse, same, or better health). HRQOL outcomes included the ODI, SRS-22, and the SF-6D. Statistical analysis was performed using ANOVA and regression analysis.

Results: Two-year HRQOL follow-up data were available for 159 of 230 eligible patients (69%). Patients were predominantly female (n=136, 85%) with an average age of 55 (std=15). Table 1 summarizes the average HRQOL measures and QALYs at follow-up by category of general health expectations elicited pre-operatively. There were no significant differences in patient demographics (gender, age, BMI, and Charlson co-morbidity index) or pre-operative radiographic measures (SVA, PT, and Cobb angle) across categories of health expectations ($p>0.05$). Average HRQOL improvements were lower for patients with higher pre-operative expectations; however, ANOVA and regression analyses indicated that such differences were not statistically significant ($p>0.05$).

Conclusion: Higher general health expectations were associated with lower average HRQOL improvements following surgery;

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however, the analysis was unable to show any significant positive or negative impact of general health expectations on post-operative HRQOL outcomes. Additional research should also consider the role of a patient's expected improvement due to surgery rather than general expectations of overall health.

ǂ 246. Revision Rate Following Thoracolumbar Fusion for Adult Deformity: Upper Versus Lower Thoracic UIV

Prokopis Annis, MD; Brandon Lawrence, MD; Michael D. Daubs, MD; Darrel S. Brodke, MD

USA

Summary: Revision rates for adult deformity surgery were assessed by location of the upper-instrumented vertebrae (UIV). Patients with the UIV in the upper thoracic spine (UT) had similar rates of revision as those with in the lower thoracic (LT) spine. UT revisions were due to non-unions while LT revisions were for proximal junctional failure.

Introduction: Complication rates are relatively high in adult deformity surgery. While nonunion appears to be the most common complication overall leading to revision surgery, early revisions may be required more often after proximal junctional failure (PJF). It has been suggested that the rate of PJF may vary based on the level of the upper-instrumented vertebrae (UIV). The purpose of this study was to review and compare early and late revision rates of fusions with UIV in the upper (UT) or lower thoracic (LT) spine.

Methods: We reviewed 110 consecutive patients, with mean age 61 years (19-82) and mean follow-up 39 months (24-103), treated operatively for deformity at a single institution. Early revision rates (return to the operative room within 12 months) and late revision rates (return by final follow up) were calculated. Patients were divided into 2 cohorts, those with fusion to the UT spine (T1-T5) and LT spine (T7-T12).

Results: At the final follow-up there was a trend for higher revision rate in the UT group (43%) as compared with the LT (26%)(p=0.07). There was no difference in the early revision rates between the two groups. Proximal junctional failure (PJF) for the LT (14%) (p=0.03) and nonunion for the UT (8%) (p=0.01) group were the most common causes of early revision surgery. Late revision rates for nonunion were significantly higher in the UT group (p=0.003).

Conclusion: Adult deformity surgery has a relatively high complication rate with revisions commonly required due to PJF or nonunion. The complication profile varied based on the location of the UIV. While revision for PJF was significantly lower in those fused to the upper thoracic spine (0%), the nonunion rate require revision was significantly higher (36%) negating any perceived benefit of the longer fusion.

247. Risk Factors Associated with Progression of Chiari I Malformation Related Scoliosis After Decompression

Steven W. Hwang, MD; Amer F. Samdani, MD; Marie Roguski, MD; Patrick A. Sugrue, MD; Senthilnathan Thirugnanasambandam, MD; Noriaki Kawakami, MD, DMSc; Peter Sturm, MD; Randal R. Betz, MD; Ron El-Hawary, MD, MSc, FRCSC; Joshua M. Pahys, MD; Patrick J. Cahill, MD

USA

Summary: Patients with Chiari I malformation related scoliosis often undergo a suboccipital decompression to attempt and halt curve progression. We retrospectively reviewed a multicenter series to identify differences between patients that progressed requiring spinal fusion after a suboccipital decompression. The group requiring surgery presented at a later age, was more skeletally mature, presented with larger primary Cobb angles, more commonly had a right thoracic curve, and had a greater average rate of curve progression.

Introduction: Chiari I malformations are radiographically defined as 5mm of tonsillar descent below the foramen magnum and up to one third of patients may develop some degree of scoliosis. Often a suboccipital decompression is performed with progressive scoliosis to attempt and halt the curve increase. We sought to identify differences between patients who underwent a decompression and continued to progress requiring deformity correction and those that did not.

Methods: We retrospectively reviewed a multi-center series of patients with a Chiari I malformation diagnosis and scoliosis. We identified two subgroups, patients who had a decompression alone (D) and patients who had a decompression and required a spinal fusion (F), and compared various parameters between them.

Results: 29 patients were treated with suboccipital decompression alone and 34 had a decompression but later required surgical spinal deformity surgery. The mean age of the cohorts was statistically different: 7.9 ± 4.4 years (Group D) and 10.7 ± 4.4 years (Group F). The mean presenting Cobb angle was 35.5° ± 18.6° (D group) vs 51.3° ± 24.7° (F group). Similarly, the fusion group was more skeletally mature. A greater number of patients in the fusion group had a right thoracic curve (88% vs 55%). The mean rate of curve progression in the D group was 0.0013°/month vs 0.932°/month in the F group (p=0.0003).

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The mean follow-up between diagnosis and decompression was similar for both groups and the overall follow-up was 52 months in the decompression group and 32 months in the fusion group (p=0.05).

Conclusion: Our results suggest that the older age of presentation, larger Cobb size at presentation and greater rate of progression are independently associated with a greater likelihood of deformity progression to the point of requiring surgery even after suboccipital decompression.

248. Severity and Treatment Response of Back and Leg Pain Differ by Curve Location in Adult Spinal Deformity (ASD)

Han Jo Kim, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Douglas C. Burton, MD; Justin K. Scheer, BS; Oheneba Boachie-Adjei, MD; Matthew E. Cunningham, MD, PhD; Justin S. Smith, MD, PhD; Shay Bess, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; International Spine Study Group

USA

Summary: Multi-center, prospective analysis of consecutive surgically treated ASD patients demonstrated high preoperative back and leg pain, however back and leg pain were most associated with sagittal and lumbar deformities. Predominant back pain patients had sagittal and lumbar deformities, while those with predominant leg pain most commonly had lumbar deformities. Two year postoperative back and leg pain was reduced for all deformity types and pain patterns. These data should be used for ASD pain pattern evaluation and surgical counseling.

Introduction: Back and leg pain are common presenting symptoms in ASD patients. Little data exists correlating deformity type with back and leg pain distribution. Purpose: evaluate distribution of preoperative back and leg pain for different curve types in ASD and efficacy of surgery to relieve pain.

Methods: Multi-center, prospective analysis of consecutive patients enrolled into an ASD database. Inclusion criteria: no prior surgery, >4 level spinal fusion for ASD and minimum 2 year follow up. ASD classified by curve type: S=sagittal deformity only, T=thoracic, L=lumbar, D=thoracic and lumbar. Patients grouped according to severity of preop back and leg pain using the numeric rating scale (NRS); BACK=back pain≥7, leg pain ≤6; LEG= leg pain≥7, back pain ≤6; HIGH= back and leg pain ≥7; LOW= back and leg pain ≤6. Demographic, radiographic and operative data were evaluated.

Results: 318 of 857 patients enrolled in the database met inclusion criteria: (S=73, T=23, L=85, D=83). Mean age was 56.6 years. Mean preop back vs. leg pain for all patients was 7.1 and 4.2 (S= 7.9 vs. 4.9; T=5.9 vs. 2.8, L=7.0 vs.4.3 and D=6.6 vs. 3.0), respectively.

Back pain was greater than leg pain for all groups; back pain was greatest in S and L groups (p<0.05). BACK had higher prevalence of S, L and D curves than T curves (32%, 30%, 32% vs. 7% respectively p<0.05). LEG had a higher prevalence of L (43%) than S, T and D curves (p<0.05). HIGH had a higher prevalence of S (38%) and L (33%) than T, and D curves. LOW had higher prevalence of L (33%) and D (42%) curves than S and T curves (p<0.05).

Mean 2 year back and leg pain was reduced for all patients (back=3.3, leg= 2.2) compared to preop values (p<0.05). Two year postop back pain (S=3.9, T=1.4, L=2.9, D=3.5) and leg pain (S=2.8, T=0.8, L=1.8, D=2.1) was lower than preop values for all curve types except D leg pain (p<0.05).

Conclusion: Surgical correction of ASD significantly reduces both back and leg pain at 2yr follow up. Back and leg pain distribution differs according to type and location of deformity. Sagittal and lumbar deformities report higher back and leg pain than T and D curves. These data should be used to council patients regarding anticipated postoperative pain relief.

249. Risk and Predisposing Factors in Surgical Site Infections After Pediatric Spinal Deformity Surgery: Density Case-Control Assessment

Jesse Allert, MD; Sina Pourtaheri, MD; Freeman Miller, MD; Kirk W. Dabney, MD; Laurens Holmes, PhD, DrPH; Suken A. Shah, MD; Susan Dubowy, BS

USA

Summary: In this large, single center cohort of pediatric patients undergoing complicated spinal deformity surgery, the Surgical Site Infection (SSI) rate was 3%.The SSI patients were compared to a random sampling of non SSI deformity patients (control) and risk factors were identified. These risk factors include: increased weight, severe spasticity, wound problems and prolonged surgical time. SSI patients had more intra-operative complications, longer ICU stays.

Introduction: The purpose of the current study was to identify risk factors for deep wound infections with pediatric spine deformities surgery. Select risk factors assessed included length of surgery, perioperative antibiotic selection and timing of presurgical antibiotics, number of assistants, mean Cobb angle,

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type of hardware, weight/BMI of patient, level of spasticity, length of stay, ICU stay, levels fused, postoperative wound appearance, and preoperative MRSA nasal swab.

Methods: A retrospective review of 851 spinal deformity surgeries from 2006-2010 by 5 surgeons at one institution was performed. Cases that required an operative I&D within 6 months of index surgery were defined as deep wound infections. Stratified systematic random sampling with a 1:3 ratio [deep wound infections: the control group (non-infected cohort)] was used. Chi-squared statistic, Fisher's exact, and independent sample t tests were used to examine the data.

Results: 21 patients had SSI: 3 AIS (14%), 14 CP (67%), 3 syndromic (14%), 1 congenital scoliosis (5%). The control (non-infected) group consisted of 58 patients with similar characteristics. The SSI and control groups were well matched: mean age at surgery = 13.8 yrs (SSI),13.8 yrs (control); Male: Female = 1.2: 1 (SSI), 1: 1.3 (control); Cobb angle = 76.8 (SSI), 78.7 (control), levels fused = 18 (SSI), 16 (control). Main risk factors for SSI events were weight, level of spasticity, wound status, and length of surgery. Mean weight = 47.6 KGS (SSI), 38.1 KGS (control) [p=0.06]. The SSI group had greater spasticity requiring oral baclofen or a baclofen pump [$\chi 2$(df) = 11.1 (3), p=0.01]. The SSI cohort had more cases of dehiscence and significant drainage within 3 days of surgery [$\chi 2$(df) = 27.7 (2), p<0.001]. Mean length of surgery = 7.5 hrs (SD± 3.1) for the SSI group vs. 6.1 hrs. (SD± 2.1) for controls, p=0.03. There were more intraoperative complications in the SSI group (25%) compared to the control (12.7%). The SSI cohort spent two extra days post-op in the ICU (8.4 vs. 10.2 days).

Conclusion: Risk factors for SSI in pediatric deformity surgery are increased weight, severe spasticity, incompetent wounds, and prolonged surgical time. The SSI cohort had more intraoperative complications and longer ICU stays.

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250. Addressing the Challenges with Surgical Correction of Adult Scoliosis: Identification of Parameters Predicting Coronar LIV-Balance, Curve Correction and Risk Factors for ASD

Heiko Koller, MD; Oliver Meier, MD; Juliane Zenner, MD; Michael Mayer, MD; Wolfgang Hitzl, PhD, MSc

Germany

Summary: To improve surgical planning and outcomes in adult scoliosis (AS),the study targeted the prediction of curve correction, postop LIV-balance in terms of LIV-take-off (LIV-TO), risk factors for ASD and treatment failure. Using prediction models,LIV-balance was predicted at best by preop LIV-TO and LIV-take-off on bending/traction-films (bLIV-TO,differences on bending- vs traction-films were not significant (13.5°/13°,p<0.5)).ASD was shown to influence outcomes. Parameters of sagittal balance rather than coronal predicted ASD.Grading of preop adjacent disc degeneration (Pfirrmann/MRI) did not improve prediction of ASD.

Introduction: In AS surgery LIV-balance is important to reduce the risk of adjacent segment disease (ASD) & revision surgery. The aims of the study were twofold:1.identify parameters predicting correction of LIV-TO; 2.determine risk factors for symptomatic ASD and the impact ASD bears on outcomes.

Methods: Analysis of 428 pts w/ AS. Age 53yrs, f/u 41 mo. SRS adult classification was: 51% ML, 24% ST, 24% DM, 1% DT. 295 pts had LIV not at S1. 64% had EV at L3/L4, 54% SV at L5.Preop LIV+UIV adjacent discs were graded acc. to Pfirrmann (MRI). PSF levels were 8. Stepwise mutlivariate regr. analyses were performed to identify predictors for LIV-TO, curve correction & ASD. Prediction models were developed to reveal the most valuable predictor for postop LIV-TO.

Results: Curve flexibility was low: TC:34%/LC:38%. Preop TC 53°, f/u 30°. Preop LC 43°, f/u 24°. Preop TC and LC (r=.9/ r=.8), flexibility (r=.8/ r=.8) & anchor density (p<.05,r=-.5 to -.82) had sign. impact on TC and LC resolution. Pts w/ anterior release had better LC correction (p<.01). Preop and f/u adjacent disc tilt (AST): Sagittal prox 1.7°/2.3°(p<.05), sagittal distal -2.5°/-1.4°(p<.05), coronal prox 4.0°/3.6°(p=.04), coronar distal 7.3°/4.2° (p<.001). Preop LIV-TO 18.2°±10, f/u 9.4°±6 (p<.001). 59 pts had ASD (54% prox/46% distal). ASD correlated w/ sagittal and coronal parameters, but not w/ Pfirrmann grades:Proximal ASD: Preop coronal prox AST(p=.01), postop & f/u SVA(p=.05/p<.05), preop & f/u PT(p=.03/p=.05); distal ASD: bLIV-TO(p=.02), preop & postop sagittal distal AST(p=.02/p=.01), preop PJK(p=.04), postop & f/u LL(p=.06/=.03), postop LC (p=.04). 32% had revision, risk was lower in pts w/ fusion not to S1(p<.001), lower BMI(p<.001), better sagittal balance (SVA, p<.001) and distal AST≤10°(p=.006). Distal ASD (SF36-MCS,p=.07) and correction of TC/LC, coronal & sagittal balance influenced outcomes (p<.05,COMI,ODI,SF36-PCS: r=-.4 to -.66). In the prediction model, bLIV-TO(p<.001) & preop LIV-TO(p<.001) remained best input variables. The equation and its high accuracy is illustrated in fig.1.

Conclusion: LIV-balancing is important to avoid ASD. ASD was shown to influence outcomes. It can be predicted best by preop LIV-TO & bLIV-TO. Grading of adjacent disc degeneration did not improve prediction.

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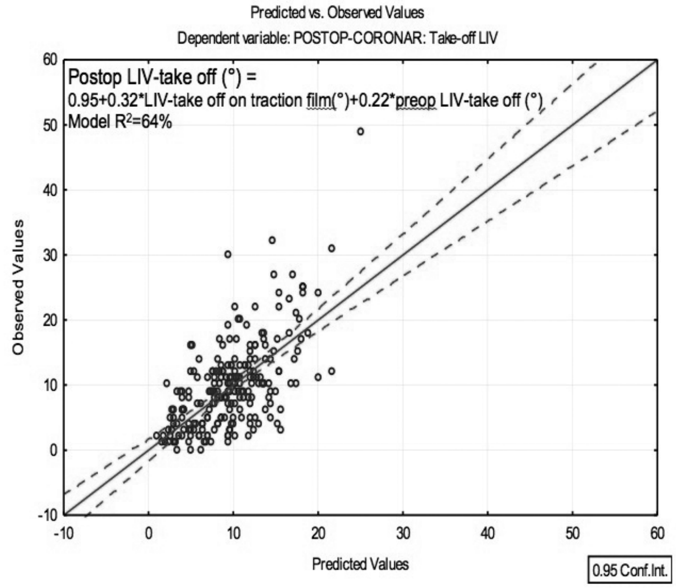

251. Inter- and Intra-Observer Reliability of the Simplified Skeletal Maturity Scoring System for Scoliosis Progression: An Analysis of 277 Patients

Kushagra Verma, MD, MS; Prakash Sitoula, MD; Peter G. Gabos, MD; James O. Sanders, MD; Suken A. Shah, MD

USA

Summary: The inter-observer agreement for the SMSS among senior authors is 71% with 99% intra-observer agreement. The intra and inter-observer agreement was lower (68-70%) for persons newly introduced to the classification system. Discrepancies seem to occur most when classifying stage 2 vs. stage 3.

Introduction: The simplified skeletal maturity score (SSMS) of an X-ray of the hand has been utilized to predict curve progression in idiopathic scoliosis. Using a large sample of patients, this study aims to validate the intra and inter observer reliability stage and for the overall cohort.

Methods: Retrospective review of scoliosis patients 8-16 years who obtained at least one hand x-ray. An orthopedic resident (OSR) newly introduced to the system, a research fellow (RF) familiar with the system, and two attending physicians (AP1, and AP2) using the system for several years were asked to independently score hand x-rays using the SMSS (stage 1-8). Inter and Intra-observer accuracy rates were calculated for each stage and for the entire cohort. Comparisons were also made between junior and senior members of the faculty.

Results: 277 hand x-rays were evaluated. The distribution of patients within SMSS 1 - 8 by AP1 was: 32(11%), 35(12%), 49(18%), 44(16%), 10(4%), 45(16%), 56(20%), 8(2%). The senior authors agreed on 197 out of 277 hand x-rays (71%). The discrepancies that occurred in SMSS 1-8: 13(16%), 27(34%), 2(2.5%), 18(22.5%), 7 (9%), 5 (6%), 8 (10%), 0 (0%). The agreement of OSR vs. AP1 and vs. AP2 was 193/277 and 195/277 (70%) respectively. The discrepancies for OSR vs. AP1 (SMSS1-8) was: 17(20%), 9(11%), 8(10%), 16(19%), 5(6%), 20(24%), 9(11%), 0 (0%). Mismatches for OSR vs. AP2 were: 5(6%), 2(2%), 33(40%), 4(5%), 4(5%), 27(33%), 8(10%), 0(%). The agreement between OSR and RF was (191/277) 69%. Mismatches for OSR vs. RF: 0 (0%), 25 (29%), 25(29%), 4(5%), 7(8%), 4(5%), 14(16%), 7 (8%). Of note, the agreement between AP1 and RF was 270/277 (97.5%). The intra-observer agreement by the senior authors was 97-99% while intra-observer agreement for OSR was 68%.

Conclusion: The inter-observer agreement for the SMSS among senior authors is 71% with 97% intra-observer agreement. The intra and inter-observer agreement was lower (68-70%) for persons newly introduced to the classification system. Discrepancies seem to occur most when classifying a stage 2 vs. a stage 3. This study further defines the inter and intra-observer validity of the SMSS for each stage and for the entire cohort. A comparison is also made between junior and senior faculty.

252. Risk Factors for a Delay in Diagnosis of Vertebral Osteomyelitis

Sina Pourtaheri, MD; Mark J. Ruoff, MD; Kumar Sinha, MD; Ki S. Hwang, MD; Arash Emami, MD; Eiman Shafa, MD; Tyler Stewart, BS; Kimona Issa, MD

USA

Summary: Vertebral osteomyelitis, especially Pott's disease, has been well established as having a delay in diagnosis due to the specific complains and findings on presentation. In this study, risk factors for a delay in diagnosis for vertebral osteomyelitis are HIV, hepatitis C, IVDA, and TB status. These cases of delayed diagnosis progressed to chronic osteomyelitis that was refractory to non-operative care and accrued higher hospital costs.

Introduction: The purpose of this study was to identify clear risk factors for a delay in diagnosis for vertebral osteomyelitis.

Methods: A retrospective review of 920 patients who had spinal osteomyelitis from 2001to 2011 from one institution was performed. Inclusion criteria included appropriate initial imaging, lab results, evaluation by the orthopedic department,

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and no treatment done prior to admission at an outside institution. Chi-squared statistic, Fisher's exact, and single sample t tests were used to examine the data. All patient characteristics were evaluated as potential risk factors. A delay of diagnosis was defined as greater than 8 weeks from first ER visit to diagnosis. Clearance of the infection was defined as normalizing of serum markers and resolution of osteomyelitis on MRI after 6 months of treatment.

Results: e-hundred six patients met the inclusion criteria with 151 admissions and readmissions specifically for the management of vertebral osteomyelitis: 62 men (58%), 44 women (42%), mean age 54 yrs., mean follow-up 38 months. The risk factors for delay in diagnosis were HIV (Odd's ratio, OR: 2.0, n = 14), hepatitis C (OR: 2.06, n = 26), intravenous drug abuse (IVDA, OR 2.11, n = 36), and tuberculosis (TB, OR: 2.75, n =25). In patients with a delayed diagnosis, the mean time to diagnosis was 2.3 months (SD±2.4). The early diagnosis cohort (ED) tended to clear the infection more often than the delayed diagnosis cohort (DD) and trended toward significance [OR 2.6, 95% CI: 0.96 to 7.07, p = 0.057]. The Oswestry scores from initial presentation to final follow-up respectively: ED= 62.9 (SD± 16.9) and 49.2 (SD±14.8), DD= 67.4 (SD±18) and 45.2 (SD±21). The mean cost of hospital admission was less in the ED group ($158,294) compared to DD group ($190,286).

Conclusion: Risk factors for a delay in diagnosis for vertebral osteomyelitis are HIV, hepatitis C, IVDA, and TB. An increased level of suspicion for vertebral osteomyelitis is need in these populations. These cases of delayed diagnosis progressed to chronic osteomyelitis that was refractory to non-operative care and accrued higher hospital costs, however long-term improvement in Oswestry scores was not affected by a delayed diagnosis.

ǂ 253. Using the Scoliosis Research Society 2011 M&M Database to Determine Significant Difference in Case Volume and Membership Status to Occurrence of Complications

Paul A. Broadstone, MD; Douglas C. Burton, MD; Michael J. Goytan, MD; Justin S. Smith, MD, PhD; Theodore J. Choma, MD; Amer F. Samdani, MD; Yongjung J. Kim, MD; Robert F. Heary, MD; Howard M. Place, MD; Jonathan E. Fuller, MD; Karl E. Rathjen, MD; John R. Dimar, MD

USA

Summary: Based on the 2011 SRS M&M reporting system, the rate of three complications was collected from Active and Candidate members. In comparing the complication rates, there was a significant difference between Active and Candidate members and between those Active members doing <200 cases/year for the complication of neurologic deficit only

Introduction: The SRS collected case data from 95% of its eligible members in 2011, which included their total number of cases and their complications of Death, Visual acuity loss, and Neurologic Deficit. The object was to compare rates of these complications to member status, active or candidate, and the case volume of the member

Methods: Method: From the 2011 SRS M&M data base, members was classified according to the number cases preformed annually by increments of 50 as well as their status.

Group A 1-50

Group B 51-100

Group C 101-150

Group D 151-200

Group E < 201.

The groups were them compared for statically significance.

Results: In regards to the occurrence of the complication of Death or Visual impairment, there was no significant difference between the Active and Candidate members. Nor was there a significant difference between the case volume groups.

In regards to the occurrence of the complication of Death, there was a very significant difference between the Active and Candidate members (p=0.0002). The active member group C and E had significantly less (p0.0006 and p=0.01.2 respectively) occurrences than the candidate groups. In comparing the Candidate Groups, there was no significant difference, while the Active Groups showed significant differences with lower rate in higher case volume Groups.

Conclusion: Conclusions: Based on the 2011 SRS M&M collecting system, there does not appear to be a significant difference in the rate of complication of Death or Visual acuity change based on membership status or case volume. There was a significant lower occurrence of Neurologic deficit within the Active members with higher cases volume

254. Intraoperative Prone Assessment of Lordosis During Pedicle Subtraction Osteotomy Overestimates Final Postoperative Standing Measurement of Lordosis

Jean-Christophe Leveque, MD; Rajiv K. Sethi, MD

USA

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Summary: This abstract reports the change in lumbar lordosis (LL) from a prone intraoperative position to a final standing film in patients undergoing a PSO. Pre- and post-operative measurements of LL compared to intraoperative prone measurements. The average change in LL after PSO from intraoperative prone to postoperative standing imaging was -12.1°.

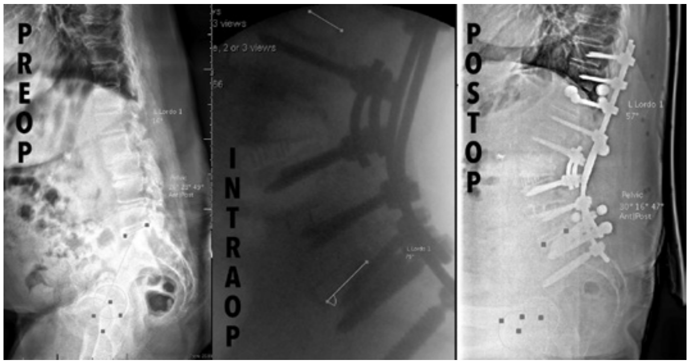
Introduction: Sagittal plane alignment has become a primary goal of adult deformity surgery. Recent authors have described the use of preoperative formulas and planning software to predict the amount of correction needed during a PSO to obtain an appropriate final standing lumbar lordosis. The relationship between the intraoperative lordosis created by an osteotomy and the final standing xrays is unknown. This abstract is the first description of the change in lordosis from a prone intraoperative position to a final standing film in patients undergoing a PSO procedure.

Methods: A total of 13 consecutive patients undergoing a PSO as part of a posterior long fusion were studied. The average patient age was 67 years (range 59-72). Fusion constructs were from T10-pelvis in 9/13 patients, from T4-pelvis in 3/13, and from L2-pelvis in 1/13. The level of osteotomy was L3 in 10 of 13 patients, while 2 patients had an L4 osteotomy and 1 patient had a dual osteotomy at L2 and L4.

Pre- and post-operative measurements of pelvic tilt, pelvic incidence and lumbar lordosis were performed on standing films. LL was measured on intraoperative films with patients in a prone position after closure of the osteotomy. Standing 36 inch digitized films at 6 weeks postop were used in this analysis.

Results: The preoperative LL was 20° (range 2-50, ± 15). The postoperative LL was 56° (range 26-75, ±13), with an average total correction of 36.8° (20-62, ±13). The intraoperative LL was 68° (range 49-86, ±11). The average change in lumbar lordosis after PSO from intraoperative prone to postoperative standing imaging was -12.1° (range -24 to 0, ±7).

Conclusion: This study demonstrates that an intraoperative measurement of lordosis created by a pedicle subtraction osteotomy overestimates the final standing lumbar lordosis by greater than 12 degrees. Given the relatively narrow target between the pelvic incidence and lumbar lordosis (±9 degrees) advocated by recent papers, this overestimation could lead to sagittal imbalance and predispose patients to failure. We therefore advocate that spinal deformity centers assess the difference in LL between intraoperative prone films and postoperative standing films in their patients in order to ensure appropriate spinopelvic balance after PSO.



Pre-operative (standing), intra-operative (prone), and post-operative (standing) films demonstrating lumbar lordosis

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255. Intraoperative Neuromonitoring (IONM) on Patients Undergoing Posterior Spinal Deformity Correction Surgery (PSDCS): Portland Experience

Ilker Yaylali, MD, PhD; Batuhan Baserdem; Jung U. Yoo, MD; Alexander C. Ching, MD; Robert A. Hart, MD

USA

Summary: The purpose of this study was to observe the effects of Intraoperative Neuromonitoring (IONM) on patients undergoing Posterior Spinal Deformity Correction Surgery (PSDCS).

Introduction: Somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) are frequently used to monitor neurological function during spinal deformity surgery.

Methods: A retrospective review of all patients undergoing PSDCS with IONM from October 2008 to December 2012 was performed. Factors including gender, operative time and spinal levels of posterior fusion were analyzed as risk factors for intraoperative alerts. A total of 782 consecutive patients who underwent Posterior Spinal Fusion (PSF) were studied. There were 45% male (355) and 55% female (427) patients with ages (during surgery) ranging between 13 and 91 years with a mean of 56 years. Operation time ranged between 2 to 15 hours with a mean of 7 hours. All patients had upper and lower SSEP and MEP as part of the intraoperative neuromonitoring. Procedure by spinal levels we as follows; 20% (153) cervical, 12% (97) cervicothoracic, 10% (79) thoracic, 15% (114) thoracolumbar, 21% (164) thoracosacral, 14% (112) lumbar, 8% (63) lumbosacral.

Results: A total of 3% (24) patients experienced intraoperative alerts. Of all the surgical levels, cervico-thoracic level was found to be the most prone to intraoperative alerts (6 of 97

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of all cervico-thoracic cases, highest among other levels, p=0.06). Among these patients; age (p= 0.32), gender (p= 0.66) and operation time (p=0.63) were not determined to be distinguishing factors. Of the cases, in 46% (11) upper extremity SSEP alerts occurred, simply corrected by repositioning the arms. In 13% (3) upper extremity SSEP and MEP alerts occurred during pre-incision neck positioning corrected by repositioning the neck. The rest of the SSEP and MEP alerts (42%, 10) occurred during spinal correction; all of which were corrected by surgeon's intervention.

Conclusion: Performing IONM during positioning (1.8 % of total monitored cases) and clear communication with the surgeon for the necessary intervention (1.3 % of total monitored cases) is important to prevent permanent neurologic deficits for PSDCS.

256. Factors Predictive of Proximal Failure After Thoracolumbar Instrumented Fusion

Jayme R. Hiratzka, MD; Paolo Punsalan, MD; Natalie L. Zusman, BS; Keegan McClary, BS; Travis Philipp, BA; Alexander C. Ching, MD; Jung U. Yoo, MD; Robert A. Hart, MD

USA

Summary: Proximal junctional failure is a complex entity complicating adult deformity surgery for which clear risk factors have not been established. This study of 79 patients undergoing thoracolumbar fusion for adult deformity attempts to identify risk factors for proximal failure. We have identified several possible risk factors, particularly increased pre- and post-op main thoracic kyphosis, which may increase risk for the development of early proximal junctional failure.

Introduction: Proximal junctional failure is a common and difficult complication of long thoracolumbar fusions in adult patients. This study attempts to identify patient factors predictive of early failure in patients undergoing long fusions into the upper thoracic spine.

Methods: Adult patients undergoing fusions from at least T9-L4 were evaluated for proximal failure. Failures were defined as kyphosis≥10° at the proximal end of the construct, compression fracture at or adjacent to the upper instrumented vertebra (UIV) or upper screw or hook dislodgement. The independent variables assessed were age, thoracic kyphosis, T5 inclination angle (angle of the superior endplate of T5 off the horizontal), UIV inclination angle and spinopelvic parameters (sacral slope, pelvic tilt and pelvic incidence). Means between the failure and non-failure groups were compared for statistical significance.

Results: 79 patients were available for review. 25 patients (32%) showed evidence of proximal failure. Of the 25 failures, 9 (36%) were compression fractures, 7 (28%) were proximal kyphosis >10°, 7 (28%) were hardware failure and 2(8%) had combined hardware failure and fracture. Patients with proximal failure were older (63.8±8.2 years vs. 58.4±12.1 years, p=0.05), and showed greater pre-op (44.5±23.0° vs. 33.0±17.8°, p=0.02) and post-op (47.4±14.9° vs. 33.9±17.0°, p<0.01) thoracic kyphosis, pre-op (36.0±15.9° vs. 26.9±16.6°, p=0.03) and post-op (24.4±11.5° vs. 18.0±10.7°, p=0.02) T5 inclination, post-op UIV inclination (27.5±23.4° vs. 18.0±18.4°, p=0.04). 15/23 (65%), patients with thoracic kyphosis ≥45° failed as well as 18/40 with T5 inclination >20° (45%). Patients with both kyphosis ≥45° and T5 inclination>20° showed failure in 15/22 patients (68%).

Conclusion: Patients with increased thoracic kyphosis and T5 inclination angle, either pre- or post-op, appear to be at higher risk of developing proximal junctional failure. In particular, patients with post-op thoracic kyphosis ≥45° appear be at very high risk for this complication. Additional fixation or more proximal fixation should be considered to prevent this complication in these patients.

257. Does Minimally Invasive Posterior Instrumentation (PPI) Prevent Proximal Junctional Kyphosis (PJK) in Adult Spinal Deformity (ASD) Surgery? A Prospectively Acquired Propensity Matched Cohort Analysis

Praveen V. Mummaneni, MD; Michael Y. Wang, MD; Virginie Lafage, PhD; John Ziewacz, MD, MPH; Jamie S. Terran, BS; David O. Okonkwo, MD, PhD; Juan S. Uribe, MD; Neel Anand, MD; Richard G. Fessler, MD, PhD; Adam S. Kanter, MD; Frank La Marca, MD; Christopher I. Shaffrey, MD; Vedat Deviren, MD; Gregory M. Mundis, MD; International Spine Study Group

USA

Summary: PJK remains a significant problem in adult deformity surgery. Soft tissue trauma likely plays a role in development of PJK. The use of MIS pedicle screws has been theorized to be protective. In this propensity matched cohort analysis the use of MIS pedicle screws was protective with PJK incidence of 0% vs. 19.4% among open posterior surgery at one-year post op. cMIS was able to maintain sagittal alignment at 1 year and HYB able to correct the sagittal plane deformity.

Introduction: Proximal junctional kyphosis (PJK) is an unwanted complication of ASD surgery. Multiple theories exist why PJK occurs. One potential contributor is damage to the paraspinal musculature and intervertebral stabilizers frequently disrupted during exposure and screw placement. This study

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aims to investigate the effect of PPI vs. Open screw placement on PJK development.

Methods: 280 pts in 2 prospective databases (MIS n=85; OPEN n=195) were retrospectively reviewed, divided in 2 separate approaches and propensity matched for pelvic incidence - lumbar lordosis (PI-LL) and change of LL. Inclusion criteria: age >45, Cobb >20°, min 1 yr follow up. Groups defined as: 1)cMIS-lateral interbody fusion (LIF) with PPI (n= 31) and 2)Hybrid (HYB)- LIF followed by open posterior instrumentation (n=31). PJK was defined as Proximal junctional angle (PJA) >10° and change post op >10°.

Results: A mean of 4.1 levels were fused (range 2-6). The mean age was 64 years and mean BMI was 26.1. Mean follow-up was 27.5 months. There was no preop difference between groups for LL-PI or SVA. Both groups showed significant improvement in LL (cMIS: 33°-41°; HYB: 35°-44°; p<0.001) and PI-LL (cMIS:19.7°-12.4°; HYB: 19.6°-7.4°) and significant difference in PT. SVA remained physiologic for cMIS (29-26mm) and improved in HYB (54-31 mm; p=0.024). The cMIS group had a smaller change in PJA (+1.3°) than HYB (+6°) (p=0.005). PJK developed in 19.4% of HYB patients and 0% in cMIS (p<0.01). One patient in the Hybrid group required vertebroplasty for PJK. Both groups saw significant improvement in ODI (cMIS 39 to 20.1; HYB 46.7 to 30; p<0.001).

Conclusion: The addition of PPI seems to have a protective effect on the development of PJK. The analysis controlled for preoperative sagittal alignment as well as for correction of PI-LL. HYB was effective in restoring sagittal global alignment and cMIS in maintaining it.

258. Variations in Perioperative Care of Children with Cerebral Palsy Undergoing Surgery for Scoliosis: A Multi-Center Comparison of the Drivers of Cost and Outcome

Brian Scannell, MD; Peter O. Newton, MD; Burt Yaszay, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Firoz Miyanji, MD, FRCS(C); Mark F. Abel, MD; Harry L. Shufflebarger, MD; Harms Study Group

USA

Summary: An analysis of a multicenter prospective study of scoliosis in children with cerebral palsy was undertaken to identify variations in perioperative care between institutions. Significant variation exists especially as related to blood loss, operative time, hospital stay, ICU stay, and days of intubation. Efforts are needed to identify best practices for reducing the cost and improving the quality of care.

Introduction: The purpose of this study was to identify variations in perioperative care of cerebral palsy (CP) patients with scoliosis across 6 institutions and to determine if these variations are predictive of different perioperative outcomes.

Methods: Prospectively collected data from a multicenter study of scoliosis in children with CP was retrospectively analyzed. Preoperative variables included: Gross Motor Function Classification Scale (GMFCS), blood work, radiographic measurements, curve type. Intraoperative variables included: approach, type and level of fixation, estimated blood loss (EBL), and operative time. Postoperative variables included: length of stay (LOS), ICU LOS, and mechanical ventilation (MV) days. A multivariate analysis was performed to determine predictors of longer LOS, ICU LOS, and MV days.

Results: 6 institutions for a total of 174 patients (range 10-54) who underwent scoliosis surgery were included. There were no significant differences in preoperative hemoglobin, hematocrit, albumin, total protein, radiographic measurements (mean major Cobb angle: 82°), or GMFCS Level (76% Level V; 17% Level IV). One institution had significantly higher blood loss and longer MV days, ICU LOS, and LOS (Table). In the multivariate analysis, factors predicting increased LOS were EBL as a % of blood volume (Odds Ratio 3.99), patients with uncontrolled seizures (OR 4.64), and institution (OR range from 4x less likely to have LOS >median to 20.5x more likely). Predictors of an ICU stay > the median were EBL as a % of blood volume (OR 2.5) and institution (OR range from 8x less likely - 7x more likely to have a stay > the median).

Conclusion: This study shows that significant variation exists in the perioperative care of scoliosis in CP amongst major pediatric institutions. Controlling blood loss is a variable that deserves more scrutiny. Efforts to standardize intra-operative and postoperative protocols to limit variations that may compromise care and drive up cost (e.g. need for blood transfusion, days of ventilation, ICU and total hospital LOS) are clearly warranted. These variations appear to be on both sides of the value equation: cost and quality.

259. A Prospective Critical Evaluation of Step-Wise Blood Loss During Scoliosis Surgery: Proving the Obvious and Dispelling Old Myths

Matthew A. Halanski, MD; Jeffrey Cassidy; Nabil Hassan, MD

USA

Summary: In this study we demonstrate that each step in deformity surgery contributes differently to the percentages of overall blood loss. The majority of blood loss occurs during the

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instrumentation/facetectomy phase of the procedure. While greater blood loss occurs in NM patients, this appears due to the length of time spent in each of the phases of the procedure and not due to an inherent elevated blood loss rate when compared with the AIS counterparts.

Introduction: The purpose of this study was to critically evaluate blood loss during deformity surgery to identify potential targets for future blood conserving treatments.

Methods: As part of a previously reported randomized, double-blinded prospective trial comparing the use of TXA with Amicar in scoliosis surgery, we recorded the time and blood loss at set points (exposure, instrumentation/facetectomy, correction, and some cases closure) during posterior spinal fusion. Stepwise comparisons between blood loss, operative times, percentage of blood loss and operative times, and normalized blood loss rates (ml/kg/level/hr) were performed.

Results: Forty-two of the forty-seven patients enrolled in the prospective study had adequate stepwise data for review (AIS/AIS-like)-Amicar 18, TXA 16, NM 8). The differences in the percentages of time and blood loss between steps were found to be significant in the AIS cohort. No significant differences in time, blood loss, or normalized blood loss rates were found between the TXA and Amicar cohorts. While the NM cohort demonstrated a greater blood loss at each step, only in the exposure (384 ml vs. 198 ml) did this approach significance ($p=0.09$). The step-wise percentage of blood loss and the normalized blood loss rates between AIS and NM were similar. The only statistically significant difference between the AIS and NM cohorts was the amount of time spent during the exposure (78 min vs. 46 min) $p<0.01$, the correction (75 min vs. 57min) $p=0.04$ and the Closure (44 min vs. 24 min) $p=0.02$, these differences are likely due to the overall increased levels fused (15 vs. 9) $p<0.01$.

Conclusion: This study provides a comprehensive review of intra-operative blood loss during scoliosis surgery using contemporary techniques. It demonstrates the important relationship between step-wise operative time and blood loss in NM patients. Techniques to limit blood loss during the instrumentation/facetectomy phase and decrease the time of exposure, correction, and closure in the NM population appear the most promising to pursue in future studies.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

260. Sagittal Alignment Two Years After Selective and Nonselective Thoracic Fusion for Lenke 1C Adolescent Idiopathic Scoliosis

Paul C. Celestre, MD; Leah Y. Carreon, MD, MSc; Lawrence G. Lenke, MD; Daniel J. Sucato, MD, MS; Steven D. Glassman, MD

USA

Summary: Compared to nonselective fusion, selective thoracic fusion for Lenke 1C adolescent idiopathic scoliosis may predispose patients to increased thoracolumbar kyphosis. While it is unlikely that the risk of a small increase in thoracolumbar kyphosis will outweigh the well accepted advantages of leaving the lumbar spine unfused, this study highlights the need to study AIS patients throughout the aging process.

Introduction: Sagittal balance is a major predictor of outcomes in adults with scoliosis, but this is rarely a problem in children with AIS. In patients with Lenke 1C AIS, the impact of sagittal curve parameters after selective thoracic fusion (STF) versus fusion of both curves (non-selective thoracic fusion, NSTF) has not been well studied. Sagittal balance appears to be adequately maintained following STF for up to 20 yrs post-op. However, moderate kyphosis may not become clinically relevant until the patient loses the ability to compensate through pelvic retroversion. The purpose of this study is to compare the thoracic and thoracolumbar sagittal alignment after STF versus NSTF in Lenke 1C AIS curves.

Methods: A multi-center database of AIS patients was queried for patients with right sided Lenke 1C curves treated with posterior correction and fusion. Independent t-tests were used to compare continuous variables and Fisher's test was used to compare categorical variables between the STF (LIV at L1 or higher) and NSTF (LIV at L3 or L4) groups.

Results: 94 patients had STF and 78 had NSTF. Mean preop T5-T12 sagittal Cobb was 23.9° in the STF and 19.5° in the NSTF group ($p = 0.036$). Two years post-op, the T5-T12 sagittal Cobb was statistically significantly greater in the STF than the NSTF group, 25.2° and 20.6° respectively ($p = 0.003$). Mean preop T10-L2 sagittal Cobb was -1.3° in the STF and -1.2° in the NSTF group ($p = 0.943$). Two years post-op, the mean T10-L2 sagittal Cobb was 3.0° in the STF and -7.9° in the NSTF group ($p <0.000$). There was no significant difference in C7-S1 sagittal balance or SRS22R domain scores between the groups either pre- or post-operatively.

Conclusion: Compared to NSTF, STF for Lenke 1C AIS resulted in greater T5-T12 kyphosis and greater thoracolumbar kyphosis two years from surgery. It is unknown whether this may predispose these patients to later problems associated with sagittal imbalance as these patients eventually lose the ability

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to compensate through pelvic retroversion. While it is unlikely that the risk of a small increase in thoracolumbar kyphosis will outweigh the well accepted advantages of leaving the lumbar spine unfused, this study highlights the need to study AIS patients throughout the aging process.

261. New Optimized Braces Using Computer-Assisted Design and Modeling are Lighter and More Comfortable than Standard TLSO Braces in the Treatment of AIS

Nikita Cobetto; Carl-Éric Aubin, PhD, PEng; Frederique Desbiens-Blais; Sylvie Le May, RN, PhD; Julien Clin, PhD; Hubert Labelle, MD; Stefan Parent, MD, PhD

Canada

Summary: The objective was to demonstrate that lighter and comfortable braces optimized with a CAD/CAM and simulation technique (NewBrace) could be as efficient as a standard TLSO brace. The NewBrace average correction was similar to one obtained with the standard brace: 19° vs. 20° and 16° vs. 13° respectively for the thoracic and lumbar curve reduction. But the NewBrace was 58% thinner and had 32% less material. These first clinical results on 14 cases showed the possibility of designing more comfortable and lighter braces while ensuring biomechanical efficiency.

Introduction: Brace non-compliance and resulting ineffectiveness for the treatment of AIS are often associated to its awkwardness and discomfort resulting from pressure points, humidity and restriction of movement. The objective of this study was to demonstrate that lighter and comfortable braces optimized with CAD/CAM and simulation techniques could be as efficient as a standard TLSO designed brace using the plaster-cast method.

Methods: Fourteen AIS cases were recruited, and for each a patient-specific finite element model was built using 3D reconstruction from bi-planar radiographs and surface topography. A linked CAD/CAM software (Rodin4D) was used to simulate the scoliosis correction and the pressures exerted on the torso, as well as to design the braces (NewBrace). All brace material located at more than 6 mm from the patient's skin was removed. A second TLSO (SDTBrace) was constructed for each patient using a plaster-cast method. X-Rays were used to evaluate both braces' effectiveness (immediate effect). A pressure mat was inserted under both tighten braces to measure pressures applied. Further, each patient filled a questionnaire on comfort comparing both braces.

Results: The NewBrace correction was similar to one obtained with the SDTBrace (average curve reduction: 19° vs. 20° (thoracic Cobb) and 16° vs. 13° (lumbar Cobb)). However, the NewBrace was 58 % thinner and had 32 % less material than the SDTbrace. Pressures applied by both braces were equivalent (±20%). The NewBrace was considered more or equally comfortable than the SDTBrace for all patients.

Conclusion: This pilot study confirmed that braces could be comfortable and lighter when designed using CAD/CAM and optimization techniques while ensuring biomechanical efficiency. This comparative study provides the basis for a randomized controlled trial using this new brace design method with the ultimate goal of improving brace effectiveness and patient's compliance to treatment.

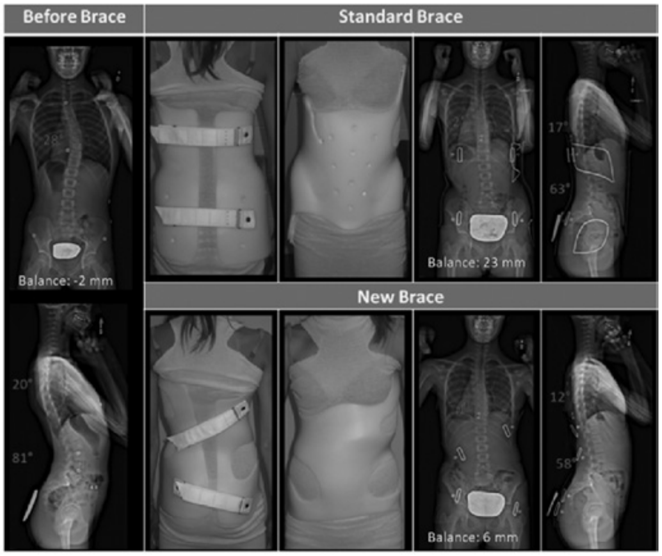

Fig.1. Radiographic results for a patient before bracing (Initial), with the STDBrace and with the NewBrace and the resulting spinal shape in the postero-antorior and lateral views

262. Blood Loss Reduced During Surgical Correction of AIS with an Ultrasonic Bone Scalpel

Carrie E. Bartley, MA; Tracey Bastrom, MA; Peter O. Newton, MD

USA

Summary: Using an ultrasonic bone scalpel to perform facetectomies and Ponte osteotomies when surgically treating AIS resulted in significantly less EBL than cuts made with standard osteotomes and rongeurs.

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Introduction: Recently an ultrasonic powered bone cutting device has come onto the market with approval for use in the spine. The unit efficiently cuts bone, but spares soft tissues. We began using this device and perceived a reduction in bone bleeding associated with cut boney surfaces. The purpose of this study was to evaluate the blood loss in adolescent idiopathic scoliosis (AIS) cases with and without the use of the bone scalpel.

Methods: The first 20 patients of a single surgeon with AIS who underwent posterior spinal fusion utilizing the bone scalpel were compared to control groups consisting of both the 20 most recent prior cases of the same surgeon before beginning use of the bone scalpel, and 20 cases of the same surgeon prior to using the bone scalpel matched based on Cobb angle magnitudes. Both the cases and the controls had Ponte releases and none had an anterior procedure. Patient demographic and surgical data were analyzed utilizing ANOVA (p<0.05).

Results: Preoperatively, the bone scalpel group was similar to both control groups in terms of primary and secondary curve magnitudes, the number of levels fused, the number of levels released, antifibrinolytic use, and patient age at time of surgery (p>0.05). The Bone Scalpel group had significantly less EBL (550 ± 359cc) than both the most recent controls (799 ± 376cc, p=0.039) and the matched Cobb controls (886 ± 383cc, p=0.007). Similarly, Cell Saver blood transfused was less for the Bone Scalpel group (94 ± 146cc) than each of the control groups (most recent: 184 ± 122cc, p=0.042; Cobb matched: 198 ± 115cc, p=0.017). The bone scalpel group had an average EBL of 48 ± 30cc for every level fused, whereas the most recent control group had an EBL of 72 ± 28cc per level fused (p=0.01), and the Cobb matched controls had and EBL of 78 ± 30cc per level fused (p=0.003). The surgical times were equivalent and there were no dural tears in any group.

Conclusion: The use of an ultrasonic bone scalpel to perform the bone cuts associated with facetectomies (both inferior and superior articular processes) results in significantly less bleeding compared to cuts made with standard osteotomes and rongeurs. The cut surfaces of the bone were “sealed” limiting overall blood loss by 30-40%.

263. Identification of Risk Factors Predicting Treatment Failure and Complications in Adult Scoliosis Surgery

Heiko Koller, MD; Oliver Meier, MD; Juliane Zenner, MD; Michael Mayer, MD; Wolfgang Hitzl, PhD, MSc

Germany

Summary: Analysis of correction and failures in a consecutive series of >400 adult scoliosis (AS) patients identified significant risk factors. Multiple stepwise regression analyses revealed that non-union was elevated in patients with smaller postop LL (p=.02), greater postop SVA (p<.001) and increased BMI (p<.001). Curve correction was improved by higher screw density (p<.05 for TC: r=-0.6 and LC:r=-0.7) and outcome by avoidance of revision surgery and better curve correction in coronal and sagittal plane (p<.05, COMI, ODI, SF36-PCS:r=-0.41 to r=-0.66).

Introduction: Delineation of risk factors in AS surgery is important to improve patient care. Hence, based on a large single center series the aim of this study was to determine risk factors that allow better prediction of correction,complications and outcomes.

Methods: Clinical and radiographic assessment of 448 adult pts who had primary AS surgery. Mean ASA score was 2.1, pts’ age 51yrs, BMI 26, f/u 40 months. 13% had Lenke Type A modifier, 21% Type B, 66% Type C. 153 pts (34%) had fusion to S1; 25% had ALIF, 32% had anterior release. Mean PSF levels were 8, screw density was 73%.Predictive parameters for complication, e.g. adjacent segment disease (ASD), were elaborated using stepwise multiple regression analyses.

Results: Preop thoracic curve (TC) was 53°, f/u 33°. Correction (38%) was influenced by preop TC (r=.9) and flexibility (r=.8), but not by screw density. Lumbar curve (LC) preop was 43°, f/u 24°. Correction (50%) was influenced by preop LC (r=.8), flexibility (r=.8) and screw density (r=-.7). Pts w/ anterior release had sign. improved LC correction (p<.01). Preop SVA was 2.9cm±3.9, f/u 3.3cm±4.2. Preop PJK was 5°±10, f/u 9°±11, PJK was not a risk factor for revision. Preop LL was 45°±19, f/u 46°±17. 20% had a non-union (18% at L5-S1), 4% infections, 3% ASD. 32% had revision surgery. 7% had a periop surgical complication, ALIFs did not increase this rate (p=.9). Risk factors for revision were fusion to S1 (p<.001), higher age (p=.02), BMI (p=.03), postop SVA (p<.001) and postop sagittal distal segment tilt>10° (p=.006). The risk for non-union L5-S1 was elevated w/ increased age (p=.04), lower screw density (p=.03) and postop sagittal imbalance (T9-inclination (p=.01), SVA (p=.01), LL (p=.01) and PI-LL mismatch (p=.01). Outcomes (ODI:18%, COMI:5, SF36-PCS:39, SF36-MCS:45) negatively correlated (p<.05) w/ revision (SF-36-MCS), ASD (SF36-PCS,SF36-MCS), periop surgical compl (SF36-

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MCS), age (COMI,ODI), postop correction of TC and LC (COMI,ODI,SF36-PCS), sagittal and coronal imbalance at f/u: SVA, PT and SVA (COMI,ODI SF-36 PCS).

Conclusion: Correction was influenced by higher screw density, outcome was dependent on surgical correction indicating that the dimension of curve correction in sagittal and coronal plane plays a significant role in AS pts.

264. Interbody Fusion and Adult Deformity: Are the Benefits Worth the Risks?

Michael S. Chang, MD; Yu-Hui Chang, PhD; Jan Revella, RN; Dennis Crandall, MD

USA

Summary: 127 patients undergoing adult scoliosis correction with 2 year f/u were examined. 35 patients received anterior-posterior surgery with interbody cages. 48 patients underwent posterior spinal fusion with multiple TLIFs to assist in deformity correction. 44 patients underwent posterior spinal fusion alone. All groups had similar and substantial improvement in clinical and radiographic outcome measures. PSF alone had lower complication rates and better sagittal balance compared with either interbody-assisted correction group.

Introduction: Interbody fusions via an anterior, lateral, or transforaminal (TLIF) approach have often been advocated in deformity surgery to improve curve correction and obtain better clinical results. However, the actual clinical benefit of interbody use to assist with deformity correction in the adult population relative to posterior spinal fusion alone is uncertain.

Methods: 127 consecutive adult patients with minimum 2 year follow-up (f/u) underwent spinal deformity correction via anterior-posterior approach with anterior interbody cages (group A, n=35), posterior spinal fusion with TLIFs (T, n=48), or posterior-only without interbodies (P, n=44). Diagnoses were adult idiopathic scoliosis (n=60) or degenerative scoliosis (n=67). Outcomes were obtained prospectively by visual-analog pain scale (VAS) and Oswestry Disability Index (ODI) at pre-op, 1 year, 2 year, and latest f/u. Radiographs included PA and lateral scoliosis films.

Results: There was no difference in curve correction (A:66.8%, T:65.5%, P:61.4%, p=0.405) at 2 years post-op. There were also no significant differences between the groups in regards to lumbar lordosis, thoracic kyphosis, and coronal balance at 2 years. Sagittal balance was significantly better in the PSF group compared with the 2 interbody groups (A:4.3, T:1.9, P:0.8, p=0.023), but all were within acceptable limits. Improvement in VAS and ODI scores at 2 years was similar between all groups and highly significant compared with pre-op (p<0.0001). Complications were greatest in the A/PSF group and lowest in the PSF group and included revision surgery (A:7[20.0%], T:10[20.8%], P:5[11.4%]), non-union (A:4[11.4%], T:4[11.1%], P:0[0%]), adjacent level disease (A:13[37.1%], T:15[31.3%], P:16[36.4%]), infection (A:2[5.8%], T:6[4.7%], P:0[0%]), and imbalance (A:8[22.9%], T:8[16.7%], P:3[6.8%]). Medical complications included 1 stroke and 1 death in A/PSF, 1 pulmonary failure in TLIF, and 1 MI in PSF.

Conclusion: Compared with either A/PSF or TLIF-assisted correction, posterior spinal fusion alone achieves similar radiographic and clinical outcomes at 2 years in adult scoliosis patients while enjoying a lower rate of complications and revision.

265. Short-Term Mortality and Morbidity After Surgical Treatment of Fixed Spinal Deformities: Two-Year Experience in 102 Adult Patients

Benny Dahl, MD, PhD, DMSci; Tanvir Bari; Sven Karstensen; Sidsel S. Fruergaard; Martin Gehrchen, MD, PhD

Denmark

Summary: In a one-center prospective study the short-term mortality after surgical treatment of fixed spinal deformities was 1.2 % and permanent motor deficit was seen in two patients. This confirms that posterior osteotomy carries an acceptable level of short-term mortality and morbidity in a high-volume center.

Introduction: During the last decade increasing evidence suggests that improved sagittal balance is of major importance to obtain improved health related quality of life in the surgical treatment of adult spinal deformities. In patients with fixed deformities, the two primary surgical techniques used are pedicle subtraction osteotomy (PSO) and vertebral columna resection (VCR). Due to the surgical demands of these techniques, assessment of mortality and morbidity associated with these procedures is of relevance.

Methods: In a prospective cohort study, all complications in adult patients (> 17 years of age) undergoing posterior correction of fixed spinal deformities in the thoracolumbar region from February 1st 2010 through January 31st 2012 were included. Patients were excluded if they had undergone previous posterior instrumentation on more than five levels for a degenerative condition. Also, patients with previous malignant, infectious or traumatic conditions of the spine were excluded

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. All relevant information regarding surgical procedure and perioperative complications were registered, and the neurologic condition was assessed at the one-year follow-up. Intraoperative neuromonitoring was used in all cases. Survival status was obtained through the National Health Service. The study was approved by the National Data Protection Agency.

Results: A total of 102 patients were operated with a mean age of 61 at the time of surgery (range 19 - 86). 52 were men and 50 women. A median number of 10 levels were instrumented with pedicle screws (range 5 - 17). 81 % of the patients underwent PSO and 19% VCR. The 30-day mortality was 1.2% and the primary complication was dura lesion (16%). Two patients (2 %) had permanent neurological deficit corresponding to 1 ASIA motor grade deterioration and four patients (4 %) patients had persisting sensory deficits.

Conclusion: This prospective one-center study confirms recent national database reports suggesting that surgical treatment of fixed spinal deformities carries a relatively low risk of short-term mortality and severe neurological complications.

266. Cervical Spine Alignment After Lumbar Pedicle Subtraction Osteotomy (PSO) for Sagittal Imbalance

Ibrahim Obeid; Anouar Bourghli, MD; Jean M. Vital; Olivier Gille; Vincent Pointillart, MD, PhD; Virginie Lafage, PhD

USA

Summary: Cervical spine alignment varies significantly after lumbar pedicle subtraction osteotomy for major sagittal spine deformities. Distal cervical spine lordosis and C7 slope decrease significantly; proximal cervical spine lordosis and occipito C2 angle increase slightly after correction.

Global position of the head toward C7 evaluated by the external auditory meatus tilt seems to be very close to the vertical axis and still unchanged.

Introduction: The position of the cervical spine is of primary importance to obtain an horizontal gaze and contribute to the functional outcome. Cervical spine alignment after correction of major sagittal imbalance has been rarely analyzed

Methods: Retrospective review of 31 consecutive patients with severe sagittal plane deformities operated by lumbar PSO. Etiologies were degenerative (n=12), posttraumatic (n=4) and iatrogenic (n=15). Pre and 3 months post-operative EOS radiographies were analyzed for general spino-pelvic parameters as well as the following cervical specific parameters: Occipito C2 angle (angle between Mc Gregor line and inferior endplate of C2), Global cervical lordosis (CL), Proximal CL (C1 to C2 inferior endplate), Distal CL (C2 superior endplate to C7 superior endplate of C7), C7 slope angle, and External Auditory Meatus (EAM) Tilt (angle the vertical and the line joining the center of C7 and EAM)

Results: As expected, there was a significant increase in Lumbar lordosis (LL), pelvic tilt (PT), and sagittal vertical axis (SVA). There was also a significant increase in thoracic kyphosis. The analysis of cervical region revealed that there was no significant difference between pre- and post-operative Global cervical lordosis angle and EAM tilt. There was a significant decrease of 'C7 slope', 'Distal cervical lordosis'; and a significant increase in proximal cervical lordosis and occipito C2 angle

Conclusion: LL restoration decreases the need of compensation at the pelvis and thoracic spine. The distal CL and C7 tilt decrease because there's no need for compensation at this level after the surgery but the proximal cervical spine take a slightly flexed position to maintain horizontal sight. The tilt of EAM is a global parameter of the head position toward C7. The value of this angle is close to 0° even in severe cases. The changes of this parameter after surgery are very small and not significant. This is probably due to the balance between upper and lower cervical segments when one of these segments go backward the second go forward and the result is a balanced head over C7. Global position of the head toward C7 evaluated by EAM tilt seems to be very close to the vertical axis and still unchanged

Figure 1

Pre and Postoperative measurement of cervical parameters. EAM tilt remains close to 0°, upper and distal cervical curvature changes are significant

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267. Is There a Better Derotation Manoeuvre in Posterior Correction of Thoracic Adolescent Idiopathic Scoliosis?

Mario Di Silvestre, MD; Francesco Lolli; Francesco Vommaro; Massimo Balsano, MD; Konstantinos Martikos, MD; Tiziana Greggi

Italy

Summary: Retrospective review of 62 consecutive patients affected by AIS (Lenke type 1 or 2) treated by posterior fusion with pedicle screw-only instrumentation. Three groups identified: Pre-Rod (direct derotation procedure done before inserting rods), Single-Rod (derotation done after concave rod insertion) Double-Rod (after both rods). The Pre-Rods insertion cases showed a significantly better final correction of apical vertebral rotation (61.9% vs 55.8% and 50.1%) and a greater final correction of main thoracic curve.

Introduction: Different manoeuvres can be adopted for direct derotation in posterior correction of thoracic adolescent idiopathic scoliosis (AIS). Aim of the study is to evaluate the better manoeuvre in AIS posterior surgery

Methods: 62 consecutive patients affected by AIS (Lenke type 1 or 2), were treated by posterior fusion with pedicle screw-only instrumentation, between 2007 and 2009 at one single institution. Three groups were identified: a Pre-Rod group with the direct derotation procedure done before inserting rods (Pre-R group; n=22 patients), a Single-Rod group with the derotation done after concave rod insertion (Single R group; n=20) and a Double-Rod. group after both rods inserted (Double R group; n=20). There were no statistical differences in the 3 groups, in terms of age, Risser's sign, curve patterns, Cobb main thoracic (MT) curve magnitude and flexibility, extension of fusion, sagittal pre-operative contour and rotation angle (RAsag) of the apical vertebra, measured with axial CT on pre-op and last follow-up control.

Results: (Average FU 3.6 years, range 2.8 to 4.6). The Pre-Rods insertion cases showed a significantly better final correction of apical vertebral rotation (Pre-R 61.9% Single-R 55.8% Double-R 50.1%; p<0.05) and a greater final correction of MT curve (63.4% vs 61.1% and 59.1%; ns) with similar maintenance of initial correction (-1.71° vs -1.78° and -1.73; ns).

The T5-T12 kyphosis angle was similar before surgery (Pre-R 16.9° vs Single-R 17.5° and Double-R 17.2°): it was reduced at final follow-up in Single-R and Double-R cases in comparison with Pre-R patients that presented instead a little increase (19.8° vs 12.5° and 13.5°;ns). Lumbar lordosis was similar before surgery (-42.9° vs -41° and -42.1°) and at final follow-up (-45.1° vs -44.9° and -43.2°; ns). At the latest follow-up, SRS-30 and SF-36 findings were similar between the three groups.

Conclusion: The direct derotation procedure resulted more effective both concerning correction of apical vertebral rotation and magnitude of MT curve, when applied to the spine before both rods insertion. The hypokyphotic effect of derotation procedure, registered in Single-R and Double-R groups, was avoided doing derotation before rods insertion.

268. Does Size Matter? Comparison of 6.35 mm Versus 5.5 mm Diameter Rods for Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis

Joshua M. Pahys, MD; Patrick J. Cahill, MD; Jahangir Asghar, MD; Randal R. Betz, MD; Harms Study Group; Amer F. Samdani, MD

USA

Summary: In a large dataset (n=956) of AIS patients, BMI and coronal/sagittal pre-op curves were higher in patients undergoing PSF using 6.35 mm vs. 5.5 mm diameter rods (p=0.02). Choice of rod diameter was surgeon specific with 91% of 6.35 patients from 3/13 sites (p<0.001). However, in a matched cohort, there was no difference in curve correction, maintenance of correction, sagittal/coronal radiographic measurements, SRS scores, or complication rates for 6.35 mm vs. 5.5 mm diameter rods in PSF for AIS at 2 years post-op.

Introduction: Varying rod diameters are available and commonly used in AIS. However, there exists little evidence to guide their use. We evaluate the indications, efficacy, and stability of a larger (6.35 mm) vs. a smaller (5.5 mm) diameter rod for PSF in AIS.

Methods: A multicenter, prospectively collected database was evaluated to identify all patients with AIS (n=956) who underwent a PSF using either 6.35 mm or 5.5 mm rods with a minimum two year follow-up. The entire dataset was evaluated as well as a matched cohort, which was subsequently developed to directly pair patients with 6.35 vs. 5.5 rods to assess outcomes with rod diameter as the only variable. Patients were directly matched for body mass index (BMI), age, gender, curve type/magnitude, curve flexibility, levels fused, rod composition, and type/density of fixation points. A total of 39 6.35 mm patients were directly matched to 39 5.5 mm patients, with no significant differences between the two groups with regards to the aforementioned parameters.

Results: Analysis of the entire dataset (n=956), revealed that the BMI was higher in the 6.35 vs. 5.5 group (22.8 vs. 21.1 kg/

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m2, p=0.02). Pre-op Cobb angles were larger for the 6.35 group in both the coronal (59.1° vs. 55.9°, p=0.02) and sagittal (26.4° vs. 22.8°, p=0.02) planes. Surgeon preference was significant (p<0.001), with 91% of the 6.35 patients coming from 3/13 sites, while 6/13 sites had no 6.35 patients. In the matched cohort (n=78), there were no significant differences between both groups with regards to curve correction nor all coronal and sagittal radiographic measurements at initial and 2 years post-op. Complication rates and SRS outcome scores at initial and 2 years post-op were also similar between both groups (p=0.9).

Conclusion: In a closely matched cohort that included BMI as a matched parameter, there were no differences in postoperative radiographic and clinical outcomes, or complications at initial and 2 year follow-up for PSF with 6.35 vs. 5.5 mm diameter rods for AIS. Further, there was no loss of correction or significant change in sagittal/coronal radiographic parameters from initial to 2 years post-op.

269. The Adherence to Lenke Rules in Idiopathic Scoliosis: Are We Treating Adults Differently from Adolescents?

Francisco J. S. Pérez-Grueso, MD; Mar Perez Martin-Buitrago; Ferran Pellise, MD; Montse Domingo-Sàbat; Ahmet Alanay, MD; Emre Acaroglu, MD; José Miguel Sánchez Márquez, MD; European Spine Study Group

Spain

Summary: There are no clear guidelines regarding surgical strategy to be followed in Adult Scoliosis without degeneration.

Objective: evaluate the adherence to Lenke's classification in AS without degeneration compared to AIS.

Guidelines were not adhered to in 38% of AS and in 44% of AIS. Lenke1 curves had the highest proportion of rule breakers in both groups. Upper thoracic region and selection of upper fusion levels were the most frequent reasons for rule breaking in both groups.

Introduction: The introduction of Lenke classification has led to a reduction in the variation of treatment approaches in adolescent idiopathic scoliosis (AIS). Young adult idiopathic scoliosis (AS) on the other hand, may be considered as a different entity. There are no clear guidelines regarding the surgical strategy to be followed in AS.

Objective: To evaluate the adherence to the Lenke classification in the fusion level selection in AS without degenerative changes. To compare these results with those of AIS.

Methods: Two groups were defined. 1)Adults: Patients included in a consecutive prospective multicenter adult deformity database accomplishing these inclusion criteria: age 18-40, idiopathic scoliosis, no major radiological degenerative changes. 2)Adolescents: Matched number of AIS patients treated by the same surgeons during the same period.

An independent observer classified all curves by Lenke's guidelines and identified "Rule-breakers" using postop x-rays. Statistical analysis was done with Fisher's test.

Results: Forty AS patients (av age 26yr, 18-36) met the inclusion criteria and 41 matching AIS patients (av age 14.5yr, 12-17) were identified from our database. Lenke1 curves were predominant in both samples (Table 1). Guidelines were not adhered to in 38% of AS and in 44% of AIS (p>0,05). Lenke1 curves had the highest proportion of rule breakers in both groups (52% AIS vs 61% AS). The upper thoracic region and the selection of upper fusion levels were the most frequent reasons for rule breaking in both groups followed by curves with lumbar modifiers B and C in which the lumbar curves were fused. There were three patients in AS group and two in the AIS where the rules were broken with shorter fusions.

Conclusion: Conclusions: The adherence to Lenke classification in young adults appears to be similar to adolescents although the adherence in this group was less than previously reported. Upper thoracic spine turned out to be the most controversial region in the fusion level selection process for which deviations from guidelines resulted in longer fusions.

Type	AIS	AS
Lenke1	18	16
Lenke2	10	4
Lenke3	3	5
Lenke4	0	1
Lenke5	8	8
Lenke6	2	6
TOTAL	**41**	**40**

270. Safety of Surgical Treatment for Scoliotic Patients with Surgically Corrected Congenital Cardiac Malformations: A Retrospective Case Control Study

Jinqian Liang; Jianxiong Shen; Zheng Li

China

Summary: This retrospective case-cntrol study was undertaken to investigate the postoperative complications in unselected scoliotic patients with surgically corrected congenital cardiac

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malformations and to identify whether spinal fusion is safe in this population.

Introduction: It is reported that the prevalence of scoliosis in children is approximately 2% to 3%. However, among children with congenital heart disease (CHD), scoliosis is much more common.Over the last two decades, advances in the fields of paediatric cardiology and paediatric cardiac surgery have led to an increase in the rates of survival of these patients,creating at the same time a subset of patients which will require spinal surgery for the correction of their spinal deformity. However, there is limited published data about the safety and efficacy of spinal fusion in children with surgically corrected congenital cardiac malformations.

Methods: A retrospective study was conducted on 42 SCCCM patients who underwent spine surgery for spinal deformity. Eighty-four age-, gender- and diagnosis-matched scoliotic patients who received spinal fusion served as the control group.

Results: The age and preoperative curve magnitude of SCCCM patients (mean, 66.8°±23.0°) were similar to that of the scoliotic patients in the control group. (mean, 60.3°±12.9°). Overall, 3 SCCCM patients (7.1%) and 4 scoliotic patients in the control group (4.8%) had postoperative complications during hospitalization. No significant differences were observed between the two groups in the incidence rate of postoperative complications (P>0.05). In the SCCCM patients, neither the preoperative minor abnormal echocardiogram abnormality nor the extent of curve magnitude correlated with the surgical outcomes, whereas a shorter surgical interval was found to be predictive for the postoperative complications.

Conclusion: Surgical treatment is effective and safe in preventing curve progression for the SCCCM patients. The postoperative complications are comparable to those are observed in scoliotic patients in the control group. A shorter surgical interval may be a risk factor in predicting postoperative complications in SCCCM patients.

271. Should Cerebral Palsy Patients Undergo Scoliosis Deformity Correction in the Winter Months?

Burt Yaszay, MD; Paul D. Sponseller, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Firoz Miyanji, MD, FRCSC; Jahangir Asghar, MD; Peter O. Newton, MD; Harms Study Group

USA

Summary: Due to their comorbidities, scoliosis surgery in CP patients is typically associated with greater complications. This may influence some surgeons to perform these surgeries outside the winter months to reduce respiratory risk. Our study suggests that CP scoliosis surgery can safely be performed during the winter. While one-third of our polled surgeons subjectively attempt to avoid winter surgery in patients with frequent respiratory hospitalization, this does not appear to be consistently applied.

Introduction: The comorbidities that exist with cerebral palsy (CP) patients can present management challenges when planning surgical correction of spinal deformities; specifically the timing of the intervention may be influenced to reduce the risk of pulmonary complications. This study sought to determine if surgical correction of scoliosis in CP is avoided or is associated with increased complications during the winter months when there is potential for increased respiratory risk.

Methods: Prospectively collected cases from a multi-center database were reviewed. Preoperative, peri-operative, and complication data were included. Patients were divided into those having surgery during winter months (Dec-Mar) or non-winter months (Apr-Nov). Additionally, 16 experienced surgeons were polled on whether they are more or less likely to operate during winter months and what factors contribute to this decision.

Results: There were 177 patients identified, 56 in winter and 121 in non-winter months. There were no differences in the number of winter vs non-winter cases based on curve type, surgical approach, or feeding status (p>0.05). There was a significantly smaller proportion of patients with poorly controlled seizures (7%) operated on during winter (p=0.03) than non-winter months (20%). There were no differences in intubation duration, length of ICU and hospital stay, pneumonia, or infection rate (p>0.05). There were significantly more medical (non-infection) complications during non-winter months (p=0.003). The surgeon poll showed that 50% of the surgeons did not use season as a criteria for determining when to operate. Six (38%) of the surgeons preferred to operate in non-winter months on a select group of patients with frequent hospitalizations for respiratory infections. Other factors included OR availability and the patient's overall health at the preop appointment.

Conclusion: It does not appear necessary to actively avoid CP scoliosis surgery during winter months that have a higher risk for respiratory infections. Some surgeons do use subjective reasons (e.g. frequent respiratory infections) to avoid winter months, but this is not consistently applied. It remains reasonable to assess each CP patients individually for their risk.

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272. VEPTR (Vertical Expandable Prosthetic Titantium Ribs) Promotes Spinal Growth in Instrumented Segments: A 3D Radiographic Analysis

Carol C. Hasler, MD; Marcelo De Oliveira, PhD(c); Philippe Buechler, PhD; Amélie Burckhardt

Switzerland

Summary: Though simplistic by nature, T1-S1 distance is the most common parameter to objectify the growth promoting effect of telescopic spinal implants. In this study a new software for 3D assessment of spinal length offered a novel approach to prove growth stimulation in a cohort of 26 patients treated with VEPTR.

Introduction: The growth promoting effect of repeat expansions of VEPTR implants in children with early onset scoliosis has so far only been examined by simple measurement of the global T1-S1 distance and by a single CT study investigating the elongation of osseous spinal bars in patients with congenital deformities. The latter was performed at the institute of the VEPTR inventor. We therefore tested the hypothesis that VEPTR promotes spinal growth.

Methods: A new software was developed which allows to compute the length of the spine in space based on a digitized measurements on an ap and lateral standard radiograph. Since magnification factors are not consistent and the computation of absolute lengths may lead to errors, we compared the relation R (I/NI) between the lengths of the instrumented (I) and non instrumented (NI) parts of the spine. Untreated, the sick segments of the spine would grow less than the normal vertebrae. We therefore hpyothetized that VEPTR promotes growth if the relation R would not change significantly over time. We included 26 early onset scoliosis patients (14 congenital, 10 neuromuscular, 1 idiopathic, 1 secondary) treated at our institution with an observation period of 4 years. The relative lengths after the index procedure R1 and after 4 years R2 were statistically evaluated by paired-sample-t-tests (SPSS Vers.12, significance level p<0.05) by an independent statistician.

Results: Repetitive measurements of the same radiographs at different time points showed a high reliability (coefficient of variation of <0.03%)

There was no significant change in the relation of lengths between the instrumented and non instrumented parts of the spine over time.

Conclusion: A new software and methodology provides reliable assessment of the growth stimulating effects of spinal implants in children with early onset deformities.

VEPTR instrumentation and repeat halfyearly expansions of the telescopic mechanism promotes growth of the affected, instrumented spine segments. Subsequently the resulting, stimulated growth does not significantly differ from the growth in the normal, unaffected segments as it would naturally without treatment.

274. Outcomes in Surgery for Adolescent Idiopathic Scoliosis: Drivers of Satisfaction and Durability of Results

Ian G. Dorward, MD; Keith H. Bridwell, MD; Lawrence G. Lenke, MD; Brian J. Neuman, MD; Kevin R. O'Neill, MD, MS; Terrence F. Holekamp, MD, PhD; Azeem Ahmad, BA, BS; Christine Baldus, RN, MHS

USA

Summary: We analyzed the SRS scores and radiographs of 186 patients undergoing surgery for adolescent idiopathic scoliosis (AIS) from 2003-2009 at a single institution. At 2 yr and 5 yr f/u, appearance correlated most strongly with satisfaction. Radiographic variables showed only weak negative correlations with satisfaction. SRS-30 scores did not decline in any domain between 2 and 5 yr follow-up (f/u).

Introduction: Prior work has shown that SRS-30 pain scores worsen between 2 and 5 yr f/u for AIS pts. Meanwhile, patient satisfaction is increasingly considered as vital for outcomes, and thus satisfaction may be the most important domain of the SRS-30. It is unknown what other domains correlate most strongly with--and may thereby act as drivers for--satisfaction.

Methods: We reviewed SRS-30 scores and radiographs of 186 consecutive adolescents undergoing surgery for AIS from 2003-2009 at a single institution, with minimum 2 yr f/u. 57 pts also had 5 yr f/u. Pearson correlations were calculated for the satisfaction domain and the other SRS-30 domains, as well as for the satisfaction domain and various radiographic variables.

Results: SRS-30 scores improved significantly in every domain from preop to 2 and 5 yr f/u; satisfaction and appearance had the greatest absolute change (2 yrs: satisfaction mean improvement + 0.86, appearance + 0.98; 5 yrs: satisfaction + 0.78, appearance + 0.90). No significant decrease was noted in any SRS-30 domain between the 2 and 5 yr time points. At 2 yrs, appearance correlated more strongly with satisfaction (r = 0.53, P<0.0001) than did activity (r = 0.36, P<0.0001), mental health (r = 0.25, P=0.0006), or pain (r = 0.21, P=0.0039). At 5 yrs as well, appearance had a stronger correlation with satisfaction (r = 0.46, P=0.0003) than did the other domains, for which significant correlations were not established (Pain: r = 0.26,

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P=0.053; mental health: r = 0.22, P=0.11; activity: r = 0.037, P=0.79). Radiographic variables showed only weak negative correlations with satisfaction at 2 year f/u (MT Cobb: r = -0.18, P=0.029; TL/L Cobb: r = -0.16, P=0.059; coronal balance: r = -0.22, P=0.0092).

Conclusion: Appearance correlated most strongly with patient satisfaction at 2 yrs and 5 yrs postop, while radiographic corrections were not strongly correlated with satisfaction. These findings suggest that it is the patient's perception of appearance—not the radiographic curve correction—that drives satisfaction. Contrary to prior work showing a decrement in pain scores between 2 and 5 yrs, the SRS-30 scores in these patients showed durable improvements in all domains.

275. Spinal Deformity Progression after Modern Segmental Instrumentation and Fusion: Is this Crankshaft?

Vidyadhar Upasani; Michael Glotzbecker, MD; Daniel J. Hedequist, MD; Michael T. Hresko, MD; Lawrence Karlin, MD; John B. Emans, MD

Summary: Although modern posterior segmental instrumentation provides three-column fixation, deformity progression can occur in immature patients with remaining growth potential.

Introduction: The purpose of this study was to assess for spinal deformity progression after modern segmental instrumentation and fusion in the treatment of idiopathic scoliosis, and to analyze variables associated with progression after fusion.

Methods: Retrospective review of a consecutive series of idiopathic scoliosis patients with major thoracic curves

(Lenke 1-4) treated with modern segmental instrumentation (primarily pedicle screws) and fusion with minimum 2 year follow-up from a single institution. Deformity progression was defined as a 10 degree increase in Cobb angle between the first erect (4-6 week post-operative) and 2-year post-operative radiographs. Clinical and radiographic data between the two cohorts (deformity progression vs control) were analyzed to determine the variables associated with deformity progression.

Results: Eighty-one patients were in the control cohort (14M/67F; pre-op Cobb: 58.9°) and 16 patients were in the deformity progression cohort (3M/13F; pre-op Cobb: 55.3°). The patients in the deformity progression group had a significantly greater increase in Cobb (14.5°±4.5° vs 4.0°±2.5°; p<0.001), upper (7.2°±4.6° vs 4.2°±3.8°; p=0.009) and lower (6.8°±4.4° vs 3.8°±2.6°; p=0.004) instrumented vertebral angulation, and apical vertebral translation

(11.2mm±10.7mm vs 4.3mm±9.3mm; p=0.044) at 2 years post-op. SRS-22 scores in the appearance domain were also significantly worse in the deformity progression group (4.04±0.65 vs 4.42±0.51; p<0.001). There was a significant association between deformity progression and change in height between the one- and two-year postoperative periods (3.1cm±2.7cm vs 0.9cm±2.9cm; p=0.007). There was a trend towards younger patients in the deformity progression group (12.9±2.8 years vs 14.2±2.1 years; p=0.073); however Risser grade and state of the triradiate cartilage were not significantly different between the two groups.

Conclusion: Deformity progression either due to crankshaft or distal adding-on does occur with modern segmental instrumentation. Although no patients required revision surgery for deformity progression, patient determined measures in the SRS-22 appearance domain were significantly affected.

276. Correction of Sagittal Imbalance in Adult Deformity Patients with Smith-Petersen Osteotomy Combined with Transforaminal Interbody Fusion (SPO+TLIF)

Farbod Khaki; Robert A. Hart, MD

USA

Summary: We evaluated adult spinal deformity patients undergoing surgical treatment including SPO+TLIF for sagittal imbalance at minimum 2-year follow-up. Focal correction averaged 14.3° per level of SPO+TLIF at 2-year follow-up. Total increase in lumbar lordosis (LL) averaged 18.4° at 2-year follow-up. SPO+TLIF can effectively increase focal lordosis and total LL.

Introduction: Including bilateral facet resection, or Smith-Peterson Osteotomy (SPO) in combination with Transforaminal Interbody Fusion (SPO+TLIF) has been described as a means of increasing lordosis in patients with degenerative lumbar conditions (Figure 1). We are unaware of any reports describing SPO+TLIF as a technique to increase LL in adult deformity patients with sagittal imbalance.

Methods: Retrospective review at minimum 2-year follow-up of patients undergoing SPO+TLIF from 2005 to 2009. Radiographic measurements included focal correction (at SPO+TLIF level), pre- and post-op LL (T12-S1), and pelvic incidence minus LL (PI–LL).

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Results: 16 patients (11F:5M) age 61.5±13.1 years underwent 18 SPO+TLIFs. 8 patients had scoliosis, 7 flatback syndrome, and 2 post-traumatic kyphosis. 14 patients were revision surgeries and 2 were primary. Number of posterior levels fused averaged 5.7±2.7 (range 1-9); 5 patients had combined anterior procedures. Focal correction averaged 14.3°±6.9 per level of SPO+TLIF at 2-year follow-up (range 5.5-31.8). Total increase in LL averaged 18.4°±15.2 at 2-year follow-up (range −2.5-61.6). Pre-op PI−LL averaged 27.7°±13.7 and 10.5°±17.1 at 2-year follow-up. 13 complications occurred in 8 of 16 patients (50%) including 2 cases of transient neurologic deficit, 2 cases of proximal junctional failure, and 1 deep wound infection.

Conclusion: SPO+TLIF can effectively increase focal and total LL in adult patients with sagittal imbalance. Although complications were common, all patients underwent extensive spinal reconstruction and no complications were directly attributable to SPO+TLIF. The SPO+TLIF technique should be considered as an option to restore lordosis in adult spinal deformity surgery.

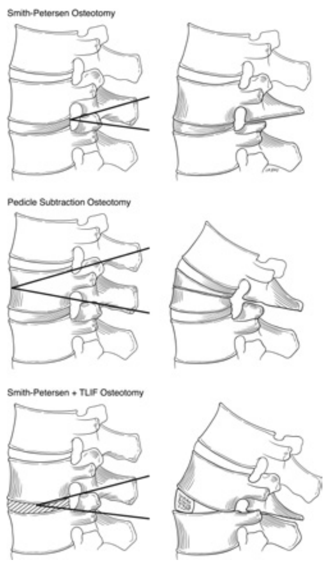

Figure 1: SPO+TLIF compared to SPO and PSO.

277. Symptomatic Operative Adolescent Idiopathic Scoliosis Patients: Can Their Increased Perception of Deformity Be Changed?

Anna M. McClung, BSN, RN; Daniel J. Sucato, MD, MS

USA

Summary: Comparison of SRS-30 outcomes between symptomatic and non-symptomatic operative AIS patients shows an increased effect of deformity across all domains in the symptomatic patients. Postoperatively symptomatic patients scores improved significantly and were comparable to non-symptomatic peers.

Introduction: There is much in the literature regarding factors that influence patient assessment of deformity in AIS as captured by SRS outcomes questionnaires. Most of these studies have focused on corollaries related to radiographic or surgical outcomes. This study endeavors to document the outcomes on the SRS-30 of symptomatic patients in comparison to non-symptomatic patients.

Methods: A retrospective review of a prospective, consecutive series of AIS patients operatively treated at a single, pediatric orthopedic institution between 2002 and 2011. Preoperative assessment includes questioning of patients their AIS is symptomatic, symptom categories are: no symptoms (NS) spinal pain (SP), physical - restricted spine motion, and shortness of breath, clinical - spine imbalance, rib prominence, lumbar prominence, and waist asymmetry (PC). Patients fill out SRS-30 questionnaires after being asked if they are symptomatic. Comparisons were made between NS, SP and PC groups with regards to SRS domains, radiographic and clinical parameters preoperatively and at 2 years.

Results: In the NS group 393 patients, SP-294, PC-125, all had similar BMI, age, gender and Lenke type distribution. Preop Major Cobb was no different (60.3 to 61.3°,p=.754); however symptomatic patients had greater kyphosis (29.1° PC, 28.8° SP vs 25.9° NS, p=.019). Preoperatively the symptomatic patients scored worse across all SRS-30 domains, especially the PC group (see table). Two year follow-up was available in NS-233, SP-177, PC-80; all groups had >50% correction of their major curve (p=.639), and similar kyphosis (31.4° to 33.7°, p=.153). The symptomatic patients had vastly improved scores across all domains and scored the same as the NS group (see table).

Conclusion: Over 50% of AIS patients were aware of negative impact by symptoms related to scoliosis; this is reflected in their SRS-30 scores in comparison to non-symptomatic patients. At 2 years postoperatively symptomatic patients showed significant improvement in all domains, and were similar to the non-symptomatic peers. Surgeons can counsel symptomatic patients that surgery will likely improve or alleviate these symptoms.

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278. The Efficacy and Complications of Posterior Surgical Correction with Transpedicular Instrumentation of Congenital Kyphosis: More than Two-Year Follow-Up

Zhang Jianguo, MD
China

Summary: Most of the congential scoliosis lead to a malignant natural history. And surgical treament of congenital kyphosis is a more challenging procedure for surgerons.Until now there were few reports on posterior surgical correction of congenital kyphosis.

Introduction: This is a retrospective study to evaluate the efficacy and complications of posterior surgical correction with transpedicular instrumentation of congenital kyphosis.

Methods: 27 patients average aged 13.3(4-31) years with congenital kyphosis were treated by posterior surgical correction with transpedicular instrumentation. The mean follow-up is 51.9(24-127) months. There were 13 cases of failure of vertebral body formation, 8 cases of failure of segmentation and 6 cases of mixed failure of formation and segmentation. 6 patients has intraspinal anomalies. Osteotomy was performed on 24 patients, including 9 cases of vertebral column resection, 6 cases of pedicle substraction osteotomy, 3cases of hemivertebra resection, 6 cases of Ponte osteotomy. 3 cases underwent posterior fusion in situ. Radiograghs, operative reports and patient charts were reviewed to record the correction and complications.

Results: The mean operation time was 4.6 (2-8)hours. The averaged blood loss was 809(100-2800)ml.The segmental kyphosis was 64.9° before surgery, 22.2° post surgery and 23.9° at the latest the follow-up. And the sagittal trunk translation(difference to normal alignment) was improved from 69.5mm to 33.5mm. Complications included 2 rod breakage due to pseud-arthrosis, 1 proximal junctional kyphosis, 1 incomplete spinal cord injury and 1 transient root injures.

Conclusion: Posterior surgical correction with transpedicular instrumentation is a safe and effective procedure for congenital kyphosis. Pseudarthrosis and implant failures occurred more in patients with posterior fusion in situ. As most of these deformities are severe and rigid, techniques of osteotomies including VCR, PSO and hemivertebra resection could provide satisfied correction. However, the surgeons should pay enough attention to the complications of these aggressive procedures.

280. Parent Perception of Appearance Influences Patient Expectations of Outcomes in the Treatment of AIS

Adriana De La Rocha, MS; Daniel J. Sucato, MD, MS; Anna M. McClung, BSN, RN; David Podeszwa, MD
USA

Summary: In the treatment of AIS with a PSF, patients' and parents' perception of appearance and expectations for deformity correction varied significantly, with parents' rating the physical deformity and appearance worse than the patients rated themselves. Pts continue to want greater expectations for deformity correction after surgery which may be the result of their parents' negative perception of their deformity. Addressing these differences pre-operatively may improve overall pt and parent satisfaction.

Introduction: Multiple shoulder and trunk deformities are associated with AIS. Few studies have reported pts' assessments of their deformity. None have compared pts' and parents perceptions of appearance and expectations of correction in a larger cohort.

Methods: Retrospective review of all patients treated with a PSF for AIS from 2002-2009 at a single institution. Pts and parents completed the Spinal Appearance Questionnaire (SAQ) to assess the pts' physical deformity at pre-op and 2 yrs post-op. The Appearance and Expectations domains of the SAQ were compared with a student t-test and $p<0.05$.

Results: 411 pts (342 F, 69 M), avg age of 14.5 yrs (10.0-20.6 yrs), were included. The group included pts with Lenke Curves: 1 (53%), 2 (24%), 3 (6%), 4 (2%); 5 (8%); 6 (7%). Pre-operatively, parents' perception of their child's overall appearance was worse than the pts' ($p<0.001$) as was their perception of deformities: Curve ($p<0.001$), Rib Prominence (RP) ($p<0.01$), Flank Prominence (FP) ($p<0.01$), Head/Chest (HC) ($p<0.01$), Shoulder Level (SL) ($p<0.01$), and Spine prominence (SP) ($p<0.01$). Pts wanted greater expectations for correction of deformity compared to their parents ($p<0.01$). At 2 yrs post-op, parents again rated their child's appearance

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worse than the patients rated themselves (p<0.01). Parents perceived their child's deformity to be more severe than the pts' regarding their FP (p<0.01), HC (p<0.01), SL (p=0.01), shoulder blade rotation (p=0.01), shoulder angle (p<0.01), head position (p<0.01), and SP (p<0.01). There was poor agreement between pts and parents with choosing which category was most bothersome (k=.23). Post-op, pts desired for more correction than did their parents (p<0.01).

Conclusion: Pts' and parents' perception of appearance and expectations of deformity correction significantly differ at pre-op and 2 yrs post-op; parents report a worse perception of their child's deformity which may prompt pts to desire greater correction. These differences are complex and may play a significant role in determining whether a family proceeds with surgery and considers it successful. Addressing both may help the surgeon clarify misconceptions regarding surgery and improve overall pt and parent satisfaction.

281. Are Clinical Outcomes Favorable Following of Posterior Vertebral Column Resection (PVCR) for Severe Adult Spinal Deformity?

Woo-Kie Min, MD, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Yutaka Nakamura, MD, PhD; Dong-Ho Lee, MD, PhD; Moon Soo Park, PhD; Brenda A. Sides, MA

Republic of Korea

Summary: 31 PVCRs with minimum 2-year follow-up were reviewed in the treatment of severe adult spinal deformity. Patients had overall favorable radiographic and clinical outcomes with only one (2.3%) major neurologic deficit, despite high risks of complications in these very challenging patients.

Introduction: The safety and efficacy of a posterior vertebral column resection (PVCR) procedure in severe pediatric spinal deformity has been recently reported, but there are no reports on patient-reported outcomes of PVCR in the adult population. We performed a review of radiographic and clinical outcomes and complications of PVCR in the treatment of severe adult spinal deformity.

Methods: 44 consecutive adult patients underwent PVCR between 2005 and 2009 by 1 surgeon. One died from unrelated causes and minimum 2yr FU was available for 31/43 (72%, Mean: 39.6 mos FU, range 24.7-64.2). There were 16 primary/15 revision surgeries. Patients were divided into 4 diagnostic categories: (1) severe scoliosis (SS) (n=2); (2) global kyphosis (GK) (n=11); (3) angular kyphosis (AK) (n=8); (4) kyphoscoliosis (KS) (n=10).

Results: The average age at surgery was 39.4 years of age (18-74). The average coronal curve correction was 56%. The average sagittal curve correction was 58%. The average OR time was 625m (304-955), with an average EBL of 2034 (500-8200). 13/31 (42%) patients suffered an acute or subacute complication. 2 patients (4.5%) lost spinal cord monitoring (SCM) data, which returned to baseline following prompt surgical intervention. 1 patient (3%) had severe preop myelopathy with no obtainable SCM data, and awoke with a motor paraplegia with slow improvement. 6 patients (19%) had revision surgery: implant failure/pseudarthrosis (n=2), deep infection (n=1), spinal malalignment (n=1) and UIV fracture (n=1). There were no deaths but 1 patient had thoracic aorta injury intraoperatively, immediately treated with an endovascular graft and aborted VCR. SRS scores significantly improved at final FU: self-image (2.72±0.7 vs 3.68±0.9, p<0.001), satisfaction (2.98±1.2 vs 4.18±0.9, p=0.02), mental health (3.34±0.9 vs 3.85±0.7, p<0.001), average subscore (2.9±0.8 vs 3.6±0.8, p<0.001) and normalized total score (57.8±16.1 vs 72.9±14.3, p<0.001).

Conclusion: Although a PVCR is a technically demanding procedure, we found it effective in the treatment of severe adult spinal deformities with overall favorable radiographic results, and despite the complications seen, highly favorable SRS outcome scores at a minimum 2-year FU.

282. Revision Surgery for Proximal Junctional Failure (PJF) with Neurological Injury After Spinal Deformity Surgery

Mario Di Silvestre, MD; Francesco Lolli; Konstantinos Martikos, MD; Francesco Vommaro; Andrea Baioni; Elena Maredi, MD; Tiziana Greggi

Italy

Summary: Retrospective review of 6 patients (5 women and 1 man), surgically treated for a proximal junctional failure (PJF) with neurological lesion after spinal deformity surgery. Neurological symptoms appeared acutely or subacutely (first 2 months after surgery) in 4 cases, later in 2. There were: 1 paraplegia, 4 severe paraparesis, 1 cervical radiculopathy with deficit. Revision surgery was performed in all cases (instrumentation extension + osteothomies). There was omplete neurological recovery in 3 patients, partial in 2, no recovery in 1.

Introduction: Proximal Junctional Failure (PJF) is a not so rare and sometimes dramatic complication of spinal deformity surgery. Aim of the study is to analyze revision surgery of

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PJF with neurological injury, focusing on technical notes and results.

Methods: Six patients were included (5 women and 1 man), with mean age of 52.8 years (range, 15 to 73), surgically treated for a PJF with neurological lesion after spinal deformity surgery. Primary diagnosis was: neuromuscular scoliosis (2 cases), adult deformity (4 cases: 2 "de novo" lumbar scoliosis, 1 severe hyperkyphosis, 1 fixed sagittal imbalance). During first surgery, fusion was extended to upper thoracic spine (UIV between T1 and T4) in 5 cases, to lower thoracic spine (T10) in 1. PJF morphology was: T3-T4 spontaneous luxation (1 case), UIV fracture (1), PJK + instrumentation failure (2), UIV fracture + instrumentation failure (2). Neurological symptoms appeared acutely or subacutely (first 2 months after surgery) in 4 cases, later in 2. There were: 1 paraplegia, 4 severe paraparesis, 1 cervical radiculopathy with deficit.

Results: Revision surgery was performed in all cases (within 12 hours of appearance of neurological deficit in case of complete paraplegia, delayed in the others). In all cases a proximal extension of instrumentation was performed (using a dynamic system in 1 patient due to severe osteoporosis), up to cervical spine in 2. One patient received multilevel Smith-Petersen osteotomies, one a partial corporectomy. At final FU, we observed a complete neurological recovery in 3 patients, partial in 2; no improvement was observed in case of complete paraplegia

Conclusion: PJF is a sometimes dramatic complication of spinal deformity surgery. In case of neurological injury, surgery must be immediate, aggressive, aimed not only to correct the deformity, but also to prevent recurrence, through the correction of predisposing factors. The recovery of neurological deficit is related to initial damage, chances of recovery (patient age) and proper and timely treatment.

283. Growth Hormone Treatment for Osteoporosis in Patients with Prader-Willi Syndrome

Yutaka Nakamura, MD, PhD; Toshiro Nagai; Takahiro Iida; Satoshi Asano, MD, PhD; Satoru Ozeki

Japan

Summary: The purpose of study was to investigate bone mineral density (BMD) with Prader-Willi syndrome (PWS) patients and to verify efficacy of growth hormone (GH) for osteoporosis. We investigated 155 patients (Scoliosis, 63; Non-scoliosis,92). Total lumbar BMD (L2-4) was 0.54 g/cm3(Z score -2.14) (Scoliosis : 0.64, non-scoliosis: 0.49). GH treatment revealed a significant increase of BMD (GH +; 18.6 %, GH - : 7.7%, P<0.01). 69% patients with PWS had bone fragility. GH administration improved bone fragility.

Introduction: Patients with Prader-Willi syndrome (PWS) have fragile bone. Osteoporosis is one of the major concerns in surgical treatment for scoliosis. There are no large-scale studies for osteoporosis using growth hormone for patients with PWS. To investigate bone mineral density (BMD) with PWS patients and to verify efficacy and safety of growth hormone (GH) administration for osteoporosis.

Methods: We identified 206 PWS patients who were diagnosed using genetic testing. We investigated 155 patients who examined BMD and followed for a minimum of two-years. Measurement was taken at the lumbar spine (L2-4). The mean age was 8.9 (0-47) years.at initial BMD. Scoliosis was found in 63 PWS patients (GH plus, 43; minus, 20). Mean cobb angle was 30.9 (range 12-88) degrees. There were 92 non-scoliosis patients (GH plus; 75, GH minus; 17). Patients were administered GH five days per week from 3 to 16 years. BMD was compared with two groups.

Results: Total lumbar BMD (L2-4) was 0.54 g/cm3 (Z score -2.14). Scoliosis group was 0.64 g/cm3 (Z score -1.96) and non-scoliosis group was 0.49 g/cm3(Z score -2.27). There were no significant differences between two Groups (P=0.216). 65 (49%) patients (Scoliosis, 27; Non-scoliosis,38) had osteoporosis (Z score <-2.5) and 42 (27.1%) patients (Scoliosis, 15; Non-scoliosis, 27) had osteopenia(-1.5< Z score<-2.5). GH treatment revealed a significant increase of L2-4 BMD (GH plus; 18.6 %VS GH minus: 7.7%, P<0.01). All patients could continue drug treatment without any side effects, but 4 patients stopped this treatment due to scoliosis deterioration.

Conclusion: 69%Patients with PWS had osteopenia or osteoporosis. GH administration improved bone fragility. Three patients had scoliosis deterioration; however, GH could be used relatively safety. Preoperative GH treatment probably decreases the risk of surgical treatment for scoliosis in PWS.

284. Circumferential Bony Fusion of a Long Fusion to the Sacrum in Elderly Patients

Ayato Nohara; Noriaki Kawakami, MD, DMSc; Ryo Sugawara; Toshiki Saito; Taichi Tsuji, MD; Yoshitaka Suzuki; Tetsuya Ohara

Japan

Summary: The pseudoarthrosis rate of long adult spinal fusion of the sacrum was 28.6% in this study. No patient, radiographic, or instrumentation variables were identified as risk factors for pseudoarthrosis.

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Introduction: The purpose of this study was to assess the fusion rate in long fusion to the sacrum in elderly patients and to determine the factors causing pseudoarthrosis.

Methods: Forty-two elderly patients (average 69.2 years, 60-80) with spinal deformity and other pathological conditions that underwent long fusion of the sacrum were retrospectively analyzed and investigated clinically as well as radiographically. The mean postoperative follow-up period was 53.5 months (24-126). The preoperative diagnosis was degenerative scoliosis in 15 patients, adjacent segment or distal end breakdown after fusion surgery in 11, postoperative flat back syndrome in 5, degenerative kyphosis in 4, posttraumatic kyphosis in 4, and others in 3. The average numbers of fused vertebra were 9.7 (5-12). The anchorage methods of lumbosacral lesions, interbody fusion of L5/S1, and fusion rate were retrospectively analyzed.

Results: Twelve of 42 patients (28.6%) exhibited pseudoarthrosis. There were 10 patients that had pseudoarthrosis at L5-S1, one in L2-3, and one in L3-4. The radiographic analysis showed that anatomical factors (TK, LL, TLS angle, PT, SVA) did not have a significant correlation with the pseudoarthrosis rate. Only one patient that underwent iliac fixation (n=9) exhibited pseudoarthrosis, and 11 patients with sacral fixation alone (n=33) showed pseudoarthrosis. Four patients that received a box cage for L5/S1 interbody fusion (n=11) had pseudoarthrosis, 5 patients with an extended cage (n=17) had pseudoarthrosis. Focusing on each cases suggested no interbody fusion of L5/S1, use of box type cages, anchor placement only in the sacrum, and entire round back might be risk factors associated with pseudoarthrosis

Conclusion: The pseudoarthrosis rate of long adult spinal fusion of the sacrum was 28.6% in this study. No patient, radiographic, or instrumentation variables were identified as risk factors for pseudoarthrosis. However, some factors including no interbody fusion at L5/S1, interbody fusion with box type cages at L5/S1 and intra sacral fixation alone may lead to non-union.

285. The Effect of Three Column Spinal Osteotomy on Anterior Pelvic Plane and Acetabular Component Position in Total Hip Replacement

Joshua E. Schroeder, MD; Federico P. Girardi, MD; Seth Jerabek, MD; Andrew A. Sama, MD; Leon Kaplan; Frank P. Cammisa, MD; Darren R. Lebl, MD

USA

Summary: Changing the spine affects the relative position of the acetabulum. A cohort of 31 patients that underwent three column osteotomy was identified. Upright radiographs were reviewed. Lumbar lordosis changed by 16 degrees (P<0.05). Sacral slope increased by 6.7 degrees (P=0.015). The anterior pelvic plane increased by 7.38 degrees (P<0.0001), increasing acetabulum anteversion by a predicted 5.9 degrees. This can impede acetabular cup position. In patients with hip-spine osteoarthritis; the spine surgery should be done prior to the total hip replacement.

Introduction: The spine and pelvis are integrated. As the pelvis articulates to the lumbar vertebrae and to the femur, any change in the sagittal balance of the spine will affect the standing pelvis location, thus changing the relative position of the acetabulum. This may be critical in "hip spine" syndrome when planning acetabulum prosthesis placement in total joint replacement. A change in 1 degree of the anterior pelvic plane angle changes the anteversion of the acetabulum by 0.8 degrees. Three column decancellation osteotomy corrects fixed sagittal plane deformity.

Methods: A retrospective cohort of patients with kyphotic deformity and associated sagittal imbalance that underwent corrective three column osteotomy was identified. Upright pelvic and spine radiographs pre- and post-operatively were reviewed. On the spine x-rays patient's sagittal vertical axis and lumbar lordosis angles were assessed together with pelvic incidence and sacral slope. On the pelvic images, the anterior pelvic plane angle was assessed by two independent orthopedic surgeons. The change between pre and post operative angles was documented.

Results: 31 patients (F: 16, M: 15) at a mean age of 62.5 years underwent three column osteotomies with a mean follow-up of 26.4 months. Of them 20 patients had complete spine and pelvis pre and post x-rays that could be analyzed.

The sagittal vertical axis was 11.07 cm preoperatively, 4.8 cm postoperatively on average. Lumbar lordosis changed from 39 degrees preoperatively, to 55 degrees postoperatively on average (P<0.05). Sacral slope increased by 6.7 degrees on average (P=0.015). Pelvic tilt changed by 5.4 degrees (P=0.001). The anterior pelvic plane increased by 7.38 degrees (P<0.0001).

Conclusion: Three column spinal osteotomy changes lumbar lordosis, in an attempt to improve sagittal balance. Sagittal balance correction is associated with a concomitant increase in sacral slope, pelvic tilt and the anterior pelvic plane angles. These changes will increase acetabulum anteversion by a predicted 5.9 degrees. This increase can impede acetabular cup position, there for in patients with a combined spine and pelvic osteoarthritis that will necessitate surgery; the spine surgery should be done prior to the total hip replacement.

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287. Noninvasive Cardiac Evaluation Following Posterior Vertebral Column Resection in Patients with Severe and Rigid Spinal Deformity

Yingsong Wang, MD; Jingming Xie; Ying Zhang; Ni Bi; Tao Li; Zhi Zhao

China

Summary: We reported deterioration of cardiac function in a series patients undergoing posterior vertebral column resection (PVCR), and explored the possible factors.To assess the cardiac function changes in severe and rigid deformity patients following PVCR, and identify the factors that correlated with deterioration of the cardiac reserve function.

Introduction: PVCR to correct severe and rigid deformities has a high risk of major adverse cardiac events (MACE) peri-operatively. Moreover, this powerful technique can directly affect the geometric position of the heart and great vessels during a short-time process of deformity correction.

Methods: This study included 30 adolescent and adult who underwent PVCR and excluded patients with diagnosed congenital heart diseases. Serum creatine kinase (CK), standard electrocardiogram (ECG), ambulatory ECG monitoring, vectorcardiogram, echocardiography, blood gas analysis, and pulmonary function (PF) were before and 1-7 days after surgery investigated. Multivariate correlation analysis was performed between demographic data, radiographic parameters, main surgical records, and results of cardiac evaluation.

Results: Preoperative cardiac function was demonstrated statistically related with PF, apex location and PaO2 value, and no relationship with scoliotic and kyphotic angles. A total of 14 patients were detected significantly cardiac function deterioration following PVCR, among them 4 patients occurred peri-operative MACE. Overall values of Ejection fraction, interventricular septum thickness at enddiastole were obviously influenced by PVCR. Moreover, postoperative cardiac function deterioration was correlated to apex location, amount of bleeding, sagittal correction rate, and postoperative apex transversal displacement.

Conclusion: Severe and rigid spinal deformity showed the tendency with abnormal cardiac reserve function, and it can be deteriorated by PVCR procedure. The potential reasons related with the presence of peri-operative MACE were the abrupt displacement of heart and great vessels which synchronized with spinal deformity correction, and the secondly damage on weakly cardiac reserve function. This opinion might be previously overlooked.

288. VEPTR Fixation Loss: The Characterization, Cause and Management of the Most Common Problems Associated with VEPTR Use

Wajdi W. Kanj, MD; John M. Flynn, MD; John T. Smith, MD; Patrick J. Cahill, MD; Michael Glotzbecker, MD; Michael G. Vitale, MD, MPH; Scott J. Luhmann, MD; Sumeet Garg, MD; Jeffrey R. Sawyer, MD; Robert H. Cho, MD

USA

Summary: In this multicenter study of anchor fixation loss of the VEPTR device in children, the authors found that this adverse event occurs with a high incidence (40%). Risk factors include larger Cobb angle (HR = 1.9, $p = 0.006$), increased kyphosis (HR = 1.3, $p = 0.142$), and neuromuscular disease (HR = 2.1, $p < 0.001$).

Introduction: Loss of anchor fixation, either gradual or acutely, is the most common problem associated with the use of the Vertical Expandable Prosthetic Titanium Rib (VEPTR). Although this obstacle to care is common, it has not been studied on a large scale. Our aim was to identify the incidence of, and risk factors for, the loss of bony anchor fixation in patients treated with VEPTR, with a goal of better informed consent and prevention.

Methods: We performed a multicenter retrospective review of consecutive patients treated with VEPTR at 9 high volume centers. We identified each patient who sustained anchor fixation loss, defined as requiring operative revision. We collected demographics, diagnosis, implant construct, and management using a secure, standardized electronic survey form. Hazard ratios and Kaplan-Meier survival analysis were used to compare diagnosis, pre-operative Cobb angle, and pre-operative kyphosis.

Results: Of the 364 patients managed with VEPTR at 9 centers, 144 patients sustained 264 total episodes of anchor fixation loss (184 VEPTR; 70 VEPTR II), for an anchor loss rate of 39.6%. Time from implant to anchor failure was 21.6 months (0-90) for the first failure (N=144), 29 months (0-79) for the second failure (N=74) and 35.2 months (2-70) for the third failure (N=29). The most common diagnoses associated with anchor loss were congenital (N=65) and neuromuscular scoliosis (N=51). The hazard ratio and survivorship curves for patients with neuromuscular scoliosis and for moderate and severe pre-operative Cobb angles are shown in Figure 1. The most common site of fixation loss was proximal rib anchors (49%), followed by pelvic and spine anchors. The most common presenting sign was increased prominence (69%), while 28% of failures were incidental findings. All patients had operative confirmation and either revision or removal of the implant following anchor failure.

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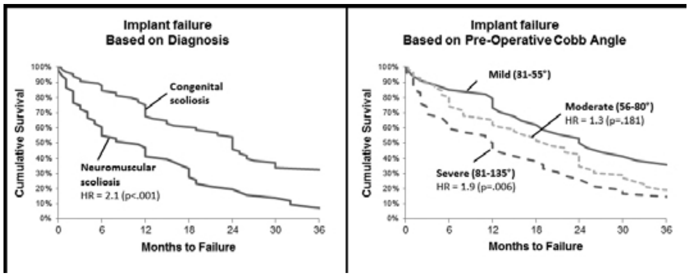
Conclusion: In a study of 364 patients, loss of VEPTR proximal or distal anchor fixation was a treatment obstacle affecting 39.6% patients. Risk factors for failure include larger Cobb angle, increased kyphosis, and neuromuscular disease. Almost all incidences of fixation loss occur between expansions, and 28% of the time anchor loss is noted in patients without symptoms.



289. Long-Term Quality of Life After Early Fusion Surgery in 10-Year-Old or Younger Patients with Congenital Scoliosis, Assessed After a Minimum of 10 Years

Toshiaki Kotani; Tsutomu Akazawa, MD; Tsuyoshi Sakuma, MD, PhD; Shohei Minami

Japan

Summary: We investigated long-term quality of life in a group of young patients with congenital scoliosis who underwent early fusion of the vertebrae. Follow-up assessment was carried out after a minimum of 10 years and showed surgery had no adverse effects on pain and mental health.

Introduction: Several long-term follow-up studies of surgically-treated adolescent patients with idiopathic scoliosis have been reported. However, the long-term clinical outcomes of early fusion in congenital scoliosis remain unknown. The purpose of this study was to investigate the clinical outcomes of surgery for congenital scoliosis.

Methods: Thirty-three cases of congenital scoliosis had surgery between 1978 and 2000. All patients were 10 years old or younger when they had their operation. Fourteen (42.4%) of the 33 patients (10 females and 4 males, mean age 26.2 (range 17-39 years) answered a questionnaire. The mean age at the initial operation was 6.0 years (range 3-10 years) and mean follow-up was 20.6 years (range 10-32 years). Twenty-nine age- and sex-matched healthy individuals (21 females and 8 males, mean age 26.8 years, range 21-38 years) were selected as a control group. The SRS-22 Patient Questionnaire and Roland-Morris Disability Questionnaire (RDQ) were used to evaluate long-term clinical outcomes.

Results: The responses to the SRS-22 showed that the patients with congenital scoliosis had significantly decreased function (patients, 4.6±0.4 vs. controls, 4.9±0.2; $p<0.01$) and self-image (patients, 2.7±0.6 vs. controls, 3.8±0.6; $p<0.01$). However, there were no significant differences between the two groups for pain or mental health. RDQ responses were 1.5±3.2 in patients and 0.3±0.6 with no significant differences.

Conclusion: Early fusion for congenital scoliosis had no adverse effects on pain and mental health after a minimum of 10 years. However, patients had significantly lower function and self-image than age- and sex-matched healthy controls.

290. Congenital Scoliosis Outcomes in Children Treated with Observation, Surgery and VEPTR

Frances A. Farley, MD; Ying Li, MD; Michelle S. Caird, MD

USA

Summary: Children with Congenital Scoliosis had SRS22 scores that compare favorably to scores in the literature for Adolescent Idiopathic Scoliosis and healthy adolescents. Higher Function and Pain scores and lower Image scores compared to OBSERVATION overall scores. Children with congenital scoliosis who had surgery had lower Image scores preoperatively and Function Scores postoperatively. Children with VEPTRs improved in Function and Satisfaction over time.

Introduction: Outcome measures in children with Congenital Scoliosis are unreported. Novel treatments such as VEPTR must show positive patient-reported outcomes during treatment as improvement in pulmonary function has not been demonstrated. The purpose is to determine the outcomes of children with congenital scoliosis using SRS-22.

Methods: The SRS 22 reports six domains: Total, Function, Mental Health, Image, Satisfaction, and Pain. Patients were divided into three groups: children under observation with congenital scoliosis (OBSERVATION), children with congenital scoliosis who had surgery and completed questionnaires preoperatively and postoperatively (SURGICAL); and children treated with VEPTR (VEPTR). SRS-22 questionnaires were prospectively collected from 177 OBSERVATION patients, 42 SURGICAL patients, and 22 VEPTR patients. 495 OBSERVATIONS, 71 SURGICAL, 111 VEPTR questionnaires were completed at 6 month intervals. Due to repeated measurement on each patient, the observations cannot be

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assumed to be independent. To account for this dependence, linear mixed models were used.

Results: The mean scores for the observation group were: Total 4.34 +/-0.58; Mental Health 4.29+/-0.69; Image 4.12+/-0.69; Function 4.53+/-0.66; Satisfaction 4.32+/- 0.80; Pain 4.44+/-0.82. The VEPTR score was significantly lower than OBSERVATION for Total, Function, and Image (p=0.013, p=0.02, p=0.05). The preoperative SURGICAL scores were lower than OBSERVATION for Image (p=0.003) and the postoperative SURGICAL scores were lower than OBSERVATION for Function (p=0.0067). VEPTR Function and Satisfaction scores significantly improved over sequential questionnaires (p=0.003, p=0.013). For the Pain scores the VEPTR scores were significantly lower than the OBSERVATION patients (p=0.003). For all questionnaires, Function and Pain were significantly higher (p=0.001, p=0.034) and Image significantly lower than the total score (p=0.001).

Conclusion: Function, Image and Pain require focus in children with Congenital Scoliosis. This is the first study which documents improvement in outcomes of VEPTR patients while in treatment.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

291. MRI Study of Idiopathic Scoliosis with a Curvature > 25 Degrees

Masatoshi Inoue; Yoshinori Nakata, MD; Hidehisa Torikai

Japan

Summary: 39(10.6%) of 369 patients who receive brace or operative treatment have NAA. The presence of NAA, as revealed by MRI, represents a risk factor for curve progression.

Introduction: A review of recent studies found that the reported prevalence of neural axis abnormality (NAA) such as syringomyelia and Chiari malformation in patients with idiopathic scoliosis ranged from 3%-37%. However, no large prospective studies have been conducted regarding magnetic resonance imaging (MRI) identification of NAA in patients with idiopathic scoliosis undergoing brace treatment.

Methods: This study was a prospective case series of patients with a presumed diagnosis of idiopathic scoliosis. A total of 369 patients (32 males, 337 females) with a curvature greater than 25 degrees were examined for NAA using MRI. Of these patients, 311 patients had received only brace treatment and 58 patients had undergone surgical treatment. The mean age at first visit was 12.6 years, and the mean initial Cobb's angle was 31.2 degrees. The MRI examinations utilized a spin echo technique with T1-weighted sagittal and axial images of the cervical and thoracic spine to determine the presence or absence of NAA. Patients were also examined for the presence of neurologic symptoms and abnormal neurologic signs.

Results: The MRI evaluation revealed that 39 patients (10.6 %) had NAA. The NAAs consisted of Chiari malformation in 25 patients, syringomyelia in 28 patients, and low conus medullaris in 1 patient. Predictive factors for an increased likelihood of abnormal MRI findings indicative of NAA were as follows: male sex, age at first visit < 11 years, left-sided curvature, thoracic kyphosis > 30 degrees, and presence of neurologic deficits (p<0.05). However, 6.8% of patients without abnormal neurologic signs had NAA. During follow-up, 12 patients (30.8 %) with NAA and 46 patients (13.9%) without NAA received surgical procedure (p<0.05). There were 7 cases of shrinkage of syringomyelia, especially, in 2 patients who admitted scoliosis surgery, preoperative MRI revealed disappearance of NAA.

Conclusion: The spinal surgeon must understand that 10% of idiopathic scoliosis patients who receive brace treatment have NAA. The presence of NAA, as revealed by MRI, represents a risk factor for curve progression.Some patients with normal preoperative MRI previously might have syringomyelia when they received conservative treatment.

292. Outcomes of Spine Surgery in Patients with Chondrodysplasia Punctata

Marios G. Lykissas, MD, PhD; Peter Sturm, MD; Anna M. McClung, BSN, RN; Daniel J. Sucato, MD, MS; Mary Riordan, BA; Kim Hammerberg, MD

USA

Summary: Medical records and spinal radiographs of 17 patients with Chondrodysplasia Punctata between 1975 and 2011 were retrospectively reviewed. Thirteen patients had spinal deformities, twelve required surgical intervention with an average of 2.6 surgeries per patient. Eighty percent who required more than one procedure were female with a probably diagnosis of X-linked dominant CDP (CDPX2). Isolated posterior fusion showed less favorable results compared with combined anteroposterior fusion in terms of revision surgery.

Introduction: Chondrodysplasia punctata (CDP) is a common manifestation of an etiologically heterogenous group of disorders. There is very little data regarding the development and management of spinal deformity in patients with CDP. The purpose of this study was to present a multicenter series of

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CDP, to describe the surgical outcomes of spinal deformities, and to emphasize important considerations that may influence choice of surgical treatment of spinal deformity in this patient population. This is the first long-term study on surgical outcomes following spine surgery in patients with CDP.

Methods: The medical records and spinal radiographs of patients with the diagnosis of CDP followed in two centers between 1975 and 2011 were retrospectively reviewed. Epiphyseal stippling was present on radiographs in all patients who fulfilled the clinical criteria.

Results: Among 17 patients who were diagnosed with CDP, 13 had spinal deformities. The mean age at diagnosis of spinal deformity was 14.6 months (range; 1 week-9 years). Males and females were close to equally represented (ten males and seven females). Twelve patients (92%) required surgery to correct spinal deformity. Patients were followed for a median of 8.4 years (range; 2.8-19.5 years). The total number of surgical procedures performed was 31 averaging 2.6 per patient. Five patients required more than one procedure. Eighty percent of the patients who required more than one surgical procedure were females with a probable diagnosis of X-linked dominant CDP (CDPX2). Revision surgery was indicated in 20% of patients treated with combined anterior and posterior fusion and 50% of patients treated with posterior fusion alone.

Conclusion: Spinal deformity in CPD patients may range from significant kyphoscoliosis to minimal deformity that does not require any treatment. For those patients in whom spine surgery was indicated, a high incidence of revision surgery and curve progression after fusion was recorded. Female patients with probable diagnosis of CDPX2 were more likely to require a second surgical procedure. Isolated posterior fusion showed less favorable results compared with combined anteroposterior fusion in terms of revision surgery.

293. Distraction Based Treatment Maintains Predicted Thoracic Dimensions in Early Onset Scoliosis

Michael Glotzbecker, MD; John B. Emans, MD; Meryl Gold, BA; Behrooz A. Akbarnia, MD; Charles E. Johnston, MD; Suken A. Shah, MD; Francisco J. S. Pérez-Grueso, MD; Growing Spine Study Group

USA

Summary: In this multicenter retrospective study, the effect that growing implants have on thoracic dimensions immediately upon insertion and at long term follow up was examined. Treatment increased the thoracic height percentile compared to expected values in patients with EOS and maintained this improvement at long term follow up. Reporting a change in normalized thoracic dimension percentiles that have been corrected for variable growth rates gives a more meaningful outcome measure compared to traditional measurement of absolute change in T1-S1 height.

Introduction: Change in thoracic dimensions and spine length is an important outcome measure in treatment of children with early onset scoliosis (EOS). Measurement of thoracic dimensions that have been normalized for expected values based on pelvic inlet width (PIW) corrects for the variable growth encountered in EOS due to different diagnoses and statures in an age independent manner. The purpose of the current study is to examine whether distraction based treatment in patients with EOS can improve thoracic dimensions compared to predicted values normalized for PIW, and whether treatment can maintain these improvements over time.

Methods: Patients with EOS treated with a distraction based therapy were identified from a multicenter database and included if they had PIW, chest width, and thoracic height measurements available at 3 time points: preoperative, immediate postoperative, and at least 5 year follow up. 41 patients met the criteria, including 23 females and 18 males, with mean age of 4.5 (0.8-9.3) years at initial surgery and a median follow up of 6.5 (5-13) years. Data was analyzed using piecewise linear mixed models.

Results: Mean chest width was similar at both preoperative (170mm, 142-225) and immediate postoperative time points (167mm, 85-201) but increased at latest follow up (207mm, 160-375). Chest width percentile normalized for PIW was similar at all 3 time points (0.93, 0.90, and 0.91). Thoracic height increased at each of the 3 time points: 142 (91-205) mm, 160 (117-233) mm, and 203 (139-348) mm, respectively. Thoracic height percentile normalized for PIW increased from a mean preoperative value of 0.8 (0.6-1) to a mean postoperative percentile of 0.9 (0.6-1) ($p<0.001$). The mean normalized thoracic height percentile at long term follow up was 0.9 (0.6-1.1), which remained significantly better than pre op ($p=0.001$) but was not significantly different from the initial postoperative time point ($p=0.13$).

Conclusion: Distraction based treatment increases chest and thoracic height over time. More importantly, compared with pre-op, initial treatment improves the thoracic height compared to predicted dimensions normalized for PIW, and sequential distractions are able to maintain this improvement at long term follow up.

The FDA has not cleared the drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an 'off label' use).

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294. Prediction of Thoracic Dimensions and Spine Length Based on Individual Pelvic Dimensions: Validation of the Use of Pelvic Inlet Width Obtained with Radiographs

Michael Glotzbecker, MD; Meryl Gold, BA; Michael Dombek; Patricia E. Miller, MS; John B. Emans, MD

USA

Summary: In this retrospective single center study, authors found that the pelvic inlet width (PIW) measurement is valid on plain radiograph compared to CT imaging (r=0.98). PIW was shown to be strongly correlated with thoracic dimensions and spine length in patients with mild spinal deformity (r values ranging from 0.86 to 0.93). Based on these correlations linear equations were created and modeled to predict TD as a function of PIW. Intraclass correlation coefficients for all measurements were between 0.978 and 0.997.

Introduction: In children with early onset scoliosis (EOS) the change in thoracic dimensions (TD) and spine length is a key treatment goal. Quantifying this change is confounded by varied growth rates and differing diagnoses. Pelvic inlet width (PIW) measured on Computed Tomography (CT) in patients without scoliosis has been shown to correlate with TD in an age independent manner. The purpose of this study is to validate PIW obtained on plain radiograph as an independent standard that can be used to correlate with TD in treated and untreated patients with EOS.

Methods: Two groups of patients were identified. The first arm included scoliosis patients with both a CT and a pelvic radiograph. The PIW measurement was compared between CT and plain radiograph. The second arm consisted of patients with minimal deformity (summation of all cobb angles less than 20 degrees) and spine radiographs in which PIW was measurable. In this latter group, PIW was measured and compared to previously published CT-based chest and spinal measurements comprised of maximal chest width, T1-T12 height, and T1-S1 height. Pearson product-moment correlation coefficient (r) was obtained for all relationships. The intraclass correlation coefficient was calculated for all measurements to evaluate interobserver reliability.

Results: In the first arm, there were 49 scoliosis patients with both CT and postero-anterior (PA) pelvic radiographs < 86 days apart (mean 16, median 2 days). The Pearson product-moment correlation coefficient (r) for CT and radiographic PIW measurements was 0.98. In the second arm, 163 patients with minimal spinal deformity (cobb mean 9.0 degrees) were identified. Strong correlations between PIW and TD were seen with r values ranging from 0.86 to 0.93. Intraclass correlation coefficients for all measurements were between 0.978 and 0.997.

Conclusion: PIW on plain radiographs correlates with PIW measurements obtained on CT in patients with deformity and with spine and thoracic parameters in patients with minimal deformity. It is a fast, reliable method of assessing skeletal growth while exposing patients to lower radiation doses than with CT imaging. It can be reliably used to assess patients with EOS, and the impact surgical treatment has on chest and spinal growth.

295. Replication Study of Estrogen Receptor 1 XbaI Polymorphism in AIS Caucasian Population

Piotr Janusz, MD; Tomasz Kotwicki, MD; Miroslaw Andusiewicz, PhD; Malgorzata Kotwicka

Poland

Summary: Genetic study of association of XbaI polymorphism in estrogen receptor 1 with AIS performed in 286 AIS and 116 healthy control Caucasian girls. No association with predisposition, curve severity, curve progression or operation rate was found.

Introduction: XbaI single nucleotide polymorphism (SNP) (A/G rs934799) in estrogen receptor 1 (ESR1) was described to be associated with curve severity in Japanese adolescent idiopathic scoliosis (AIS) patients and with both curve severity and predisposition for AIS in Chinese patients. Replication studies did not confirm these findings. The role of the XbaI ESR1 polymorphism in AIS was never described in Caucasian AIS patients. A genetic association study was performed to investigate the association between XbaI SNP in ESR1 and predisposition for, or progression of, AIS in Caucasian patients.

Methods: 286 females with AIS underwent clinical, radiological and genetic examination. Patients were divided into three groups according to progression velocity: nonprogresive (final Cobb angle <30°), slowly progressive (progression <1° per month for ≥6 months), and rapidly progressive (progression ≥1° per month for ≥6 months). For each genotype (AA, AG, GG) the mean Cobb angle and surgery rate were calculated. Control group consisted of 116 healthy females with negative family history of AIS. DNA was obtained from peripheral blood and the XbaI SNP of ESR1 was analyzed by restriction fragments length polymorphisms.

Results: There was no significant difference in alleles (p=0.63) and genotype frequency (p=0.35) between AIS patients (AA n=95, AG n=141, GG n=50) and controls (AA n=31, AG n=66, GG n=19). There was no significant difference in genotype frequency for nonprogressive, slowly progressive, and rapidly progressive curves, p=0.47. No difference among three

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genotypes for mean Cobb angle (AA 37° AG 37.3°, GG 38°) or surgery rate (AA 27.4%, AG 27.6%, GG 30%) was found. All results followed Hardy-Weinberg equilibrium.

Conclusion: No association between ESR1 XbaI polymorphism and AIS was found in the Caucasian population. None of the previously reported associations with curve severity, progression or operation rate could be confirmed.

296. Smaller Bones at Age 10 Predicts Scoliosis at Age 15: Results from a Population-Based Birth Cohort

Hilary J. Taylor; Ashley W. Blom; Ian J. Harding, BA, BMBCh, FRCS(Orth); John Hutchinson; Ian W. Nelson, MB, BSMCh, Orth(FRCS); Jon H. Tobias; Emma M. Clark

United Kingdom

Summary: There are no published studies that have investigated determinants of scoliosis using a prospective cohort design making the establishment of cause and effect difficult. We measured bone size at aged 10 and related it to presence of scoliosis at aged 15 after adjusting for age and puberty. Our results show that children with smaller bones at aged 10 are more likely to develop scoliosis.

Introduction: Understanding the aetiology of AIS may provide opportunities for early intervention, perhaps enabling limitation of curve size. One potential determinant of scoliosis that is of great interest is bone size and density. However, there are no published studies that have investigated determinants of scoliosis using a prospective cohort design making the establishment of cause and effect difficult.

Methods: This study was based on the Avon Longitudinal Study of Parents and Children (ALSPAC), a population-based cohort. Data on total body (minus head) bone area were collected by DXA in 7333 children aged 10 years. Children with scoliosis already present at aged 10 were excluded. Data was collected on the presence or absence of scoliosis at aged 15 using a validated method. Other potential confounding variables were also measured. In addition, peripheral quantitative CT (pQCT) was used to measure bone circumference and cortical thickness at aged 15. Associations between bone variables and risk of scoliosis developing over the following 5 years were examined by logistic regression. Cross-sectional analyses were also carried out between pQCT variables and presence of scoliosis at 15.

Results: Of the 4022 children who were seen at both the age 10 and age 15 research clinics, 175(4.4%) had developed scoliosis by aged 15. No association was seen with ethnicity or socio-economic status. After adjustment for confounders, the OR for scoliosis at aged 15 per SD increase in bone size relative to body size at aged 10 was 0.61 (95%CI 0.42 to 0.89, P=0.009). Bone area measured by DXA, adjusted by height, showed the strongest association with scoliosis at 15 (OR 0.58, 95%CI 0.44 to 0.76). Girls with scoliosis at 15 had smaller periosteal circumference (67.81 vs 68.86mm, P<0.05) and reduced cortical thickness (5.02 vs 5.16mm, P<0.01) compared to those without scoliosis.

Conclusion: Our results show that children with smaller bones at aged 10 are more likely to develop scoliosis. This is the first prospective study in this area and adds weight to the hypothesis that smaller bone size is associated with an increased risk of scoliosis.

297. Correlation Between Clinical Outcome and Spinopelvic Parameters in Ankylosing Spondylitis

Jung Sub Lee, MD, PhD; Jong Ki Shin; Tae Sik Goh; Jin-Hyok Kim; Jung-Hee Lee, MD; Dong-Ju Lim; Sung-Soo Kim, MD

Republic of Korea

Summary: This study shows significant relationships between sagittal spinopelvic parameters in AS patients. Furthermore, AS patients and normal controls were found to be significantly different in terms of sagittal spinopelvic parameters. In addition, correlation analysis revealed significant relationships between parameters and clinical outcomes. Sagittal vertical axis, sacral slope and lumbar lordosis were found to be significant parameters in prediction of clinical outcomes in AS patient.

Introduction: Little data is available on the relationship between sagittal spinopelvic parameters and health related quality of life (HRQOL) in ankylosing spondylitis (AS) patients. The aim of this study was to identify relationships between spinopelvic parameters and HRQOL in AS.

Methods: The study and control groups comprised 107 AS patients and 40 controls. All underwent anteroposterior and lateral radiographs of the whole spine including hip joints and completed clinical questionnaires. The radiographic parameters examined were sacral slope, pelvic tilt, pelvic incidence, thoracic kyphosis, lumbar lordosis, and sagittal vertical axis. A Visual Analogue Scale (VAS: 0-10) score for back pain, the Oswestry disability index (ODI) questionnaire, Scoliosis Research Society (SRS-22) questionnaire and Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) were administered to evaluate QOL. Statistical analysis was performed to identify significant differences between the study and control groups. In addition, correlations between radiological parameters and clinical questionnaires were sought.

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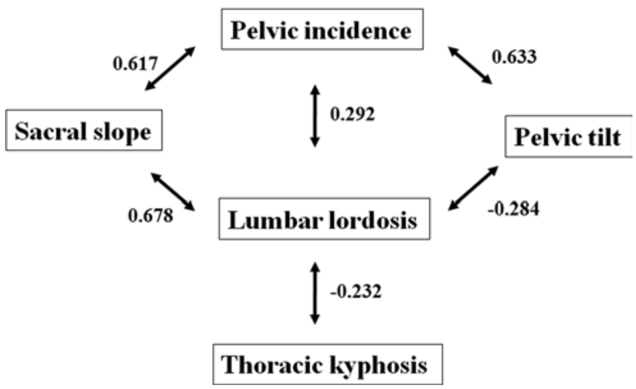
Results: The AS patients and controls were found to be significantly different in terms of sagittal vertical axis, sacral slope, pelvic tilt, pelvic incidence, and lumbar lordosis. However, no significant intergroup difference was observed for thoracic kyphosis (P > 0.05). Of the 107 AS patients, there were 18 women and 89 men. Correlation analysis revealed significant relationships between radiographic parameters and clinical outcomes. Multiple regression analysis was performed to identify predictors of clinical outcome, and the results obtained revealed that sagittal vertical axis and sacral slope significantly predicted VAS, ODI and BASDAI scores and that sagittal vertical axis and lumbar lordosis predicted SRS-22 scores.

Conclusion: AS patients and normal controls were found to be significantly different in terms of sagittal spinopelvic parameters. Correlation analysis revealed significant relationships between radiographic parameters and clinical outcomes. In particular, sagittal vertical axis, sacral slope and lumbar lordosis were found to be significant parameters in prediction of clinical outcomes in AS patient.



298. Electromyographic (EMG) Monitoring Threshold Alteration in Lumbar Spine Pedicle Screw Testing

David F. Antezana, MD; William H. Martin, PhD; Kristine L. Walter, MA

USA

Summary: In order to test local factors in the surgical bed's effects on intraoperative EMG monitoring of pedicle screws, we tested 18 different screws placed in the thoracolumbar spine—with screw heads isolated and dry, in contact with muscle, and partially submerged in fluid. In each case, we found the threshold increased from dry, to soft tissue contact, to wet. Care must be taken to keep pedicle screws dry during testing to minimize false negatives.

Introduction: Intraoperative EMG monitoring of pedicle screw placement verification is performed to aid in detection of medial wall breaches of the pedicle during screw placement. Data is accumulating in the literature describing thresholds with high specificity for breaches; however, a paucity of data exits addressing local factors in the surgical bed, and how those affect stimulation thresholds.

Methods: Two patients underwent intraoperative EMG testing during pedicle screw (n=18) placement. Each screw was tested 3 times: once while isolated and dry (D), once while in contact with muscle or soft tissue (M), and once partially submerged in fluid collected in the operative site (W).

Results: The EMG threshold for each screw was consistently increased as we progressed from dry conditions to muscular contact to partial submergence. Thresholds were as follows: dry (7->60); muscle (9.2->60); wet (14->60). Threshold differences were as follows: D-M=6; D-W=15; M-W=6.

Conclusion: Local factors in the surgical bed can have a profound influence on the thresholds reported by the neurophysiologist to the surgeon during intraoperative EMG pedicle screw stimulation. Current shunting resulting from contact between the screw and either tissue or fluid results in artificial elevation of evoked EMG thresholds that, if not identified, will mislead the surgical team into concluding that screw positions are safe. Special care must be taken to keep pedicle screws dry and free of soft tissue contact to minimize false negatives.

299. Prevalence of Scoliosis in Patients with Fontan Circulation

Antony Kallur, MD; Muayad Kadhim, MD; Christian Pizarro, MD; Laurens Holmes, PhD, DrPH; Kenneth J. Rogers, PhD; William G. Mackenzie, MD; Suken A. Shah, MD

USA

Summary: High prevalence of scoliosis was observed in patients with Fontan circulation (9.8%).

Introduction: In Fontan completion the venous blood flow passively from the venae cavae directly to the pulmonary arteries while the single ventricle pumps the blood into the systematic circulation. This study was done to examine the prevalence of scoliosis in patients with Fontan circulation.

Methods: This is a retrospective cohort (case-only) study to examine the radiographs of 194 patients who underwent Fontan completion surgery between 1998 and 2011. Median age at Fontan completion surgery was 1.3 years (25th and 75th

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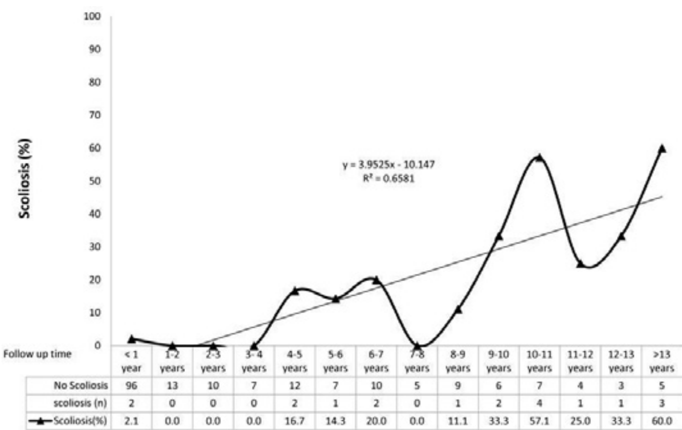
quartiles were 1.1 and 1.9 years respectively). The end point was determined as age at the last available (spine or chest) radiograph, and when scoliosis was diagnosed, we utilized the first available radiograph with scoliosis. Logistic regression model was utilized to examine the potential risk factors for scoliosis.

Results: Mean age at radiograph was 5.4 ± 4.6 years. All patients underwent at least two sternotomies, six patients underwent right thoracotomy and five patients left thoracotomy. Nineteen patients (9.8%) developed scoliosis; none had a thoracotomy. Most of the scoliosis patients were older than 5 years of age at scoliosis diagnosis, and the female to male ratio was 5:3. The scoliosis occurred more commonly with increase of time after Fontan surgery. The major curve was right in 12 patients (63%), left thoracic in four patients (21%), and high thoracic in three patients (16%). Six patients had a curve larger than 35° (mean 60°, range from 38° to 97°), four patients had a curve (20° to 35°) while nine patients had a small curve (less than 20°). There was 27% increased risk of developing scoliosis with every one year increase after Fontan completion. Girls with Fontan circulation had two times more risk of developing scoliosis than boys.

Conclusion: Although girls remain at increased risk of developing scoliosis compared to boys, boys are at higher risk of developing scoliosis compared to otherwise normal children. The risk of scoliosis increases with time after Fontan completion surgery.



Follow up time	< 1 year	1-2 years	2-3 years	3-4 years	4-5 years	5-6 years	6-7 years	7-8 years	8-9 years	9-10 years	10-11 years	11-12 years	12-13 years	>13 years
No Scoliosis	96	13	10	7	12	7	10	5	9	6	7	4	3	5
scoliosis (n)	2	0	0	0	2	1	2	0	1	2	4	1	1	3
Scoliosis(%)	2.1	0.0	0.0	0.0	16.7	14.3	20.0	0.0	11.1	33.3	57.1	25.0	33.3	60.0

Patients with Fontan circulation who developed scoliosis stratified by follow up

300. Progression of Limb-Length Discrepancy and Pelvic Obliquity in Children with Idiopathic Scoliosis

Avraam Ploumis, MD, PhD; Vikas Trivedi; Jae-Hyuk Shin; Kirkham B. Wood, MD; Brian E. Grottkau, MD

Greece

Summary: This a retrospective study of pediatric patients presented for scoliosis evaluation. Limb length difference was correlated significantly with pelvic obliquity and but not with scoliotic curve magnitude. From the 229 patients studied, 95.2% had scoliosis and 9.6% had limb length inequality more than 10mm. At a follow-up visit 1.96 (in average) years later, limb length difference remained stable but pelvic obliquity and scoliosis continued to increase.

Introduction: Both limb length discrepancy and scoliosis can include concurrent pelvic obliquity. The objective of this study is to evaluate the incidence of limb length asymmetry and pelvic obliquity in pediatric patients first presented for scoliosis and to detect coronal spinopelvic deformity changes within time.

Methods: Patients first presented for idiopathic scoliosis at a pediatric orthopaedic clinic and treated nonoperatively were retrospectively evaluated regarding limb length discrepancy (using bilateral femoral head height difference), pelvic obliquity (using bilateral iliac crest height difference and sacral takeoff angle) and scoliotic curve (using major curve magnitude and rotation) in full spine posteroanterior standing radiographs. Same radiographic parameters were measured again at a followup visit. Incidence of scoliosis and limb length discrepancy as well as statistical correlations between clinical (type of treatment)-demographic (age, sex, BMI)-aferomentioned radiographic data within time were calculated.

Results: Two hundred twenty nine consecutive patients with average (SE) age 12.8 (0.17) years at initial examination were included in the study. Scoliosis (major curve Cobb angle equal or more than 10°) was seen in 218 (95.2%) of the patients, limb length discrepancy (more than 1cm femoral head height difference) was found in 22 (9.6%) patients and pelvic obliquity (iliac crest height difference more than 1cm or sacral takeoff angle more than 5°) appeared in 85 (37%) patients. In a subsequent visit 1.94 (0.83) years later, no significant change ($p>0.05$) in limb length inequality but significant increase ($p<0.05$) in scoliotic and pelvic deformity parameters was found. However, patients with limb length inequality 14mm or more had significantly more severe major curve angle than patients with less than 14mm discrepancy.

Conclusion: : In an adolescent patient population presenting for idiopathic scoliosis evaluation, approximately 10% of the patients have limb length inequality more than 1 cm. Especially,

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when limb length difference exceeds 14mm, scoliotic curves are more pronounced. With progressive age during puberty, limb length discrepancy remains stable but scoliotic and pelvic deformity progress.

301. REACTS: A Simple Scoring System to Stratify Risks for Patients with Neuromuscular Scoliosis Undergoing Posterior Spinal Fusion

M. W. Shrader, MD; Mandy Falk, PA-C; Gregory R. White, MD; Lee S. Segal, MD

USA

Summary: REACTS is a proposed grading system that assesses risk for postoperative complications for patients with severe neuromuscular scoliosis undergoing posterior spinal fusion. Early results demonstrate the scoring system is effective in predicting complications.

Introduction: Posterior spinal fusion (PSF) for children with severe neuromuscular (NM) scoliosis carries a significantly high risk. The ability to stratify risk for these patients preoperatively could assist surgeons and families in making the difficult decision of whether to proceed with surgery or not. The REACTS scoring system gives points for preoperative morbidity in six areas: Respiratory, Eating, Ambulatory, Cognition, Talking, and Seizures. Each component can score zero, one, or two, based on the severity of the limitation. A maximum score of 12 indicates the highest risk. The purpose of this study is determine whether the REACTS scoring system correlates with postoperative complications in a population of patients with NM scoliosis undergoing PSF.

Methods: This is a retrospective review of patients with NM scoliosis undergoing PSF. A REACTS score based on the patients' preoperative status in the six areas was determined. Complications were then rated on a scale of 1 to 5, with one being a very minor complication requiring no additional treatment (such as minor wound drainage) and 5 being death. The preoperative REACTS score was then compared to the complication score for each patient to determine correlation.

Results: 23 patients (mean age 15) were included in the study. Twelve patients had a complication (52%), although five were only minor complications. The mean REACTS score was 8 (range, 1 to 11). The correlation of the REACTS score with the presence of a significant complication (complication score of 3, 4, or 5) was statistically significant ($p<0.0000001$).

Conclusion: The use of the REACTS scoring system showed significantly high correlation with the development of postoperative complications in patients with NM scoliosis undergoing PSF. The use of this scoring system could potentially stratify and identify those patients with a significant risk of perioperative mortality and allow for further preoperative evaluations to minimize complications. Prospective evaluation of this system with a larger sample size is needed to confirm its clinical utility.

302. Recovery of Sitting Balance After Correctional Surgery in Neuromuscular Patients May Also Improve the Quality of Life of Caregivers

Byung Ho Lee, MD, PhD; Seong-Hwan Moon, MD, PhD; Hak-Sun Kim, MD; Hwan-Mo Lee; Dong Eun Shin

Republic of Korea

Summary: To assess patients' and caregivers' quality of life(QOL) before and after correctional surgery of neuromuscular scoliosis and determine whether an association existes between quality of life and recovery of sitting balance. Reconstructive surgery in DMD scoliosis which improves sitting balance renders not only better functional outcome of patients also but better QOL of patients and caregivers.

Introduction: A positive indication of reconstructive surgery in patients with neuromuscular scoliosis is improvement in their functional outcome and QOL.. While most studies focus on technical and radiographic indices, functional status of patients and QOL of both patients and their caregivers are an equally important outcome to consider in the management of Duchenne muscular dystrophy (DMD). To date, there is no study have been reported to compare QOL of patients and

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caregivers (e.g. parents or occupational guardian) before and after correctional surgery using QOL questionnaire. (SF-36)

Methods: A comparison of 63 patients (40 surgical and 23 non-surgical patients) diagnosed with DMD scoliosis and their caregivers were performed. MDSQ and SF-36 for patients and SF-36 for caregivers were investigated preoperatively and at 3 months and 1 year follow-up visit postoperatively. Based on preoperative and postoperative radiographs, parameters related to sitting balance including cobb angle, pelvic obliquity and lumbar lordosis were reviewed.

Results: The MDSQ score for the surgical group was higher (37.67 ± 19.75 versus 24.89 ± 14.55) compared to the nonoperative group (p=0.0165).

Patients in the surgical group had better patient satisfaction in performing activities of daily living, and trunk balance. (p<0.05). The surgical group had better scores in terms of appearance, sitting, sleep and breathing (p<0.05). Also, QOL of patients and caregivers in the surgery group improved more significanltly for physical function and role emotion items for patients and role emotion for caregivers than in the conservative group. (P<0.05) in multiple regression analysis, sitting related items of MDSQ (question NO. 15,16,22,24,26,27,28,29) correlated positively with SF-36 of patients and caregivers, but curve magnitude, percent of curve correction did not correlate with SF-36.

Conclusion: Reconstructive surgery in DMD scoliosis which improves sitting balance renders not only better functional outcome of patients but also better QOL of patients and caregivers. The better level of function with higher satisfaction rates compared with patients treated conservatively.

303. Larger Curve Magnitude is Associated with Markedly Increased Perioperative Complications After Scoliosis Surgery in Patients with Spinal Cord Injury

Amer F. Samdani, MD; Steven W. Hwang, MD; James T. Bennett, MD; Joseph King, MD; Anthony Fine; Randal R. Betz, MD

USA

Summary: Children with spinal cord injury (SCI) are at high risk for developing scoliosis. Timing of surgical intervention is highly variable. The risk of sustaining a major perioperative complication increases substantially in larger curves.

Introduction: Children with SCI are likely to have a rapidly progressive scoliosis. Timing of surgical intervention in these children is highly variable. We sought to determine whether earlier intervention can decrease the incidence of major perioperative complications in these children.

Methods: After obtaining IRB approval, a retrospective review was performed of all patients with a diagnosis of SCI and scoliosis who underwent a PSF. 53 patients were identified and their radiographic, clinical, and major perioperative complication data collected. Patients were divided into two groups: Smaller Curves (SC) <70° (N= 23), and Larger Curves (LC) >70° (N=30). Major perioperative complications included neurologic, dural tear, unintended staged surgery, respiratory (pneumonia, aspiration, intubation > 48 hrs/reintubation), sepsis, ARDS, wound infection, and vision loss.

Results: (Table 1) The mean age at surgery for SC was 12.2±2 years and for LC 14.9±2 years (p<0.05). Major curve magnitude was SC= 56±12° and LC=88±11° (p<0.01). Average number of levels fused was similar for both groups (SC=16.1, LC=15.8, p=0.60). However, children in the SC group had a significantly shorter operative time (442±82 versus 531±119 minutes, p<0.05) and blood loss (2421±1257 cc versus 3321±2045 cc, p=0.07), although the latter did not attain statistical significance. Mean hospital stay was shorter in the SC group (12.9±3 vs. 16.2±9 days, p<0.05). 15 patients (30%) sustained 19 major complications. In the SC group, 4 patients (17.4%) had one each of dural tear, pneumonia, prolonged intubation, and wound infection. In the LC group, 11 patients (37%) sustained 4 wound infections, 3 prolonged intubations, 2 aspirations, 2 dural tears, and one each of surgery aborted secondary to excessive blood loss, sepsis, ARDS, and vision loss.

Conclusion: Larger magnitude curves in patients with SCI undergoing surgery for scoliosis demonstrate longer operative times, more blood loss, longer hospital stays and an increase in major perioperative complications. Surgeons should consider earlier intervention in these children when the likelihood of continued curve progression is high.

304. Are We Undermedicating Patients with Neuromuscular Scoliosis After Posterior Spinal Fusion?

M. W. Shrader, MD; Mandy Falk, PA-C; Gregory R. White, MD; Lee S. Segal, MD

USA

Summary: In this retrospective series of patients undergoing posterior spinal fusion, patients with adolescent idiopathic scoliosis received more than twice the amount of narcotics compared to a cohort of patients with neuromuscular scoliosis.

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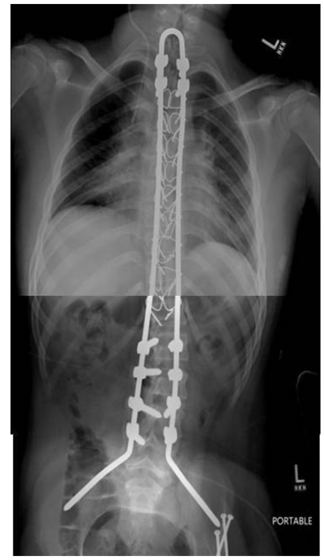
Introduction: Posterior spinal fusion (PSF) for children with severe neuromuscular (NM) scoliosis carries a significantly high risk of complications. The appropriate assessment of pain is crucial; under-treatment of pain leads to patient and family anxiety, while over-treatment in this medically fragile patient population can lead to respiratory depression. The purpose of this study is to compare the pain management for patients with NM scoliosis undergoing PSF to a cohort of patients with adolescent idiopathic scoliosis (AIS).

Methods: This was a retrospective, case-control study of patients undergoing PSF. A consecutive series of patients with NM scoliosis was matched for age, gender, and weight with a group of patients with AIS. The total narcotic used (TNU) was determined by summing all narcotics given during the hospital stay (oral and intravenous), and converting them to morphine equivalent units (mg of morphine-equivalents, normalized by body weight). The data from these two groups were then analyzed to determine differences in TNU.

Results: 25 patients with NM scoliosis (mean age 15.4) were included in the study. This group was matched with 25 patients with AIS scoliosis (mean age 15). Only those AIS patients undergoing PSF for more than 13 spinal segments were used for comparison, to match to the NM group as much as possible. The TNU for the NM group was 1.2 mg morphine/kg (range, 0.28 to 4.21), while the TNU for the AIS group was 3.52 mg morphine/kg (range, 0.71 to 15.51). Using the Student's t-test, these differences were highly significant ($p<0.0000001$).

Conclusion: In this case-control retrospective analysis, patients with AIS undergoing PSF received more than twice the amount of narcotic compared to an age and weight-matched group of patients with NM scoliosis. Pain control in a NM population can be extremely difficult, due to inherent communication and cognitive deficits in these patients. This data suggests that these NM patients' pain is under-treated compared to our AIS patients. The reasons for these findings are likely multifactoral, but more study is indicated to investigate pain assessment and pain control in this vulnerable patient population.



305. Predicting Failure of Iliac Fixation in Neuromuscular Spine Deformity

Sumeet Garg, MD; Courtney A. Holland, MD; Jaren LaGreca; Bryan McNair; Mark A. Erickson, MD

USA

Summary: Iliac screw failure occurred in 26% (23 of 90) patients with neuromuscular scoliosis having instrumented posterior spine fusion (PSF) from the upper thoracic spine to the sacrum. Patients with flaccid tone had a lower risk of failure. Alternative pelvic fixation should be considered for long PSF constructs in children with neuromuscular scoliosis due to high failure rate of standard iliac screws.

Introduction: Failure of iliac screw fixation in long posterior spinal fusion (PSF) constructs in patients with neuromuscular scoliosis is common. The purpose of this study was to determine whether any patient or surgeon factors result in a higher risk of iliac fixation failure.

Methods: All patients from 2001-2009 undergoing PSF from the upper thoracic spine to the sacrum for neuromuscular scoliosis were identified using an institutional surgery database. 90/139 patients had two year follow-up and were analyzed. Medical records and radiographs were reviewed for patient and surgeon factors that may be related to failure of iliac fixation. Iliac fixation failure was defined strictly as a broken screw, disengagement of screw to connector or connector to rod, or set plug failure. Lucency around an iliac screw was not considered as a failure.

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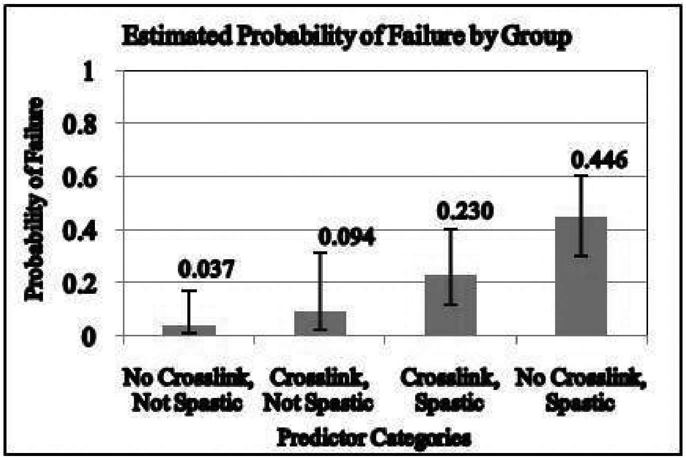
Results: There were 37 female and 53 male patients with an average age of 13.9 years (range 7-21) and follow-up of 5.5 years (range 2.1 - 9.6 years). Coronal correction averaged 58% and pelvic obliquity correction 62%. 23/90 (26%) patients had failure of iliac fixation. Lucency around iliac screws occurred in 50/90 (55%) of patients, but only 9 had associated fixation failure. Using a single predictor logistic regression model; diagnosis, GMFCS, BMI, gender, iliac screw diameter and material, number of distal fixation points (L4, L5, S1, ilium), ambulatory status, magnitude of pelvic obliquity correction, overall coronal deformity correction, were not significant predictors of iliac fixation failure. Presence of distal crosslink and flaccid tone reduced the risk of iliac fixation failure and were studied in a multivariable logistic regression analysis. Only flaccid diagnosis was found to be protective in this model.

Conclusion: Iliac screw failure is common in neuromuscular scoliosis. Patients with flaccid tone have a lower risk of failure. Use of a distal crosslink had a trend towards protective effect. Alternative pelvic fixation should be considered for long PSF constructs in children with neuromuscular scoliosis due to high failure rate of standard iliac screws.



306. The Use of Pinless Halos in Pediatric Orthopedics: Is it Safe?

<u>Hooman Bakhshi</u>; Bibek Banskota, MBBS, MRCS, MS; John P. Dormans, MD

USA

Summary: The use of a conventional halo is accompanied by the possibility of serious complications, including pin tract infection. The pinless halo was introduced in an attempt to mitigate these problems while retaining the effectiveness of a halo with pins. We retrospectively reviewed 23 patients. Major complications were seen only in 2 patients, each of whom had a pressure sore. The use of pinless halos was found to be safe with minimal complications in this cohort of patients.

Introduction: Halo devices have important applications in pediatric orthopedics, both as a definitive method of care as well as for post-operative purposes. The use of a halo with pins is accompanied by the possibility of serious complications, including penetration into the skull, pin tract infection and neurologic problems. The "pinless" halo was introduced in an attempt to mitigate these problems while retaining the effectiveness of a halo with pins.

Methods: We retrospectively reviewed 23 patients, whose treatment included the use of a pinless halo, presenting to our institution between 1/1/2007 and 11/1/2011. In addition to demographic data, indication and duration of halo application and complications were studied.

Results: There were 11 males and 12 females with an average age of 7.17 Years. Indications of the halo application included post-operative immobilization for congenital muscular torticollis in 9 cases, conservative management of C1-C2 rotatory instability in 3 cases, conservative management of C1-C2 dislocation in 2 cases, post-operative immobilization following C1-C2 fusion for cervical instability in Down syndrome in 2 cases, post-operative immobilization following anterior and posterior fusion for cervical kyphosis and instability in Larsen's syndrome in 2 cases , a case of conservative management of traumatic C1-C2subluxation , and 4 case of other post operative cervical spine immobilization . The average duration of pinless halo application was 37 days (7 to 142 days). Major complications were seen only in 2 patients, each of whom had a pressure sore; one on the scalp and the other related to the vest. Both of the pressure sores responded to local treatment, however, the patient with the sore on the scalp had permanent alopecia at the location of the sore. Other complications included alopecia in 1 patient, skin irritation in 4 patients and head lice in 1 patient. All patients were compliant to treatment.

Conclusion: The use of pinless halos was found to be safe with minimal complications in this cohort of patients. Effectiveness of treatment in comparison to invasive halos was not done and is a limitation of this study.

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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 35 orthopaedic surgeons to an international organization of more than 1,200 health care professionals.

Mission Statement

The purpose of 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 all orthopaedic surgeons, neurosurgeons and to researchers in all geographic locations who are willing to commit to a clinical practice/research which includes at least 20% spinal deformity. Candidate Fellows stay in this 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.

Programs and activities of the SRS are focused primarily on education and research and include the Annual Meeting & Course, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Regional Conferences, a Global Outreach Program, a Research Endowment 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 and printable membership applications, please visit the SRS website www.srs.org.

Society Office Staff

Tressa Goulding, CAE, CMP – Executive Director
(tgoulding@srs.org)

Katie Agard – Meetings Manager
(kagard@srs.org)

Shahree Douglas – Communications & Program Manager
(sscarborough@srs.org)

Courtney Kissinger – Executive Assistant
(ckissinger@srs.org)

Katy Kujala-Korpela – Program Manager
(kkujala-korpela@srs.org)

Cydni Schaeffler – Meetings Manager
(cschaeffler@srs.org)

Stephanie Tesch – Education Manager
(stesch@srs.org)

Nilda Toro – Membership Manager
(ntoro@srs.org)

Scoliosis Research Society

555 East Wells Street, Suite 1100
Milwaukee, WI 53202
Phone: 414-289-9107
Fax: 414-276-3349
www.srs.org

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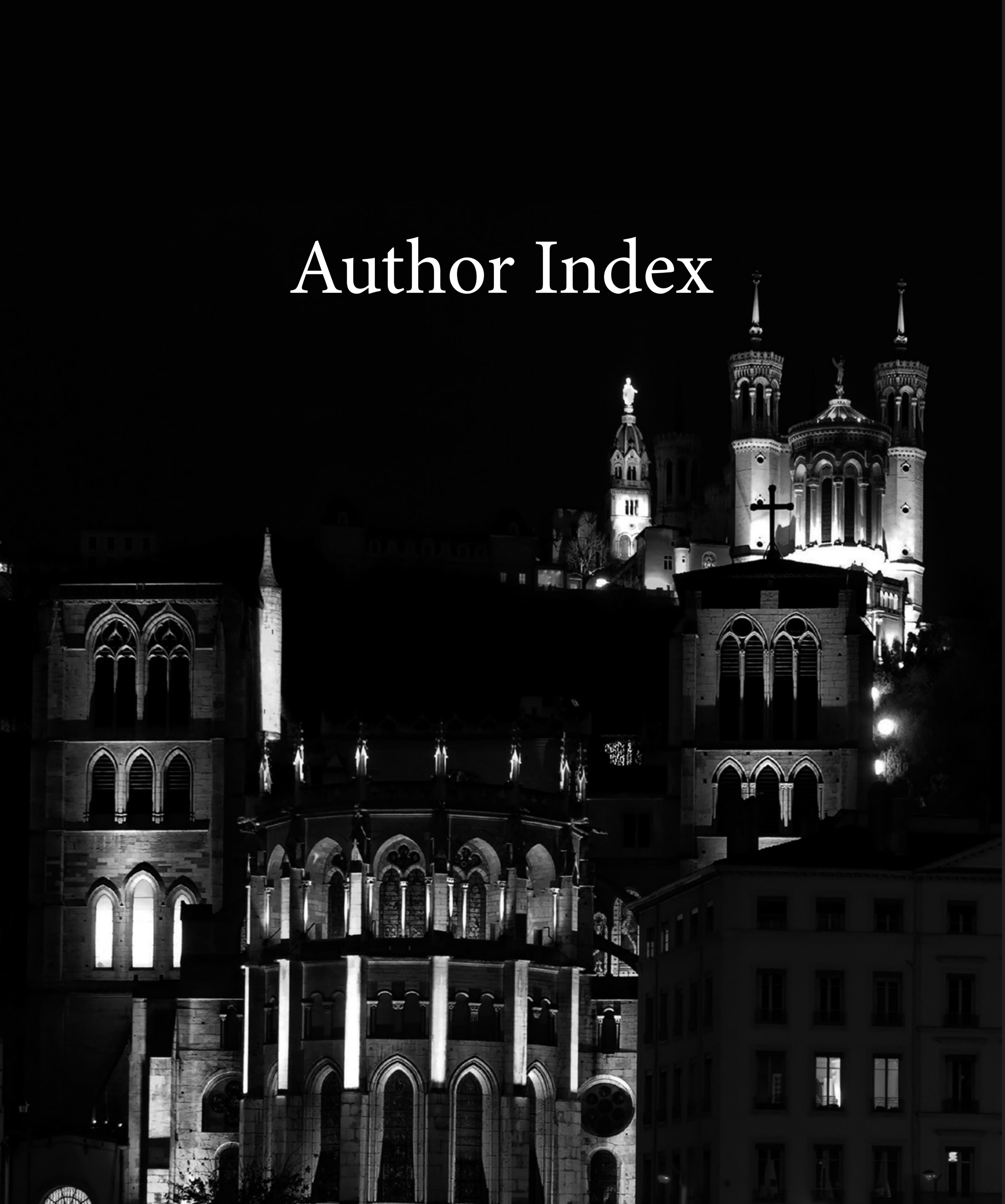

The Scoliosis Research Society gratefully acknowledges K2M for their support of the E-Poster CD-ROM, E-Poster Kiosks, Message Board and Internet Kiosks.

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PRESENTATION KEY
1-129 = Paper/ Podium Presentations   200-306 = E-Posters   PMC= Pre-Meeting Course   CASE= Case Discussion
LTS= Lunchtime Symposium   HDC= Half-Day Course

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Meeting Outline

Meeting Overview

Monday, September 16, 2013		Location
12:00-6:00pm	Board of Directors Meeting	Hilton Lyon
Tuesday, September 17, 2013		
7:00am-5:00pm	SRS Committee Meetings	Gratte-Ciel Level
1:00-5:00pm	Hibbs Society Meeting	Forum 1
2:00-6:00pm	Registration Open	Bellecour Level Lobby
7:00-10:00pm	SRS Leadership Dinner (by invitation only)	
Wednesday, September 18, 2013		
6:30am-6:00pm	Registration Open/ Internet Kiosks E-Posters Open	Bellecour Level Foyer Forum Level Foyer
7:45am-12:20pm	Pre-Meeting Course – Morning Sessions	Forum 5/6; Forum 1
12:35-1:35pm	Lunchtime Symposia Neuromonitoring Lifelong Radiology Exposure to Patients Research Grant Outcomes	 Forum 5/6 Forum 4 Forum 1
1:45-4:30pm	Pre-Meeting Course – Afternoon Sessions	Forum 5/6
4:45-5:45pm	Case Discussions	Bellecour 1, 2, 3; Forum 1
6:00-7:30pm	Opening Ceremonies	Forum 5/6
7:30-9:00pm	Welcome Reception	Forum Level Foyer
Thursday, September 19, 2013		
6:30am-4:30pm	Registration Open/ Internet Kiosks E-Posters Open	Bellecour Level Lobby Forum Level Foyer
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast	Forum 4 Forum Level Foyer
7:55am-12:30pm	Scientific Program	Forum 5/6
9:30am-1:30pm	Guest Hospitality Program	
12:30-1:30pm	Lunch & Networking for Half-Day Course Participants Member Information Session	Forum Level Foyer Forum 1
1:30-4:30pm	Half-Day Courses Myelomeningocele Non-Operative Techniques Sagittal Plane Deformity	 Forum 1 Forum 4 Forum 5/6
Friday, September 20, 2013		
6:30am-5:30pm	Registration Open/ Internet Kiosks, E-Posters Open	Bellecour Level Lobby
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast	Forum 4 Forum Level Foyer
7:55-11:50am	Scientific Program	Forum 5/6; Forum 4
9:30am-1:30pm	Guest Hospitality Program	
12:00-1:00pm	Lunchtime Symposia Culture of Safety in Your Operating Room Global Outreach Update Research Planning	 Forum 1 Forum 4 Forum 5/6
1:15-5:15pm	Scientific Program	Forum 5/6
7:45-11:00pm	Farewell Reception	Les Halles de Lyon - Paul Bocuse
Saturday, September 21, 2013		
6:30am-12:45pm	Registration Open/ Internet Kiosks E-Posters Open	Bellecour Level Lobby Forum Level Foyer
6:30-7:45am	Members Business Meeting Non-Members Continental Breakfast	Forum 4 Forum Level Foyer
7:55-12:45pm	Scientific Program	Forum 5/6
1:00-3:30pm	Board of Directors Meeting	Hilton Lyon