

Scoliosis Research Society 56th Annual Meeting

September 22-25, 2021
St. Louis, Missouri, USA

**FINAL
PROGRAM**



www.srs.org
www.srs.org/am21

Corporate Supporters

We are pleased to acknowledge and thank those companies that provided financial support to SRS in 2021.

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ANNUAL MEETING VENUE

Hyatt Regency St. Louis at The Arch
315 Chestnut Street, St. Louis, Missouri, US, 63102

VIRTUAL MEETING PLATFORM

<http://srs.brightspace.com>



Scoliosis Research
SOCIETY

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Welcome Letter



On behalf of the Scoliosis Research Society, it is my great pleasure to welcome you to the first-ever Hybrid SRS 56th Annual Meeting in St. Louis, Missouri, USA.

For the past 54 years, the Annual Meeting has served as the gathering place for surgeons and scientists who want to know the latest information for the optimal treatment for all patients with spinal deformity. This year will be no different, but with a broader reach and extended audience engagement by providing attendees with the option to attend in-person from the Hyatt Regency St. Louis at The Arch or virtually from an offsite location.

This year there were 933 abstracts submitted from 29 countries. Michael P. Kelly, MD and the Program Committee have done outstanding work in reviewing all of the submissions and putting together a truly outstanding scientific program.

I would like to thank Munish C. Gupta, MD, our local host in St. Louis who has enthusiastically showed us this beautiful city. Please take some time during the meeting to enjoy the spectacular sites in St. Louis.

The Education Committee, led by Committee Chair, Amer F. Samdani, MD, have put together an excellent program, beginning on Wednesday morning with the Pre-Meeting Course titled, *Spine is Just the Tip of the Iceberg: Comprehensive Management of the Patient with Spine Deformity and Surgeon*. After the Pre-Meeting Course, there are three concurrent lunchtime symposia, an abstract session featuring papers on Adolescent Idiopathic Scoliosis, and three concurrent case discussions.

The Annual Meeting will officially begin with the Opening Ceremonies and Welcome Reception on Wednesday evening. The evening will include an introduction of the SRS officers, recognition of the 2020 award winners, presentation of the 2020 and 2021 Walter P. Blount Humanitarian Awards, and this year's Howard Steel Lecturer, Tunç Findik, professional climber, instructor, and motivational speaker. Following the Opening Ceremonies, is a hosted reception featuring hors d'oeuvres, cocktails, and reunions with colleagues and friends.

Thursday morning commences with sessions from the scientific program, followed by presentation of the Harrington Lecture given by Charles E. Johnston, MD, and the Lifetime Achievement Awards presented to Donald P. K. Chan, MD and Robert N. Hensinger, MD.

Industry Workshops, highlighting topics and technologies selected by the supporting companies take place on Thursday during lunch. Delegates are encouraged to attend one of the five concurrent workshops. Half-Day Courses on the topics, *Preoperative Planning for Adult Deformity* and *When New Technology in Pediatric Deformity Grows Up: Lessons Learned* follow the workshops. We conclude Thursday with an Early Career Surgeon Session titled, *Express Yourself*, immediately followed by an Early Career Surgeon Social, hosted by Medtronic.

Friday will be a full day of scientific sessions beginning with the Hibbs Award-Nominated Papers for Best Basic/Translational and Clinical Research. The Members Business Meeting will be held during lunch from 12:30-14:15. During this time, there will also be a lunch session on, *Limits of MIS: A SRS-AANS Collaboration*.

We close the 56th Annual Meeting with a half-day of scientific sessions on Saturday, September 25 from 8:00-12:30 allowing delegates to enjoy St. Louis with friends from around the world in the afternoon.

The SRS staff, led by Executive Director, Ashtin Neuschaefer deserve special recognition for their countless efforts. They make the work of being SRS President so much easier. I also want to thank my fellow Presidential Line colleagues who have made this year significant for me and have advanced our Society; Past President, Paul D. Sponseller, MD; Past President II, Peter O. Newton, MD; President-Elect, Christopher I. Shaffrey, MD; and Vice President, Serena S. Hu, MD.

It has been a pleasure and an honor to serve this year as your President of our extraordinary Society.

Best wishes to all for a great meeting!



Muharrem Yazici, MD
Scoliosis Research Society President 2020-2021

Meeting Information



The Scoliosis Research Society gratefully
acknowledges Medtronic, NuVasive, and
OrthoPediatics for their support
of the Annual Meeting
Welcome Reception.



Annual Meeting Committees

SRS PRESIDENT

Muharrem Yazici, MD

LOCAL HOST

Munish C. Gupta, MD

SRS EDUCATION COUNCIL CHAIR

Suken A. Shah, MD

PROGRAM COMMITTEE

Michael P. Kelly, MD, Chair
Shay Bess, MD, Chair Elect
Lindsay M. Andras, MD, Past Chair
Michael C. Albert, MD
Sébastien Charosky, MD
Steven W. Hwang, MD
Khaled M. Kebaish, MD
David E. Lebel, MD, PhD
Amy L. McIntosh, MD
Joseph H. Perra, MD
Sebastien Pesenti, MD
Amer F. Samdani, MD
Vidyadhar V. Upasani, MD

EDUCATION COMMITTEE

Amer F. Samdani, MD, Chair
Justin S. Smith, MD, PhD, Chair Elect
Baron S. Lonner, MD, Past Chair
Ahmet Alanay, MD
Carlos Eduardo Barsotti, MD
Mark A. Erickson, MD
Arvinder Ghag, MD, FRCS
Munish C. Gupta, MD
Christina K. Hardesty, MD
Ali Humadi, MB, ChB, MS, FRACS
Steven W. Hwang, MD
Charles E. Johnston, MD
Marissa M. Muccio, PT
Luiz Müller Avila, MD
Ibrahim Obeid, MD
Stefan Parent, MD, PhD
Nicolas Plais, MD
Yong Qiu, MD

PROGRAM REVIEWERS

Paloma Bas Hermida, MD
Patrick J. Cahill, MD
Michael S. Chang, MD
Christopher J. DeWald, MD
Charla R. Fischer, MD
Sumeet Garg, MD
Joseph P. Gjolaj, MD, FACS, FAOA
Ryan C. Goodwin, MD, MBA
Mari Louise Groves, MD
Jeffrey L. Gum, MD
Yong Hai, MD
Darrell S. Hanson, MD
David Lazarus, MD
Darren R. Lebl, MD, MBA
Charles Gerald T. Ledonio, MD
Scott John Luhmann, MD
Kamran Majid, MD
Praveen V. Mummaneni, MD
Ahmad Nassr, MD
Stefano Negrini, MD
Colin Nnadi, FRCS (Orth)
Masayuki Ohashi, MD, PhD
Bangping Qian, MD
Yong Qiu, MD
Juan Carlos Rodriguez-Olaverri, MD, PhD
Byron F. Stephens, MD
Fernando Techy, MD
Khoi D. Than, MD
ZeZhang Zhu, MD, PhD

General Information

MEETING DESCRIPTION

The Scoliosis Research Society (SRS) Annual Meeting is a forum for the realization of the Society's mission and goals, the improvement of patient care for those with spinal deformities. Nine faculty-led instructional course lectures, case discussions, and 180 abstract papers will be presented on an array of topics, including adolescent idiopathic scoliosis, growing spine, kyphosis, adult deformity, minimally invasive surgery, machine learning, and mental health considerations.

LEARNING OBJECTIVES

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

- Analyze current research to inform best practices in clinical care.
- Request appropriate consultations to optimize management of comorbid conditions.
- Identify and support access to mental health resources for the patient and surgical team.
- Appraise and apply non-fusion technologies.
- Assess and critique artificial intelligence guidance.
- Incorporate best practice guidelines, sustainably, for pre-operative planning.
- Integrate approaches and techniques (MIS if applicable) to reduce complications.

TARGET AUDIENCE

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

ACCREDITATION STATEMENT

The 56th Annual Meeting have 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 other (hybrid) activity, 56th SRS Annual Meeting, for a maximum of **37.25 AMA PRA Category 1 Credits™**. Physicians should claim only the credit commensurate with the extent of their participation in each activity.

ATTIRE

Business (suits) or business casual attire (polo or dress shirt, sport coat) are appropriate for all Annual Meeting sessions; ties are not required.

LANGUAGE

Presentations and meeting materials will be provided in English.

WIRELESS INTERNET

Wireless Internet access is available throughout the meeting space.

Network: SRS2021
Password: AM2021

Wireless Internet is supported, in part, by Medtronic.

REGISTRATION DESK HOURS

Location: Grand Foyer, Fourth Floor

Tuesday, September 21	12:00-17:00
Wednesday, September 22	6:00-19:00
Thursday, September 23	7:00-19:00
Friday, September 24	7:00-17:00
Saturday, September 25	7:30-10:00

SPEAKER UPLOAD AREA

Room: Mills 3

Presenters may upload their presentations onsite in the Speaker Ready Room. Presentations should be uploaded no later than 24 hours before the session is scheduled to begin.

Tuesday, September 21	12:00-18:00
Wednesday, September 22	6:00-20:00
Thursday, September 23	6:30-19:00
Friday, September 24	6:30-18:00
Saturday, September 25	7:30-12:30

CME CERTIFICATES

CME certificates will be available to pre-registered delegates upon the opening of the meeting at <https://www.srs.org/am21/cme-evaluations>. Delegates who register onsite may access their certificates beginning October 20.

To claim CME, delegates will need to enter their last name and SRS ID. The system will ask delegates to indicate which sessions they attended, and then will generate a PDF certificate which may be printed or saved to the delegate's computer.

CME certificates will not be mailed or emailed after the meeting. The online certificate program is the only source for this documentation. Please contact SRS at cme@srs.org with any questions.

TAKE THE SCIENCE HOME

Included with your registration materials is a complimentary USB containing the 56th Annual Meeting E-Posters.

#SRSAM21



General Information

ABSTRACT VOLUME

All abstracts accepted for presentation at the 56th Annual Meeting are published in the Final Program (pages 79-204). All in person meeting attendees will receive one copy of the program along with their registration materials. Abstracts are also available online on the Program page of the SRS Annual Meeting website (www.srs.org/am21/program) and in the Annual Meeting mobile app.

E-POSTERS

There are 75 E-Posters available for your review on the virtual meeting platform in the E-Poster module. E-Posters are also available on the USB included with in-person meeting registration materials.

LIVE WEBCAST

On Friday, September 24 the SRS-AANS Lunchtime Symposium on Limits of MIS will be webcast live. More information about the webcast is available on the Annual Meeting website, www.srs.org/am21.

The webcast is supported, in part, by NuVasive.

ANNOUNCEMENT BOARD

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

NAME BADGES

Official name badges are required for admission to all Annual Meeting sessions, breaks, and lunches. Meeting attendees will receive a name badge with their registration materials. Name badges are required to be worn while inside the meeting venue, 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.

EVALUATIONS

Please take time to complete the evaluations for each session you attend. Session evaluations and the overall meeting evaluation are available on the AM21 Meeting App. Your input and comments are essential in planning future Annual Meetings.

VIRTUAL MEETING ACCESS

Online Platform: <https://srs.brightspace.com/>

The Annual Meeting online platform is available to in-person and virtual-only meeting delegates September 20 through December 31, 2021. If you were unable to attend a concurrent session, you can watch it on-demand after the meeting. To access the virtual content, go to <https://srs.brightspace.com>, login with your SRS username and password, and select the 56th Annual Meeting listed under "My Courses".

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 Meeting.

CELL PHONE PROTOCOL

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

NO SMOKING POLICY

Smoking is not permitted during any Annual Meeting activity or event.

PHOTOGRAPHY POLICY

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

SRS MEETING BAGS

SRS has decided to take a greener approach in 2021 and not produce meeting bags in order to save resources. We invite Annual Meeting delegates to bring a previous year's bag to see who has the oldest, most interesting, and/or most worn SRS bag.



General Information

VIDEO RECORDING PROHIBITED

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

SPECIAL NEEDS

If you have any health issues for which you may require special accommodations or assistance, please notify a SRS staff member. SRS will make every effort to accommodate any special needs.

EMERGENCY & FIRST AID

The Hyatt Regency St. Louis at The Arch is fully prepared to handle emergency requests and first aid. Contact a SRS staff person for support. Remember to note all emergency exits within the venue.

DISCLOSURE OF CONFLICT OF INTEREST

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

FDA STATEMENT (UNITED STATES)

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

INSURANCE/LIABILITIES AND DISCLAIMER

SRS will not be held liable for personal injuries or for loss or damage to property incurred by participants or guests at the Annual Meeting including those participating in tours, social events or virtually. Participants and guests are encouraged to take out insurance to cover loss incurred in the event of cancellation, medical expenses or damage to or loss of personal effects when traveling outside of their own countries.

SRS cannot be held liable for any hindrance or disruption of the Annual Meeting proceedings arising from natural, political, social or economic events or other unforeseen incidents beyond its control. Registration of a participant or guest implies acceptance of this condition.

The materials presented at this Continuing Medical Education activity are made available for educational purposes only. The material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement, or opinion of the faculty that may be helpful to others who face similar situations.

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

SRS Membership

Apply Today: www.srs.org/membership



Session and Event Information

HIBBS SOCIETY MEETING

Tuesday, September 21 | 13:00-17:00

Available to in-person meeting delegates for an additional fee of \$50.

Over the years, the Russell A. Hibbs Society, formed in 1947 as an international travel club for continuing medical education and furthering orthopaedic knowledge, has held an educational meeting at the SRS Annual Meeting. These meetings address difficult and complex issues that do not lend themselves to the usual kind of scientific presentations. The meeting encourages interaction among international participants and new ideas, new concepts, and reports on personal experience.

OPENING CEREMONIES AND WELCOME RECEPTION

Wednesday, September 22 | 17:30-20:45

The Annual Meeting will officially begin with the Opening Ceremonies and this year's Howard Steel Lecturer, *Tunç Fındık*, professional climber, instructor, and motivational speaker. The evening will include an introduction of the SRS officers, presentation of the Walter P. Blount Humanitarian Awards, and highlights from 2020. Following the Opening Ceremonies, we will move to a hosted reception featuring heavy hors d'oeuvres, cocktails, and plenty of lively conversations with colleagues and friends. See page 55 for the Opening Ceremonies agenda.

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

EARLY CAREER SURGEON SESSION

Thursday, September 23 | 17:35-19:05

The Early Career Surgeon Session is a part of SRS's recently developed Early Career Surgeon Program. The session features tips and tricks for the early career surgeon and offers a unique opportunity for SRS members and non-members to interact closely with their early career peers and senior experts, through didactic case-based discussion.

The Early Career Surgeon Session is supported, in part, by Globus Medical, Inc.; Medtronic; NuVasive; and Zimmer Biomet.

EARLY CAREER SURGEON SOCIAL

Thursday, September 23 | 19:05-20:30

Immediately following the Early Career Surgeon Session is an Early Career Surgeon Social hosted by Medtronic.

The social will include light refreshments, beverages, and an opportunity to connect with colleagues and friends.

INDUSTRY WORKSHOPS

Thursday, September 23 | 13:30-15:00

Delegates are encouraged to attend the industry workshops on Thursday, September 23 from 13:30-15:00. Each workshop is programmed by a single-supporting company and features presentations on topics and technologies selected by the company. Boxed lunches will be available during the workshops. CME credits are not available for workshops. See pages 59-60 for more information.

MEMBER BUSINESS MEETING

Friday, September 24 | 12:30-14:15

All SRS members are invited to the Member Business Meeting on Friday, September 24. Agendas will include reports from the various SRS committees, updates on SRS activities and programs, and voting. Voting will take place electronically. Directions will be provided during the Business Meeting as well as via email.

Current Concepts in 
SPINE DEFORMITY

Online | Self-paced Course: November 1 - December 31, 2021
Live Case Discussions: December 4-5, 2021

 **Scoliosis Research Society**

www.srs.org/ccsd

Annual Meeting App

A mobile app delivering content, networking, engagement, and navigation all in one convenient location is available to all delegates during the meeting.

DOWNLOADING THE APP

1. Go to your device's app store and search for *SRS 56th Annual Meeting*.
2. Select the meeting app and install.

PUSH NOTIFICATIONS

Apple and Android device users who have downloaded the meeting app can receive push notifications including reminders and schedule changes. Upon downloading the app, you must provide permission to receive these notifications on your device. You can update these permissions at any time within the Settings area of your device if necessary.

USING THE APP

1. Open the downloaded app and enter your email address to sign up or log in.
2. If you already have an account, you will be asked to enter your password. If you do not already have an account, you will be prompted to create a password and add profile information (optional).
3. The app can also be accessed by entering the URL, www.eventmobi.com/am21 on any current internet browser.
4. Once you are logged in, all event information will be readily available.

USER DASHBOARD

Click the icon in the top-right corner to access the User Dashboard. Here, you can find your personal schedule, notes you have taken, companies you have added to your favorites, documents you have added to your collection, and your chat inbox.

EVENT MENU

Access the event menu by clicking the Menu icon in the top-left corner. Here, you will find a list of sections that contain all of the event content, from speakers and sessions to meeting information and social media links. Select the section you are interested in and navigate through to find the information.

ASK A QUESTION IN THE APP

If you see the Q&A feature within a session page, you can submit pertinent questions and comments to the moderator during that session. You can submit as many questions as you would like and view questions submitted by other attendees.

1. From the Agenda, click on the session you are in and then click the Q&A tab.
2. Type your question within the question box and hit "Submit". Your question will appear within the question list.
3. To upvote a question, click the up arrow to the right of the question in the list.

LIVE SESSION POLLS

Live session polls can be found within the session pages in the Agenda. Participate in a poll by clicking the "Polls" tab, selecting your answer, and hitting the "Submit" button. You can navigate from question to question by using the arrows to the left and right of the Submit button. You can also find polls in the "Polls and Surveys" section of the app.

Moderators can display the poll results live on screen for the entire audience to view.



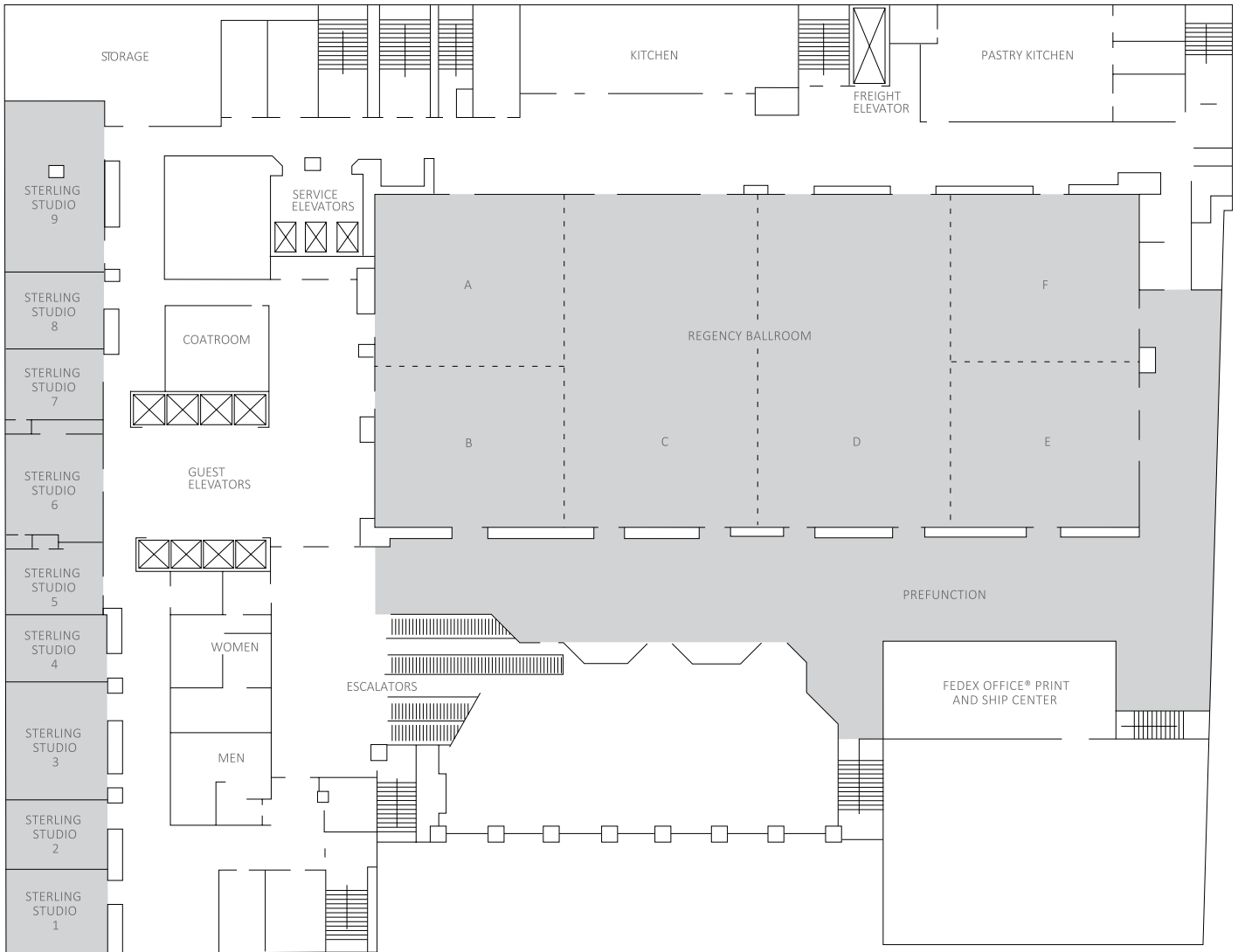
GAME ON!

This year we have added a new element to the Annual Meeting App- **Gamification**. It is a unique way to interact with your peers and engage with the presenters by collecting codes to earn points. Download the app and on the first screen, you will get your first code. Pick up a second code at the registration desk. Are you on Facebook, Twitter or Instagram? Share our content and earn another code. Want a free code right now? Enter **program** in the Gamification tab within the app.

The app includes the details on points available and other ways to earn them. Delegates with the most points will collect SRS merchandise and/or a free registration to the 29th IMAST in Miami, USA. The app also includes a leader board so you can see who is earning the highest points throughout the week.

Meeting Space Floorplans

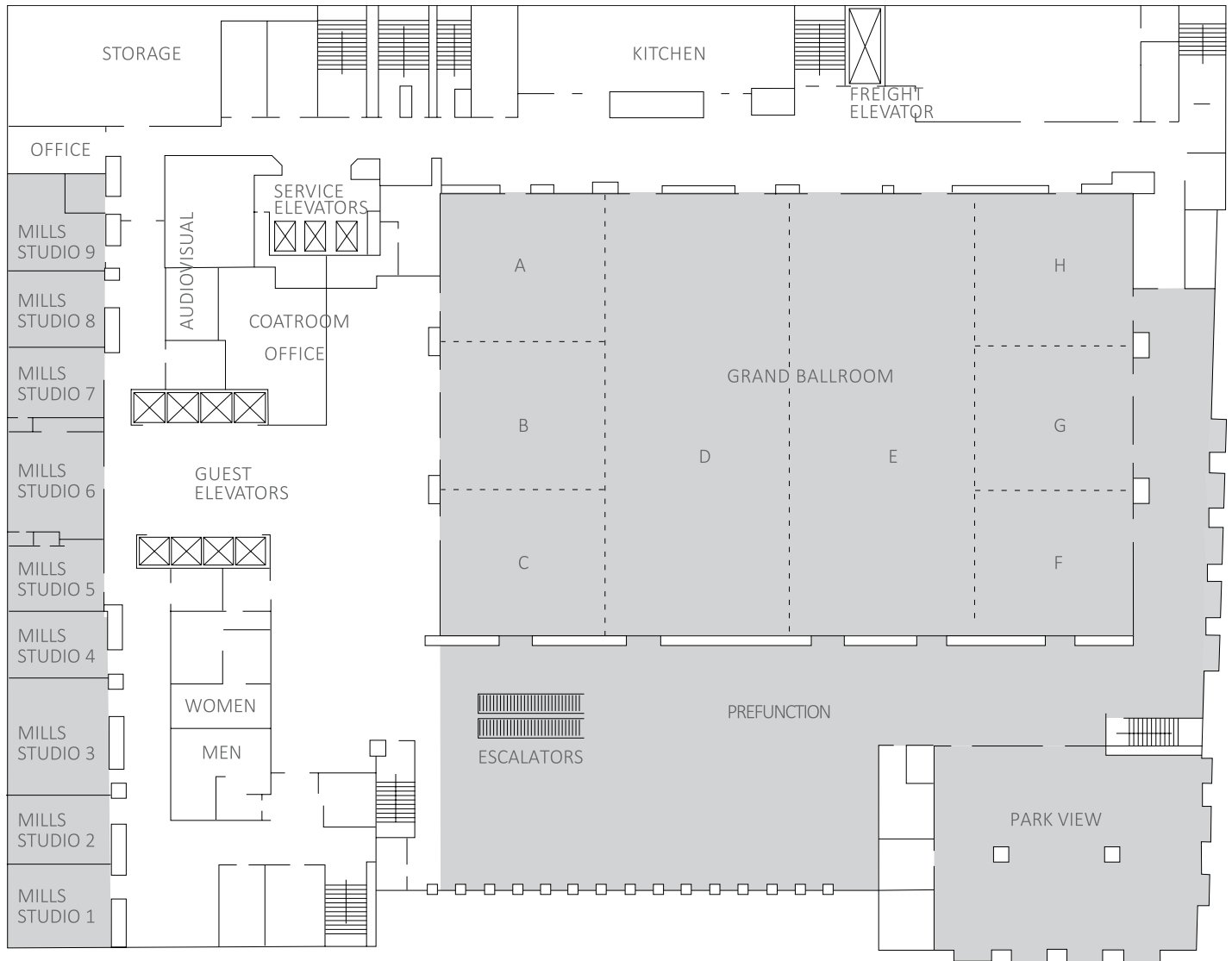
SECOND FLOOR



ROOM	FUNCTION
Regency ABC	Concurrent Session, Industry Workshop
Regency DEF	Concurrent Session, Industry Workshop
Sterling 3	Education Council Meeting, Pop-up Meeting Room 1
Sterling 6	Research Council Meeting, Pop-up Meeting Room 2
Sterling 7	Finance & Communications Council Meeting
Sterling 8	Governance Council Meeting
Sterling 9	Board of Directors Meeting (Mon. & Tues.)

Meeting Space Floorplans

FOURTH FLOOR



ROOM

FUNCTION

Grand Foyer	Registration
Grand Ballroom	General Session, Opening Ceremonies
Grand Ballroom ABCD	Industry Workshop
Grand Ballroom EFGH	Industry Workshop
Park View	Industry Workshop, Early Career Surgeon Session, Early Career Surgeon Social, Past Presidents Breakfast, Board of Directors Meeting (Sat.)
Mills 1	Double Diamond Hospitality Suite: Medtronic
Mills 2	Double Diamond Hospitality Suite: Globus Medical, Inc.
Mills 3	Speaker Ready Room
Mills 4	Double Diamond Hospitality Suite: DePuy Synthes
Mills 5	Double Diamond Hospitality Suite: Zimmer Biomet
Mills 6	Video Recording
Mills 7	Double Diamond Hospitality Suite: Stryker
Mills 8	Double Diamond Hospitality Suite: NuVasive

ST. LOUIS ARCH ▶

Meeting Outline

MONDAY, SEPTEMBER 20, 2021

8:00-14:00	SRS Board of Directors Meeting*	Sterling 9
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TUESDAY, SEPTEMBER 21, 2021

8:00-11:00	SRS Board of Directors Meeting*	Sterling 9
11:00-12:00	Council Meeting Lunch*	Foyer Outside of Sterling 3, 6, 7, 8
11:30-13:00	Council Meetings*	Sterling 3, 6, 7, 8
12:00-17:00	Registration Open*	Grand Foyer
12:00-18:00	Speaker Ready Room Open*	Mills 3
13:00-17:00	Hibbs Society Meeting	Regency DEF
18:30-21:30	SRS Leadership Dinner* (by invitation only)	<i>Offsite</i>

WEDNESDAY, SEPTEMBER 22, 2021

6:00-20:00	Speaker Ready Room Open*	Mills 3
6:00-19:00	Registration Open*	Grand Foyer
7:30-12:00	Pre-Meeting Course	Grand Ballroom
12:00-12:30	Boxed-lunch Pick-up*	
12:30-13:30	Lunchtime Symposia (3 Concurrent Sessions)	Grand Ballroom, Regency ABC, Regency DEF
13:30-14:00	Break*	
14:00-15:30	Abstract Session 1	Grand Ballroom
15:30-16:00	Refreshment Break*	Grand Foyer
16:00-17:00	Case Discussions (3 Concurrent Sessions)	Grand Ballroom, Regency ABC, Regency DEF
17:00-17:30	Break*	
17:30-19:45	Opening Ceremonies*	Grand Ballroom
19:45-20:45	Welcome Reception*	Grand & Regency Foyers

THURSDAY, SEPTEMBER 23, 2021

6:30-19:00	Speaker Ready Room Open*	Mills 3
7:00-19:00	Registration Open*	Grand Foyer
8:00-9:55	Abstract Session 2	Grand Ballroom
9:50-10:25	Refreshment Break*	Grand Foyer
10:25-12:45	Abstract Session 3 and Harrington Lecture	Grand Ballroom
12:45-13:30	Boxed-lunch Pick-up*	
13:30-15:00	Industry Workshops* (5 Concurrent Sessions)	Grand Ballroom ABCD, Grand Ballroom EFGH, Regency ABC, Regency DEF, Park View
15:00-15:30	Break*	
15:30-17:30	Half-Day Courses (2 Concurrent Sessions)	Regency ABC, Regency DEF
17:35-19:05	Early Career Surgeon Session	Park View
19:05-20:30	Early Career Surgeon Social, Hosted By Medtronic	Park View

Meeting Outline

FRIDAY, SEPTEMBER 24, 2021

6:30-7:30	Past President's Breakfast*	Park View
6:30-18:00	Speaker Ready Room Open*	Mills 3
7:00-17:00	Registration Open*	Grand Foyer
8:00-9:50	Abstract Session 4: Hibbs Award-Nominated Papers	Grand Ballroom
9:50-10:20	Refreshment Break*	Grand Foyer
10:20-12:00	Abstract Session 5 and Presidential Address	Grand Ballroom
12:00-12:30	Boxed-lunch Pick-up*	
12:30-14:15	Member Business Meeting and Lunch*	Grand Ballroom
12:30-14:00	Lunchtime Symposium: A SRS-AANS Collaboration	Regency DEF
14:15-14:45	Break*	
14:45-16:10	Abstract Sessions 6 and 7 (2 Concurrent Sessions)	Grand Ballroom, Regency DEF
16:10-16:40	Refreshment Break*	Grand Foyer
16:40-18:05	Abstract Sessions 8 and 9 (2 Concurrent Sessions)	Grand Ballroom, Regency DEF

SATURDAY, SEPTEMBER 25, 2021

7:00-8:00	SRS Board of Directors Meeting*	Park View
7:30-12:30	Speaker Ready Room Open*	Mills 3
7:30-10:00	Registration Open*	Grand Foyer
8:00-10:05	Abstract Session 10	Grand Ballroom
10:05-10:35	Refreshment Break*	Grand Foyer
10:35-12:35	Abstract Session 11	Grand Ballroom

*Denotes Non-CME Session

WIRELESS INTERNET

Network: SRS2021 | Password: AM2021
Wireless Internet is supported, in part, by Medtronic.

Guest Lectures

WEDNESDAY, SEPTEMBER 22

Howard Steel Lecture: K2 the Mountain Of Mountains

By Tunç Fındık



Born in Ankara, Turkey in 1972, Tunç Fındık is a graduate of Ankara Bilkent University Faculty of English Language and Literature. Tunç is a professional climber, climbing instructor, motivational speaker and writer.

Tunç is an overall alpinist with more than 500 new routes; first winter ascents and first ascents in Turkish mountains and

abroad, with a total sum of more than 1000 summits and an uncountable number of short traditional rock climbs and frozen icefalls to his credit. Tunç is a member of the Turkish Alpine Club (TDF) as well as being a member of Zirve Alpine Club of Turkey, the local athlete for The North Face, and a member of Grivel team.

Tunç Fındık is the first Turkish person to summit Mount Everest twice, from different routes. He is running his project of 14x8000, climbing all the summits above 8000-meter altitude on our planet. His 13 8000 meter summits include Everest 8850m, K2 8611m, Kanchenjunga 8586m, Makalu 8463m, Dhaulagiri 8167m, Cho Oyu 8205m, Lhotse 8516m, Shishapangma 8013m, Manaslu 8163m, Gasherbrum II 8035m, Annapurna 8091m, Gasherbrum I 8058m, and Broad Peak 8047m.

Tunç has climbed in Nepal, China, Pakistan, Kazakhstan, Kyrgyzstan, Tajikistan, Russia, France, Georgia, Switzerland, Italy, Bulgaria, England, Iran, Argentina, Tanzania, and Kenya.

He has translated books about climbing and mountains from English to the Turkish language. He is also the author of the only existing Turkish climbing guidebook to the Kackar range in northeastern Turkey *Kackar-Vercenik Guide* and the author of another detailed and unique guidebook to the Taurus mountain range, *Aladaglar Climbing Guide*. He wrote his own book about his ascent of Mount Everest in 2001 and other adventure books of his own Karakorum climbs, *80 Days in Karakorum*, *Altitude 8000*, *K2- The Mountain of Mountains*, along with his technical instruction book, *Winter Climbing- Technics and Tactics*.

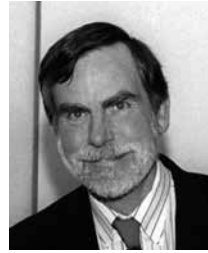
For more information, please visit: www.tuncfindik.com.

Instagram: @tuncfindikclimber

THURSDAY, SEPTEMBER 23

Harrington Lecture: Toward Biologic Treatments Addressing Etiology of Scoliosis

By Charles E. Johnston, MD



Charles E. Johnston, MD (“Charlie”) is assistant chief of staff emeritus at Texas Scottish Rite Hospital for Children, where he has practiced continuously since 1985. A native Southern Californian with strong family ties to south Texas, he graduated from Yale University and Columbia University College of Physicians and

Surgeons, then did a surgical internship in San Antonio, eventually completing orthopedic surgery residency at the UVA Medical Center Charlottesville. He returned to Texas as a Harrington Fellow in Pediatric Orthopaedics and Scoliosis at Texas Scottish Rite Hospital for Children in Dallas 1981-2 (fellowship had no relationship to Dr. Paul R. Harrington).

Dr. Johnston is currently Professor in the Department of Orthopaedic Surgery at the University of Texas Southwestern Medical Center at Dallas. He is a reviewer for The Journal of Bone and Joint Surgery and the Journal of Children’s Orthopaedics. He is a fellow in the American Academy of Orthopaedic Surgeons and serves on the executive committee of the Pediatric Spine Study Group and Foundation. An active member of the SRS since 1987, and has served on and chaired several committees, most recently the Education and Growing Spine committees. He is also a member of the Pediatric Orthopedic Society of North America, receiving its Humanitarian Award in 2020; the European Pediatric Orthopaedic Society; and the Texas Orthopedic Association.

Dr. Johnston has published over 150 papers in peer-reviewed journals and approximately 30 books chapters. Most important, Charlie and Ellen have been married for 45 years; have two daughters and five grandchildren.

Award Recipients

2021 WALTER P. BLOUNT HUMANITARIAN AWARD

Presented for outstanding service to those with spinal deformity and for generosity to the profession and Society. The 2021 Blount award will be presented on Wednesday, September 22.

Kenneth MC Cheung, MD



Kenneth MC Cheung, MD is internationally recognized for his work on intervertebral disc degeneration and low back pain. He is part of a multidisciplinary team of clinicians and scientists working on understanding the cause of degenerative disc disease (DDD) and ways to prevent it. Over the past 18 years, he has collected the largest cohort of population-based individuals in the

world with MRI phenotypes and DNA, the so-called Hong Kong DDD cohort. Using this unique resource, they have discovered novel pre-disposing genes such as CHST3 (Journal of Clinical Investigation 2013), and have altered the understanding of clinicians to DDD. In the last 5 years alone, they have published 37 original peer reviewed manuscripts, of which Prof. Cheung is the first or corresponding author on 16.

Prof. Cheung's positions and honors include Jessie Ho Professor in Spine Surgery, Head of Department of Orthopaedic and Traumatology, Chair Professor, Editor-in-Chief for the Journal of Orthopaedic Surgery, and Past-president of the Scoliosis Research Society.

He is a well-recognized global leader in the treatment of spinal deformities. Prof. Cheung and his group have published extensively on a new method of assessment of flexibility of the spine using the "fulcrum bending" technique. Since its original description in 1997, the technique has been adopted as the standard by nearly 50% of spine surgeons around the world. In addition, Prof. Cheung carried out a first-in-man clinical trial using a novel magnetically controlled growing rod for scoliosis correction in young children. The work was published in Lancet in 2012, and received global press coverage at the time. It also won the faculty's research output prize that year. Objective evidence of global leadership in spine deformities, include his recent election to become the Vice-President of the Scoliosis Research Society. In 2016, he became the President of the Scoliosis Research Society. This was a historic event for this international learned society, as he was the first President in its 55-year history to be from outside of North America.

Prof. Cheung's research interests are in the genetics of intervertebral disc degeneration and scoliosis, stem cell regeneration of the disc, and the development of novel surgical technologies for the treatment of spinal deformities. He has been invited as visiting professor and speaker on multiple occasions to international meetings. He has published 14 book chapters and 300 publications in top scientific and spine journals, including Lancet, American Journal of Human Genetics, Arthritis and Rheumatism, Biomaterials, Journal of Bone and Joint Surgery and Spine.

2021 LIFETIME ACHIEVEMENT AWARDS

Presented to members who have exhibited long and distinguished service to SRS and to spinal deformity research and care. The 2021 Lifetime Achievement awards will be presented on Thursday, September 23.

Donald P. K. Chan, MD



Dr. Donald P.K. Chan was born and raised in Rangoon, Burma, and he received his medical degree in 1960 from the University of Rangoon. His advanced training was done at the University of Hong Kong Queen Mary Hospital, where he pioneered the development of anterior spinal techniques with Professor Hodgson.

Dr. Chan and family immigrated to the United States in 1968 to do a residency at University of Vermont, after which he became board certified. He was awarded the SRS traveling fellowship, which he chose to spend at Harvard University Boston Children's under Dr. John Hall and University of Rochester Strong Memorial Hospital under Dr. Louis Goldstein.

Dr. Chan joined Strong Memorial Hospital in 1972 as Assistant Professor and quickly rose to become Chief of Spine in 1974 and served through 1994. During his tenure in Rochester he directed the Goldstein Spine Surgery Fellowship. He then joined University of Virginia where he was Professor and Chief of the Division of Spine Surgery from 1994 to 2004 and consultant to the Department of Neurosurgery. In 2000 Dr. Chan was appointed the Warren G. Stamp Professorship in Orthopaedic Surgery.

Dr. Chan is acclaimed for his surgical techniques and traveled the world to train surgeons in spinal surgery. Highly regarded for his work in the treatment of patients with scoliosis and other spinal deformities, Dr. Chan has contributed significantly to the procedures of spinal instrumentation and fusion.

He was involved in the development of Moiré topography, a technique for acquiring contour images of childrens' torsos, to reduce radiation exposure during follow up. He was also involved in developing a machine for monitoring spinal cord function during surgery.

He is a past President of the SRS (1997-1998). Dr. Chan believed in the importance of opening up the SRS to foreign surgeons and encouraged the SRS to broaden its membership. From 1997 through 2015 he served on many SRS Committees, including the Governance Council, Worldwide Conference, Ethics Committee (Chair), and Global Outreach. In 2005 he served as SRS Senior Traveling Fellow and arranged for his three SRS fellows to visit spine centers in Sapporo, Seoul, Beijing, Hong Kong, Bangkok, and Singapore. In 2015 he participated as a panel member in the SRS "Legends of Spine".

Award Recipients

Throughout his career, he returned to Asia and was instrumental in developing spine programs in Singapore, Indonesia, Taiwan, and Thailand, where he was honored by the Royal Family. Dr. Chan has served extensively as a visiting professor across Asia, Europe and Latin America.

Dr. Chan was a member of the Diversity committee of the AAOS, Chairman of the Committee on Awards and Honors of the AOA, and member of the Committee on Awards and Honors of the NASS. He served on the editorial board of the Journal of Neurosurgery, Spine, the Journal of American College of Surgeons, and the Journal of Occupational Rehabilitation.

There are two endowments under Dr. Chan's name. The endowment at University of Rochester continues to invite scholars to do laboratory research, and the endowment at University of Virginia sponsors visiting professors.

Since his retirement, Dr. Chan has been involved with philanthropic work. He is Chairman of the Board of Directors of Care For Peace, a nonprofit organization dedicated to general health-care in rural Myanmar. He is responsible for having set up a rural health clinic, which required installation of electricity, running water, and internet connectivity. This facility was donated to Myanmar's Ministry of Health. In 2020, during the early stages of the COVID-19 pandemic, Dr. Chan secured a donation of PPEs from MedShare, and personally shipped packages to four regional clinics in Myanmar for the protection of healthcare staff.

Robert N. Hensinger, MD



Dr. Hensinger was born and raised in Jackson, Michigan. He attended the University of Michigan and earned a Bachelor of Arts in 1960. He was accepted to the University of Michigan Medical School and graduated in 1964. He completed an internship and first year residency in Surgery at the University of Michigan. From 1966-1968 he served in the United States

Navy as a Submarine Medical Officer. He returned to Michigan and finished his residency in Orthopaedic Surgery, under the direction of William S. Smith. At the completion of his training in 1971, he moved to the Alfred I. DuPont Institute in Wilmington, Delaware for a fellowship in Pediatric Orthopaedics with G. Dean MacEwen. He remained on the faculty, returning to the University of Michigan in 1974 as the first Pediatric Orthopaedist at the University of Michigan.

He was promoted to full Professor of Surgery, Section of Orthopaedics in 1981. Dr. Hensinger was selected to be the Orthopaedic Section Head in 1996. In 2001, he was named the William S. Smith Collegiate Professor of Orthopaedic Surgery and Chairman of the Department of Orthopaedic Surgery. Dr. Hensinger was very active in his professional societies and was elected to several leadership positions including Pediatric Orthopaedic Society of North America- Secretary 1983-1985 and President 1985-1986. Scoliosis Research Society- Secretary 1982-1986 and President 1988-1989. American Academy of Orthopaedic Surgeons-Secretary 1990-1992 and President 1992-1993.

During his career, he received many honors and awards. Arthur H. Huene Memorial Award, for outstanding contributions to Pediatric Orthopaedics- 1999. Distinguished Achievement Award the Pediatric Orthopaedic Society of North America- 2005. Distinguished Service Award from the University of Michigan Alumni Society- 2005. With the help of his patients, associates, and former residents,- The Robert N. Hensinger, MD Collegiate Professorship was established in 2013.

He has had over 200 publications in peer-reviewed journals and 40 chapters on all aspects of orthopedic issues in the growing child. He published 12 books; the topics include Management of Multiply Impaired Children, Neonatal Orthopaedics, Pediatric Spine, and Standards in Pediatric Orthopaedics. In 1980, he and Lynn Staheli, MD founded the Journal of Pediatric Orthopaedics, now in its 41st year. Dr. Hensinger continues as the Editor-In-Chief providing peer reviewed scientific reports for the entire community of Pediatric Orthopaedic practitioners. He was particularly proud of his work with the late Frank H. Netter, MD in developing two Ciba Clinical Symposiums- Congenital Dislocation of the Hip and in conjunction with Hugo Keim, MD- Spinal deformities. Scoliosis and Kyphosis.

2021 ANNUAL MEETING AWARDS

The 2021 Annual Meeting awards for the best basic/translational science and clinical research papers (Russell A. Hibbs Awards) and the best basic/translational science and clinical research e-posters (John H. Moe and Louis A. Goldstein Awards) at the 56th Annual Meeting will be presented on Saturday, September 25.

2020 Award Recipients

2020 WALTER P. BLOUNT HUMANITARIAN AWARD

Presented for outstanding service to those with spinal deformity and for generosity to the profession and Society. The 2020 Blount award will be presented on Wednesday, September 22.

Francisco Javier Sánchez Pérez-Grueso Sr., MD



Dr. Francisco J. Sánchez Pérez-Grueso was born in Toledo, Spain. He completed his medical school at the Universidad de Salamanca and did his Orthopedic Surgery residency program at Hospital Universitario La Paz, Madrid. After his Residency, he joined the Spinal Deformity Unit as a staff member and soon after started a surgical program on pediatric spinal deformity surgery.

He expanded his training in spine deformity surgery visiting different specialized international centers (The Robert Jones and Agnes Hunt Orthop. Spine Disorders Dep. Oswestry, UK; Deutsches Skoliosezentrum, Bad Wildungen, Germany; Hospital Saint Vincent de Paul, Paris; Hospital for Special Surgery, New York, USA). He was promoted to Chief of the Spine Unit Hospital La Paz in 2006 until his retirement in October 2018. He has been appointed Emeritus of Madrid Health System developing his research activity at Hospital La Paz.

His membership with the SRS began in 1995. He served on the Growing Spine, Global Outreach, and Globalization Committees. He became chair of the Growing Spine Committee in 2009, Director at large in the SRS Board from 2010 to 2012, and senior SRS travelling fellow in 2018.

He began working in Ghana in 2003 as part of the FOCOS initiative led by Dr. Oheneba Boachie-Adjei. For over 10 years he worked with a group of committed surgeons focused on helping children suffering from severe spine deformities. Ultimately, the Foundation was able to establish the FOCOS teaching hospital, which currently trains orthopaedic surgeons from Ghana and across West Africa.

Also alongside Dr. Boachie, they established the curriculum for the development program of spine surgeons in Sofia, Bulgaria, sponsored by the SRS. After a year of navigating administrative hurdles, the first surgery took place in 2008, working together with Dr. Steve Mardjetko. In the subsequent four years, the project helped local surgeons lead by Dr. Yablansky to achieve full autonomy in performing complex spine surgery.

In May 2017, there was a gathering to mark the 10-year anniversary of the program in Plovdiv, where the founders joined local surgeons, as well as Dr. David Clements and Dr. Ahmet Alanay, who have continued with the initiative.

Throughout these years in Spain, he developed a great activity in the dissemination of new concepts and techniques in the treatment of spinal deformities. In 2004 he became the president of the Spanish Spine Society (GEER) from 2004 to 2006.

Within his research activity, his participation in different Study Groups (GSSG and ESSG) stands out. He has published more than 50 peer-reviewed papers and more than 100 podium presentation in national and international meetings.

2020 LIFETIME ACHIEVEMENT AWARDS

Presented to members who have exhibited long and distinguished service to SRS and to spinal deformity research and care. The 2020 Lifetime Achievement awards will be presented on Wednesday, September 22.

Jean Dubousset, MD



Jean Dubousset, born in 1936, is a pediatric orthopedic surgeon, now retired from clinical work. He received his medical education at Clermont Ferrand and Paris Universities, graduating with his MD in general surgery in 1965. He practiced pediatric orthopedics both privately and publicly in Paris until 1979, then moved to full time public practice at St. Vincent de Paul

hospital for his entire remaining career, and acted as Professor of Pediatric Orthopedic surgery until 1991. He became a Member of the National Academy of Medicine and a member of the French Academy of Surgery in 2002. He was also member of the scientific committee of the Yves Cotrel Foundation at the Institut de France and is Chevalier de la Légion d'Honneur (2000).

Jean Dubousset has participated in the SRS Annual meeting almost every year beginning in 1969. He attended the meeting in Anaheim alongside Christian Salanova and Pierre Stagnara and after a 6 week tour of important scoliosis institutions in the US, he later returned to France with his new knowledge of the Halo device and the Milwaukee brace. He became a corresponding member of SRS in 1978, then Active Fellow, and is currently an Emeritus Member. He was the Harrington lecturer of the SRS at the Ottawa meeting of 1996 under the presidency of Vernon Tolo, and got the prestigious W. Blount Humanitarian award of the Society in 2010.

After reading the book of Hodgson in 1970, Jean Dubousset introduced France to wide anterior spine surgery in children. After working on paralytic pelvic obliquity in preparation for the GES (A French scoliosis Study group founded in 1969 on the model of SRS) Meeting in 1973 in Paris, he introduced the 3D basic principles for spinal pathology describing pelvic & cephalic vertebra concepts leading to economical conical balance system in humans. He is Co-inventor with Yves Cotrel of CD instrumentation for spine surgery in 1983, which describes the succession of scoliotic curves along the gravity line axis of the body with their apical and junctional zone, and is useful for the segmental instrumentation as well as the rotation maneuver of the rods and important for the strategies for correction. He performed the first CD instrumentation in the US at the Leatherman Center in Louisville in 1985 and soon after in Boston with John Hall.

2020 Award Recipients

He was an active developer of GICD study group, travelling and teaching all over the world. With his wife, Anne Marie, he spent 1987 on sabbatical in the USA, half in Miami with Harry Shuflebar and the other half at Texas Scottish Right Hospital in Dallas with Tony Herring's team. During his sabbatical year in the USA, he did important work researching about etiology of idiopathic scoliosis and doing experimental research in chickens after a pinealectomy and the role of melatonin in its initiation which was presented at the SIROT meeting in 1988. His work continued with Masafumi Machida in Japan, later being presented and receiving awards at the 2016 SRS Annual Meeting in Prague.

He also had the opportunity during his sabbatical year in the US to develop the use of ILIZAROV system to perform salvage procedures of difficult spinal problems, elongating or shortening by compression of the pathological deformities.

Jean Dubousset was the initiator of the EOS imaging low dose radiation system, thanks to his collaboration with George Charpak (Nobel Prize winner) and Biomechanics engineers from ENSAM Paris and LIO Montreal. Creating a 3D computer reconstruction of the entire skeleton in a standing functional position, the first application was at St Vincent de Paul Hospital in Paris in 2000.

Jean Dubousset is a member of the most important scientific societies all over the world regarding pediatric orthopedics, especially spine, general pediatrics, and pediatric tumor diseases with many distinctions. He still continues to research human biomechanics focusing on Etiology of AIS and the importance of transversal plane of the body and on the consequences of ageing on the spinal alignment.

Finally Jean Dubousset's artistic activities include modern stained glass restoration of the destroyed windows of a 15th century church close to his country side family house. He also creates smaller picture pieces using original techniques.

Stuart L. Weinstein, MD



Dr. Weinstein is the Ignacio V. Ponseti Chair and Professor of Orthopaedic Surgery and Professor of Pediatrics at The University of Iowa. Dr. Weinstein received his A.B. Honors degree in Political Science and History from the University of Illinois in 1968. He received his medical degree (Alpha Omega Alpha) from the University of Iowa in 1972. After interning in Internal

Medicine at The University of California San Francisco, he returned to the University of Iowa for a residency in Orthopaedic Surgery. In 1976 he joined the faculty of the Department of Orthopaedic Surgery at The University of Iowa.

Dr. Weinstein was an NIH funded researcher. He has published more than 260 scientific articles in peer review journals (including the NEJM, JAMA, The Lancet, Nature). His research work has focused on spinal deformity in children and the natural history and long-term outcome of pediatric musculoskeletal conditions. He has edited three major textbooks including *The Pediatric Spine: Principles and Practice*; *Lovell and Winter's Pediatric Orthopaedics* and *Turek's Orthopaedics*.

Dr. Weinstein's many contributions to orthopaedics have been recognized by his receipt of the Bristol-Myers Squibb/Zimmer Award for Distinguished Achievement in Orthopaedic Research; The Kappa Delta /Orthopaedic Research and Education Foundation Clinical Research Award (1998 and again in 2015- for the Evidence Base for the Prognosis and Treatment of Adolescent Idiopathic Scoliosis); The ABJS/CORR Nicolas Andry Award for research (2018); The Russell Hibbs Award for Clinical Research (1998, 2014, 2015) given by the Scoliosis Research Society; and The Arthur H. Heune Memorial Award, given by the St. Giles Foundation and The Pediatric Orthopaedic Society of North America. In 2005, Dr. Weinstein was the recipient of the Alfred R. Shands, Sr., MD Award, presented by the Orthopaedic Research Society and The American Orthopaedic Association for his significant contributions to orthopaedics and his devotion of a professional lifetime to furthering knowledge in the fields of musculoskeletal disease.

Dr. Weinstein received the 2000 Iowa Board of Regents Award for Faculty Excellence for sustained record of excellence across the spectrum of faculty endeavors. In 2003, he received the Ernest O. Theilen Clinical Teaching and Service Award presented by the Roy J. and Lucille Carver College of Medicine. In 2009, he received the highest award in the College of Medicine, the Distinguished Mentor Award presented by the Roy J. and Lucille Carver College of Medicine. In 2011, Dr. Weinstein received the William W. Tipton, Jr., MD Award for Outstanding Leadership in Orthopaedics from the American Academy of Orthopaedic Surgeons and the Orthopaedic Research and Education Foundation. In 2010 he received the lifetime achievement from POSNA. In 2012, he received the American Orthopaedic Association's Distinguished Contributions to Orthopaedics Award. In 2016, he was honored by the Vietnamese Government and Minister of Health and awarded the Civilian Medal for Contributions to the Development of Healthcare in Vietnam. In 2019 he received the lifetime achievement award from SOSORT.

Dr. Weinstein was a recipient of an American, British, Canadian (ABC) Traveling Fellowship in 1985. He has been honored for his contributions to Orthopaedic Surgery by honorary memberships in National Orthopaedic Associations around the world including Australia, New Zealand, Germany, Great Britain Thailand, China, Portugal, and Argentina. In 2007, he was made a Fellow of The Royal College of Surgeons of England and in 2014 he was made an Honorary Member of the European Federation of National Orthopedic Associations of Orthopaedics and Traumatology (EFORT).

2020 Award Recipients

Dr. Weinstein is past president of the American Academy of Orthopaedic Surgeons, The American Orthopaedic Association, The American Board of Orthopaedic Surgery, The Pediatric Orthopaedic Society of North America, The United States National Action Network of the International Bone and Joint Decade, The International Center for Orthopaedic Education (ICOE), Doctors for Medical Liability Reform (DMLR), Past Chairman of the Board of Trustees of the Journal of Bone and Joint Surgery (JBJS) and past Chairman of the American Association of Orthopaedic Surgeons Political Action Committee. He currently serves as an American College of Surgeons Children's Hospital Surgery Surveyor and a Trustee for the Orthopaedic Research and Education Foundation.

55TH ANNUAL MEETING RUSSELL A. HIBBS AWARDS

Presented to the best basic science and clinical research papers at the 55th Annual Meeting. The 2020 Hibbs awards will be presented on Wednesday, September 23.

2020 Hibbs Award for Best Basic Research Paper

A Novel Imaging Study to Quantify Respiratory Function in Early Onset Scoliosis-Introducing Quantitative Dynamic Magnetic Resonance Imaging (QdMRI)

Yubing Tong, PhD; Jayaram K. Udupa, PhD; Joseph M. McDonough, MS; Caiyun Wu, MS; Catherine Qiu, MS; Carina Lott, MS; Nirupa Galagedera, BA; Jason B. Anari, MD; Drew A. Torigian, MA; Patrick J. Cahill, MD

2020 Hibbs Award for Best Clinical Research Paper

Complications Following Posterior Surgical Treatment of Adolescent Idiopathic Scoliosis: Prospective 10-Year Follow-Up Study

Arun R. Hariharan, MD; Suken A. Shah, MD; Margaret Baldwin, MD; Joseph Petfield, MD; Burt Yaszay, MD; Peter O. Newton, MD; Baron Lonner, MD; Firoz Miyanji, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD

55TH ANNUAL MEETING JOHN H. MOE AND LOUIS A. GOLDSTEIN AWARDS

Presented to the best basic science and clinical research e-Posters at the 55th Annual Meeting.

2020 Moe Award for Best Basic Research Poster

3D Classification of the Right Thoracic Scoliotic Spine by the Means of Two View Spinal Radiographs: A Validation Study

Saba Pasha, PhD; Keith Baldwin, MD; Jason B. Anari, MD; Victor Ho-Fung, MD

2020 Goldstein Award for Best Clinical Research Poster

Definitive Fusions are Better than Growth Friendly Procedures for Juvenile Patients with Cerebral Palsy and Scoliosis: A Prospective Comparative Cohort Study

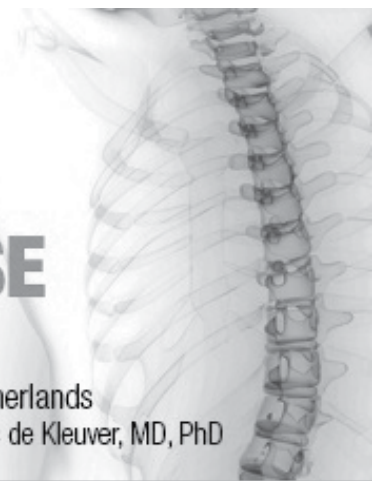
Arun R. Hariharan, MD; Suken A. Shah, MD; Joseph Petfield, MD; Margaret Baldwin, MD; Carlos Pargas, MD; Paul D. Sponseller, MD; Burt Yaszay, MD; Michael P. Glotzbecker, MD; Patrick J. Cahill, MD; Tracey P. Bastrom, MA; Geraldine I. Neiss, PhD; Harms Study Group; Pediatric Spine Study Group



SPINE DEFORMITY SOLUTIONS: A HANDS-ON COURSE OCTOBER 27-29, 2021

Radboud University Medical Center • Nijmegen, the Netherlands

Course Chairs: Ahmet Alanay, MD; Munish Gupta, MD; Marinus de Kleuver, MD, PhD



Conflict of Interest Disclosures



The Scoliosis Research Society gratefully acknowledges Globus Medical, Inc. and Zimmer Biomet for their support of the Pre-Meeting Course and NuVasive for their support of the Pre-Meeting Course and Half-Day Courses.



Conflict of Interest Disclosures

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Conflict of Interest Disclosures

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Minimize Implants Maximize Outcomes Study Group, Study Group	United States	No Relationships

Conflict of Interest Disclosures

Name	Country	Disclosure(s)
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Meeting Agenda

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The Scoliosis Research Society gratefully
acknowledges NuVasive and OrthoPediatrics
for their Educational Grant support
of the Annual Meeting.



12:00-17:00

Registration Open

GRAND FOYER

13:00-17:00

Hibbs Society Meeting

REGENCY DEF

An additional registration fee of \$50 applies for the Hibbs Society Program.

Management of Spinal Infections

Chairs: John M. Caridi, MD; Addisu Mesfin, MD; Gregory M. Mundis Jr., MD; George H. Thompson, MD

13:00-14:00

Part 1. Post Infectious Deformity

Moderators: John M. Caridi, MD & Addisu Mesfin, MD

13:00-13:05 **Introduction**

George H. Thompson, MD

13:05-13:15 **Management of Deformity Following Infection**

S. Rajasekaran, MD, FRCS, MCh, PhD

13:15-13:20 **Case Discussion**

Ajoy Prasad Shetty, MS Orth

13:20-13:30 **Management of TB Associated Deformity in Pediatric Patients**

Muharrem Yazici, MD

13:30-13:35 **Case Discussion**

Kwadwo Poku Yankey, MD

13:35-13:45 **Management of TB Associated Adult Spinal Deformity**

Kwadwo Poku Yankey, MD

13:45-13:50 **Case Discussion**

Gokhan Demirkiran, MD

13:50-14:00 **MRSA in Spine Surgery: Colonization, Infection and Prevention**

John M. Caridi, MD

14:00-14:30

Break

14:30-15:00

Part 2. Prevention of Infections in Neuromuscular Scoliosis and AIS

Moderators: Gregory M. Mundis Jr., MD & George H. Thompson, MD

- 14:30-14:40 **Prevalence of Infections in Pediatric Spine Patients**
Dror Ovadia MD
- 14:40-14:45 **Case Discussion**
Jaysson T. Brooks, MD
- 14:45-14:55 **Prevention Methods for Infections in Neuromuscular Scoliosis**
Muharrem Yazici, MD
- 14:55-15:00 **Case Discussion**
Gokhan Demirkiran, MD
- 15:00-15:10 **Management of the Patient with Delayed Infection After AIS Fusion**
Paul D. Sponseller, MD, MBA
- 15:10-15:15 **Case Discussion**
John C. Quinn, MD
- 15:15-15:25 **Prevention of Infections in Tethering Procedures**
Ahmet Alanay, MD
- 15:25-15:30 **Case Discussion**
Caglar Yilgor, MD

15:30-16:00

Refreshment Break

16:00-17:00

Part 3. Surgical Site Infections Following Adult Deformity and Spine Tumor Surgery

Moderators: John M. Caridi, MD & George H. Thompson, MD

- 16:00-16:10 **The Role of Subclinical Infection in Causing Degenerative Disc**
S. Rajasekaran, MD, FRCS, MCh, PhD
- 16:10-16:20 **Prevention Methods and Treatment of SSI in Adult Deformity**
Gregory M. Mundis Jr., MD
- 16:20-16:25 **Case Discussion**
Hamid Hassanzadeh MD
- 16:25-16:35 **Prevention and Management of Infections in Spine Tumor Surgery**
Addisu Mesfin, MD
- 16:35-16:55 **Discussion**
- 16:55-17:00 **Conclusion**
George H. Thompson, MD

6:00-19:00

Registration Open

GRAND FOYER

7:30-12:00

Pre-Meeting Course

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The Pre-Meeting Course is supported, in part, by Globus Medical, Inc; NuVasive; and Zimmer Biomet.

Spine is Just the Tip of the Iceberg: Comprehensive Management of the Patient with Spine Deformity and Surgeon

Chair: Amer F. Samdani, MD; Co-Chairs: Michael P. Kelly, MD & Justin S. Smith, MD, PhD

7:30-8:55

Part 1: Challenges that Present in Childhood

Moderators: Meric Enercan, MD & Amer F. Samdani, MD; e-Moderator: Burt Yaszay, MD

- 7:30-7:35 **Course Welcome**
Amer F. Samdani, MD
- 7:35-7:43 **Neurofibromatosis: Medical Considerations**
Stephanie M. Morris, MD
- 7:43-7:49 **Neurofibromatosis: Surgical Considerations**
Steven W. Hwang, MD
- 7:49-7:57 **Spinal Muscular Atrophy: Medical Considerations**
Craig M. Zaidman, MD
- 7:57-8:03 **Spinal Muscular Atrophy: Surgical Considerations**
Michael G. Vitale, MD, MPH
- 8:03-8:12 **Discussion**
- 8:12-8:20 **Cerebral Palsy: Medical Considerations**
Bhooma Aravamuthan, MD, DPhil
- 8:20-8:26 **Cerebral Palsy: Surgical Considerations**
Selina C. Poon, MD
- 8:26-8:34 **Osteogenesis Imperfecta: Medical Considerations**
Gary S. Gottesman, MD
- 8:34-8:40 **Osteogenesis Imperfecta: Surgical Considerations**
Suken A. Shah, MD
- 8:40-8:49 **Discussion**
- 8:49-8:55 **Summary Perspective: Pediatric**
Paul D. Sponseller, MD, MBA

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**Denotes Non-CME Session*

8:55-10:15

Part 2: Adult Challenges

Moderators: Michael P. Kelly, MD & Justin S. Smith, MD, PhD; e-Moderator: Addisu Mesfin, MD

- 8:55-9:03 **Degenerative Scoliosis and Refractory Pain in the Octogenarian: Medical Considerations**
Mahshid Mohseni, MD
- 9:03-9:09 **Degenerative Scoliosis and Refractory Pain in the Octogenarian: Surgical Considerations**
Christopher I. Shaffrey, MD
- 9:09-9:17 **Global Sagittal and Coronal Malalignment in the Patient with Parkinson's: Medical Considerations**
Jon T. Willie, MD, PhD
- 9:17-9:23 **Global Sagittal and Coronal Malalignment in the Patient with Parkinson's: Surgical Considerations**
Heiko Koller, MD
- 9:23-9:32 **Discussion**
- 9:32-9:40 **The Obese Diabetic Patient Who Smokes: Medical Considerations**
Devyani Hunt, MD
- 9:40-9:46 **The Obese Diabetic Patient Who Smokes: Surgical Considerations**
Juan S. Uribe, MD
- 9:46-9:54 **Other Comorbid Conditions: Renal and Cardiac: Medical Considerations**
Stephen H. Gregory, MD
- 9:54-10:00 **Other Comorbid Conditions: Renal and Cardiac: Surgical Considerations**
Ferran Pellisé, MD, PhD
- 10:00-10:09 **Discussion**
- 10:09-10:15 **Summary Perspective: Adult**
Lawrence G. Lenke, MD

10:15-10:45

Refreshment Break

10:45-12:00

Part 3: Mental Health Impact on the Patient and Provider

Moderators: Baron S. Lonner, MD; e-Moderator: Jennifer M. Bauer, MD, MS

- 10:45-10:55 **Management of the Adult Patient with Mental Health Challenges**
Munish C. Gupta, MD
- 10:55-11:05 **The Psychological Burden of Early Onset Scoliosis**
Muharrem Yazici, MD
- 11:05-11:15 **Discussion**
- 11:15-11:25 **Burnout, Substance Abuse and Suicide: Are We Any Better at Helping Ourselves?**
Todd J. Albert, MD
- 11:25-11:35 **Strategies to Handle the Misery: Second Victim Syndrome**
Marinus de Kleuver, MD, PhD
- 11:35-11:45 **Panel Discussion**
- 11:45-11:55 **Discussion**
- 11:55-12:00 **Summary Perspective: Mental Health**
David S. Marks, FRCS, FRSC(Orth)

12:00-12:30

Boxed Lunch Pick-Up

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12:30-13:30

Lunchtime Symposia (Three Concurrent Sessions)

The Lunchtime Symposia are supported, in part, by Globus Medical, Inc.; NuVasive; and Zimmer Biomet.

12:30-13:30

LTS A. My Worst Complication and How I Dealt with It

GRAND BALLROOM

Moderators: Michael P. Kelly, MD & Gregory M. Mundis Jr., MD

- 12:30-12:35 **Case Presentation: Permanent Neurologic Deficit**
Munish C. Gupta, MD
- 12:35-12:45 **Dealing with Patients and Yourself Amidst a Chronic Condition You Induced**
Richard E. McCarthy, MD
- 12:45-12:50 **Case Presentation: Perioperative Death**
Michael P. Kelly, MD
- 12:50-12:55 **Discussion**
- 12:55-13:15 **Does Death of a Patient Result in a Small Death of Ourselves: Lessons Learned from Cardiothoracic Surgery**
G. Alexander Patterson, MD
- 13:15-13:30 **How Should Surgeons Engage in Active Recovery from a Major Complication**
Washington University Helpline

12:30-13:30

LTS B. Artificial Intelligence and Computerized Decision Support Tools

REGENCY DEF

Moderators: Christopher P. Ames, MD & Ferran Pellisé, MD, PhD

- 12:30-12:40 **Introduction: Use of Big Data for Risk and Outcome Prediction - Why is it Critical?**
Christopher P. Ames, MD
- 12:40-12:50 **Current State of the Art in Adult Risk and Outcome Prediction Tools**
Ferran Pellisé, MD, PhD
- 12:50-13:00 **Moving from Dashboards to AI for Quality Benchmarking in Complex Disease**
Shay Bess, MD
- 13:00-13:05 **Discussion**
- 13:05-13:15 **Benchmarking in the AIS Population**
Michelle C. Marks, PT, MA
- 13:15-13:25 **AI Predicting Scoliosis Progression and VBT Application**
Stefan Parent, MD, PhD
- 13:25-13:30 **Discussion**

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12:30-13:30

LTS C. Vertebral Body Tethering: Topics for Debate and Discussion

REGENCY ABC

Moderators: Amer F. Samdani, MD & Michelle C. Welborn, MD

12:30-12:31 **Introduction**
Michelle C. Welborn, MD

12:31-12:36 **Tips on Doing Your First Tether**
Lawrence L. Haber, MD

Debate 1

Moderator: Daniel G. Hoernschemeyer, MD

12:36-12:41 **Tethering is Only Indicated in Skeletally Immature Patients**
Michelle C. Welborn, MD

12:41-12:46 **Tethering is Indicated in Select Skeletally Mature Patients**
Baron S. Lonner, MD

12:46-12:51 **Discussion**
Moderator: Suken A. Shah, MD

12:51-12:56 **Technical Tips: Level Selection and Tensioning**
Firoz Miyanji, MD, FRCSC

12:56-13:01 **Reoperations: Incidence and Tips**
Amer F. Samdani, MD

Debate 2

Moderator: A. Noelle Larson, MD

13:01-13:06 **Thoracolumbar Curve: Fusion Remains the Gold Standard**
Peter O. Newton, MD

13:06-13:11 **Thoracolumbar Curve: Tethering is the Best Treatment**
Randal R. Betz, MD

13:11-13:16 **Discussion**
Moderator: Amer F. Samdani, MD

13:16-13:30 **Panel Case Discussion**
Randal R. Betz, MD; Lawrence L. Haber, MD; Baron S. Lonner, MD; Michelle C. Welborn, MD

13:30-14:00

Break

14:00-15:30

Abstract Session 1. Adolescent Idiopathic Scoliosis I

GRAND BALLROOM

Moderators: Lawrence G. Lenke, MD & G. Ying Li, MD

14:00-14:05 **Welcome**

14:05-14:09 **Paper #1: Retrospective Matched Comparison Study on Anterior Vertebral Body Tethering (AVBT) vs. Posterior Spinal Fusion (PSF) for Primary Thoracic Curves**
Peter O. Newton, MD; Firoz Miyanji, MD; Ahmet Alanay, MD; Dan Hoernschemeyer, MD; Stefan Parent, MD, PhD; Baron S. Lonner, MD; Kevin M. Neal, MD; Laurel C. Blakemore, MD; Tracey P. Bastrom, MA; Harms Non-Fusion Study Group

14:09-14:13 **Paper #2: Unsuccessful Vertebral Body Tethering: Incidence and Predictive Factors**
Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Alejandro Quinonez, BS; Erica Johnson, BS; Hannah Miravich, BS; Ross Chafetz, PhD; Steven W. Hwang, MD

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- 14:13-14:17 **Paper #3: Does LIV Selection Affect Radiographic Outcomes in Vertebral Body Tethering? Analysis of a Prospective Case Series of 102 Patients from the PSSG Database**
Kenny Y. Kwan, MD; Chris Yuk Kwan Tang, MBBS, FRCS; Stefan Parent, MD, PhD; Ron El-Hawary, MD; Firoz Miyanji, MD; Kenneth MC Cheung, MD, MBBS, FRCS
- 14:17-14:26 **Discussion**
- 14:26-14:30 **Paper #4: Predicting Overcorrection in AVBT: Can We Improve Patient Selection?**
Firoz Miyanji, MD; Peter O. Newton, MD; Baron S. Lonner, MD; Ahmet Alanay, MD; Dan Hoernschemeyer, MD; Kevin M. Neal, MD; Amer F. Samdani, MD; Tracey P. Bastrom, MA; Harms Non-Fusion Study Group
- 14:30-14:34 **Paper #5: Operative Differences for PSF After VBT: Are We Fusing More Levels in the End?**
Daniel Hoernschemeyer, MD; Melanie Boeyer, PhD; Ahmet Alanay, MD; Kevin M. Neal, MD; A. Noelle Larson, MD; Andrew Gronck; Stefan Parent, MD, PhD; Peter O. Newton, MD; Firoz Miyanji, MD; Lawrence L. Haber, MD; Harms Non-Fusion Study Group
- 14:34-14:38 **Paper #6: Results of Fusion after Failed Anterior Vertebral Body Tethering**
Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Taylor Blondell, BS; Alejandro Quinonez, BS; Erica Johnson, BS; Hannah Miravich, BS; Steven W. Hwang, MD
- 14:38-14:47 **Discussion**
- 14:47-14:51 **Paper #7: Estimating the Risk of Scoliosis Progression in Adolescent Idiopathic Scoliosis Based on Skeletal Maturity**
Mitchell A. Johnson, BS; Shivani Gohel, BS; John (Jack) M. Flynn, MD; Jason B. Anari, MD; Patrick J. Cahill, MD; Stuart L. Mitchell, MD; Jennifer J. Winell, MD; *Keith Baldwin, MD, MPH, MSPT*
- 14:51-14:55 **Paper #8: Could Have Tethered, Glad We Didn't: A Review of AIS Patients Meeting Anterior Vertebral Body Tethering Criteria While Bracing**
Ryan Guzek, BS; Mitchell A. Johnson, BS; Arielle R. Krakow, BA; Lacey Magee, BA; Lori Jia, BS; Keith Baldwin, MD, MPH, MSPT; Jennifer J. Winell, MD; John (Jack) M. Flynn, MD
- 14:55-14:59 **Paper #9: 2 to 5-Years Follow-Up Results after Thoracoscopic VBT: A Single Surgeon's Experience**
Ahmet Alanay, MD; Altug Yucekul, MD; Kadir Abul, MD; Ilkay Karaman, MD; Atahan Durbas ; Tais Zulemyan, MSc; Gokhan Ergene, MD; Sahin Senay, MD; Sule Turgut Balci, MD; Pinar Yalinay Dikmen, MD; Yasemin Yavuz, PhD; Caglar Yilgor, MD
- 14:59-15:09 **Discussion**
- 15:09-15:13 **Paper #10: Thoracolumbar Curve Behavior after Selective Thoracic Anterior Vertebral Body Tethering in Lenke 1A vs. Lenke 1C Curve Patterns**
Michelle C. Welborn, MD; Laurel C. Blakemore, MD; Cameron Hanford, MD; Frank Rodgers, MD; Firoz Miyanji, MD; Ron El-Hawary, MD; Pediatric Spine Study Group; Stefan Parent, MD, PhD
- 15:13-15:17 **Paper #11: Sagittal Alignment after Vertebral Body Tethering: 2 Years Follow-Up**
Alice Baroncini, MD, PhD; Filippo Migliorini, MD; Per D. Trobisch, MD
- 15:17-15:21 **Paper #12: 10-year Follow-Up of Lenke V Curves in Patients with Adolescent Idiopathic Scoliosis**
Nicholas D. Fletcher, MD; Tracey P. Bastrom, MA; A. Noelle Larson, MD; Baron S. Lonner, MD; Burt Yaszay, MD; Mark A. Erickson, MD; Stefan Parent, MD, PhD; Harms Study Group
- 15:21-15:30 **Discussion**

15:30-16:00

Refreshment Break

16:00-17:00

Case Discussions (Three Concurrent Sessions)

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16:00-17:00

Case Discussion 1. Neurovascular Perioperative Complications

GRAND BALLROOM

Moderators: Michael P. Kelly, MD & Gregory M. Mundis, MD

- 16:00-16:15 **1A. Hemodynamic Instability from Patient Positioning with Pectus Excavatum Leading to Procedural Discontinuance**
Terry D. Amaral, MD; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Vishal Sarwahi, MD, MBBS
- 16:15-16:30 **1B. The Use of D-Waves as a Prognostic Tool after Signal Loss in Complex Spinal Deformity Surgery**
Gulsen Oztosun; Altug Yucekul, MD; Irem Havlucu; Tais Zulemyan, MSc; *Caqlar Yilgor, MD*; Elif Ilgaz Aydinlar, MD; Ahmet Alanay, MD; Pinar Yalinay Dikmen, MD
- 16:30-16:45 **1C. Delayed Post-operative Spinal Cord Ischemia after Posterior Spinal Fusion in a Pediatric Patient with Syrinx and Decompressed Chiari**
Jennifer M. Bauer, MD; Sebastian E. Welling, BS
- 16:45-17:00 **1D. Delayed Presentation of Quadriplegia Due to Cervical Cord Ischaemia Following Posterior Scoliosis Correction and Thoracolumbar Spinal Instrumentation for Lenke Type 1AR Adolescent Idiopathic Scoliosis**
Vigneshwara M. Badikillaya, MD; Keyur Akbari, MD; Muralidharan Venkatesan, MD; Pramod Sudarshan, MD; Sajan K. Hegde, MD

16:00-17:00

Case Discussion 2. Neuromuscular/Syndromic

REGENCY DEF

Moderators: Firoz Miyajani, MD, FRCS & Muharrem Yazici, MD

- 16:00-16:15 **2A. Surgical Management of Cervicothoracic Lordoscoliosis in an Emery-Dreifuss VI Muscular Dystrophy Patient: A Case Discussion**
Brandon A. Ramo, MD; Devan James Devkumar; Daniel J. Sucato, MD, MS
- 16:15-16:30 **2B. Vertebral Column Resection for Correction of Right Bronchus Occlusion from Thoracic Lordosis**
Richard E. McCarthy, MD; David B. Bumpass, MD
- 16:30-16:45 **2C. Don't Underestimate Preoperative Kyphosis in Cerebral Palsy**
Margaret Baldwin, MD; Julieanne P. Sees, MD; Suken A. Shah, MD
- 16:45-17:00 **2D. Shorter Fusion in Neuromuscular Scoliosis Patients Give Rise to Long-Term Problems**
Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Terry D. Amaral, MD

16:00-17:00

Case Discussion 3. Novel Approaches to Instrumentation

REGENCY ABC

Moderators: David L. Skaggs, MD & Kristen Jones, MD

- 16:00-16:15 **3A. The First MCGR in the World: Lessons Learned Over the Past 10 years from Implantation to Graduation**
Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Teng Zhang, PhD; Kenneth MC Cheung, MD, MBBS, FRCS
- 16:15-16:30 **3B. The Iliac Kickstand Screw: A Novel Pelvic Screw for Correction of Coronal Spinal Imbalance**
James D. Lin, MD; Joseph M. Lombardi, MD; Jun Kim, MD; Joseph A. Osorio, MD, PhD; Meghan Cerpa; Melvin C. Makhni, MD; Lawrence G. Lenke, MD
- 16:30-16:45 **3C. Tether Breakage in a Mature Thoracolumbar Double Row Vertebral Body Tethering Patient**
Altug Yucekul, MD; Gokhan Ergene, MD; Ipek Ege Gurel; Atahan Durbas; Caqlar Yilgor, MD; Irem Havlucu; Tais Zulemyan, MSc; Pinar Yalinay Dikmen, MD; Binnaz Ay, MD; Sahin Senay, MD; Ahmet Alanay, MD
- 16:45-17:00 **3D. Management of AIS with Double Major Curves with Combination of Posterior Pedicle Screw Fixation-Fusion for Thoracic and Vertebral Body Tethering for Thoracolumbar/Lumbar Curves (Hybrid Technique)**
Meric Enercan, MD; Mustafa Eltayep, MD; Huseyin Ozturk, MD; Seray Gizem Gur, MD; Ayhan Mutlu, MD; Sinan Kahraman, MD; Tunay Sanli; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

All times are listed in US Central Time.

*Denotes Non-CME Session

17:00-17:30

Break

17:30-19:45

Opening Ceremonies

GRAND BALLROOM

- 17:30-17:35 **Welcome to St. Louis**
Munish C. Gupta, MD, Local Host
- 17:35-17:40 **Presidential Welcome**
Muharrem Yazici, MD
- 17:40-17:45 **Presentation of the 2020 Hibbs Awards for Best Basic Science and Clinical Research Papers**
Presentation by Lindsay M. Andras, MD
- 17:45-18:05 **Presentation of the 2020 Lifetime Achievement Awards**
Introductions by Muharrem Yazici, MD & Peter O. Newton, MD
Award Recipients: Jean Dubousset, MD & Stuart L. Weinstein, MD
- 18:05-18:15 **Presentation of the 2020 and 2021 Walter P. Blount Humanitarian Awards**
Presentation by Kenneth J. Paonessa, MD, Awards & Scholarships Committee Chair
2020 Award Recipient: Francisco Javier Sánchez Pérez-Grueso Sr., MD
2021 Award Recipient: Kenneth MC Cheung, MD
- 18:15-18:30 **Corporate Partners Acknowledgement**
Presentation by Paul D. Sponseller, MD, MBA, Corporate Relations Committee Chair
- 18:30-18:40 **Lori A. Karol, MD Recognition**
Paul D. Sponseller, MD, MBA
- 18:40-18:55 **Celebrating Tressa Goulding**
Paul D. Sponseller, MD, MBA & Muharrem Yazici, MD
- 18:55-19:00 **Introduction of the Howard Steel Lecturer**
Muharrem Yazici, MD
- 19:00-19:40 **Howard Steel Lecture: K2 the Mountain Of Mountains**
Tunç Findik
- 19:40-19:45 **Closing Remarks**
Muharrem Yazici, MD

19:45-20:45

Welcome Reception*

GRAND AND REGENCY FOYERS

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

7:00-19:00

Registration Open

GRAND FOYER

8:00-9:50

Abstract Session 2. Adult Deformity I

GRAND BALLROOM

Moderators: Han Jo Kim, MD & Justin S. Smith, MD, PhD

- 8:00-8:04 **Welcome**
- 8:04-8:08 **Paper #13: Fixed Coronal Malalignment (CM) Independently Impacts Disability in Adult Spinal Deformity (ASD) Patients when Considering the Obeid-CM (O-CM) Classification**
Louis Boissiere, MD; Anouar Bourghli, MD; Daniel Larrieu, PhD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Ferran Pellisé, MD, PhD; Javier Pizones, MD, PhD; David C. Kieser, MD, PhD; Ibrahim Obeid, MD
- 8:08-8:12 **Paper #14: Postoperative Coronal Malalignment after Adult Spinal Deformity Surgery: Incidence, Risk Factors, and Impact on 2-Year Outcomes**
Scott Zuckerman, MD; Christopher Lai, BS; Yong Shen, BS; Meghan Cerpa, MPH; Ian A. Buchanan, MD; Mena G. Kerolus, MD; Nathan J. Lee, MD; Eric Leung, BS; Alex Ha, MD; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD
- 8:12-8:16 **Paper #15: Comparative Effectiveness of Ant-IF vs. Post-IF in ASD Surgery: A Propensity Score Based Analysis**
Susana Núñez Pereira, MD; Alba Vila-Casademunt, MS; Maria Capdevila-Bayo, MS; Aleix Ruiz de Villa, PhD; Sleiman Haddad, MD, PhD, FRCS; Frank S. Kleinstueck, MD; Javier Pizones, MD, PhD; Manuel Ramirez Valencia, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Anne F. Mannion, PhD; Ferran Pellisé, MD, PhD; European Spine Study Group
- 8:16-8:25 **Discussion**
- 8:25-8:29 **Paper #16: Fractional Curve Correction Using TLIF vs. ALIF in Adult Scoliosis**
Thomas J. Buell, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Virginia Lafage, PhD; Renaud Lafage, MS; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Vedat Deviren, MD; Michael P. Kelly, MD; Alan H. Daniels, MD; Jeffrey L. Gum, MD; Alex Soroceanu, MPH; D. Kojo Hamilton, MD; Munish C. Gupta, MD; Douglas C. Burton, MD; Richard Hostin, MD; Khaled M. Kebaish, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; International Spine Study Group
- 8:29-8:33 **Paper #17: Central Sacral Pelvic Line (CSPL) is a Useful Radiographic Parameter that Correlates with Clinical Outcomes of Coronal Alignment after Spine Deformity Surgery**
 Alex Ha, MD; Scott Zuckerman, MD; Josephine R. Coury, MD; *Nathan J. Lee, MD*; Xavier E. Ferrer, MD; Ian A. Buchanan, MD; Mena G. Kerolus, MD; Meghan Cerpa, MPH; Joseph M. Lombardi, MD; Marc D. Dyrszka, MD; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD
- 8:33-8:37 **Paper #18: Radiographic Malalignment Has a Far Greater Impact on Clinical Outcomes than Perioperative and Postoperative Complications in ASD Surgery**
 Oscar Krol, BS; Peter G. Passias, MD; *Virginia Lafage, PhD*; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Breton G. Line, BS; Shaleen Vira, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Jeffrey L. Gum, MD; Khaled M. Kebaish, MD; Paul Park, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Munish C. Gupta, MD; Robert K. Eastlack, MD; Neel Anand, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Shay Bess, MD; International Spine Study Group
- 8:37-8:46 **Discussion**
- 8:46-8:50 **Paper #19: Preoperative Paraspinal Fat Atrophy of the Upper Instrumented Vertebrae Musculature in Spine Deformity Surgery is a Risk Factor for Proximal Junctional Kyphosis and Sagittal Malalignment**
 Alex Ha, MD; *Justin Mathew, MD*; Xavier E. Ferrer, MD; Josephine R. Coury, MD; Luzzi J. Andrew, MD; Daniel Hong, MD; Scott Zuckerman, MD; Ian A. Buchanan, MD; Mena G. Kerolus, MD; Meghan Cerpa, MPH; Joseph M. Lombardi, MD; Marc D. Dyrszka, MD; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD
- 8:50-8:54 **Paper #20: Dynamic Assessment Sagittal Spinal Parameter after 10 minutes of Walking Predicts Mechanical Failure and Revision of PJK**
Junseok Bae, MD; Sang-Ho Lee, MD, PhD

All times are listed in US Central Time.

*Denotes Non-CME Session

- 8:54-8:58 **Paper #21: C2 Pelvic Angle (C2PA) is a Useful Intraoperative Radiographic Parameter that Correlates with the Risk of Developing Proximal Junctional Kyphosis Postoperatively**
Alex Ha, MD; Justin Mathew, MD; Xavier E. Ferrer, MD; Josephine R. Coury, MD; Luzzi J. Andrew, MD; Daniel Hong, MD; Gerard F. Marciano, MD; Scott Zuckerman, MD; Ian A. Buchanan, MD; Mena G. Kerolus, MD; Meghan Cerpa, MPH; Joseph M. Lombardi, MD; Marc D. Dyrzka, MD; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD
- 8:58-9:07 **Discussion**
- 9:07-9:11 **Paper #22: Using Normal to Find Normal: Identifying Individualized Lordosis Alignment Targets**
Jeffrey M. Hills, MD; Zeeshan M. Sardar, MD; Jean-Charles Le Huec, MD; Stephane Bourret, PhD; Kazuhiro Hasegawa, MD, PhD; Hee-Kit Wong, FRCS; Gabriel KP Liu, MD; Hend Riahi, MD; Hwee Weng Dennis Hey, MD; Lawrence G. Lenke, MD; Michael P. Kelly, MD
- 9:11-9:15 **Paper #23: The Clinical Benefit of Addressing the Malalignment in Revision Surgery for Proximal Junctional Kyphosis Following ASD Surgery**
Peter G. Passias, MD; Oscar Krol, BS; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Breton G. Line, BS; Shaina Lipa, MD; Themistocles S. Protopsaltis, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Shaleen Vira, MD; Robert K. Eastlack, MD; Gregory M. Mundis, MD; Richard Hostin, MD; Munish C. Gupta, MD; Neel Anand, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Shay Bess, MD; International Spine Study Group
- 9:15-9:19 **Paper #24: Correcting ASD Patients to Normative Alignment Results in No Functional Benefit but More PJK and PJF**
Themistocles S. Protopsaltis, MD; Alex Soroceanu, MPH; Renaud Lafage, MS; Han Jo Kim, MD; Eaman Balouch, MD, PhD; Zoe Norris, BFA; Justin S. Smith, MD, PhD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Lawrence G. Lenke, MD; Virginie Lafage, PhD; Munish C. Gupta, MD; International Spine Study Group
- 9:19-9:28 **Discussion**
- 9:28-9:32 **Paper #25: Comparison of Sagittal Vertical Axis Correction after L4 vs. L3 Pedicle Subtraction Osteotomies**
 Joshua Rivera ; Praveen V. Mummaneni, MD; Jeremy Guinn, BS; Hao-Hua Wu, MD; Minghao Wang, MD, PhD; Pingguo Duan, MD; Zhuo Xi, MD; Justin Lee, MD; Burooj Mahmood, MD; Parikhrita Srivastava ; Rafael Guizar III ; Xiao Tan, BS; Jeremy Huang, BS; John K. Yue, MD; Vivian Le, MPH; Shane Burch, MD; Sigurd H. Berven, MD; *Dean Chou, MD*
- 9:32-9:36 **Paper #26: Delayed Staging during Same Hospitalization Increases Complication Risk following Adult Spinal Deformity Surgery**
Brian J. Neuman, MD; Kevin Y. Wang, BS; Emmanuel McNeely, MS; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Virginie Lafage, PhD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Jeffrey L. Gum, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Khaled M. Kebaish, MD; International Spine Study Group
- 9:36-9:40 **Paper #27: Pelvic Fixation Using the S2AI Technique in ASD Surgery: Ten-year Clinical and Radiographic Follow-Up**
 Varun Puvanesarajah, MD; *Kevin Y. Wang, BS*; Micheal Raad, MD; Floreana N. Kebaish, MD; Paul D. Sponseller, MD; Khaled M. Kebaish, MD
- 9:40-9:50 **Discussion**

9:50-10:25

Refreshment Break

10:25-12:45

Abstract Session 3. Early Onset Scoliosis/Kyphosis

GRAND BALLROOM

Moderators: Brice Ilharreborde, MD, PhD & Scott John Luhmann, MD

- 10:25-10:29 **Paper #28: The Basic Science Supporting Rib Fixation Rather than Spinal for Early Onset Hyperkyphotic Deformity**
Mohammed Alshareef, MD; Daniel Bonthius, BS; Zeke J. Walton, MD; Alison Smith, DVM; Richard H. Gross, MD; Hai Yao, PhD
- 10:29-10:33 **Paper #29: The Effect of Apical Vertebra Position on Growing Rod Treatment: A Clinical and Finite Element Study**
Gokay Dursun, MD; Riza Mert Cetik, MD; Dilek Guzel, BS; Gokhan H. Demirkiran, MD; Ercan Gurses, BS; *Muharrem Yazici, MD*
- 10:33-10:36 **Paper #30: Sagittal Alignment Changes During Childhood: Results of a National Cohort Analysis of 1078 Healthy Children**
Sebastien Pesenti, MD, PhD; Brice Ilharreborde, MD, PhD; Federico Solla, MD; Benjamin Blondel, MD, PhD; Solène Prost, MD; Erik-André Sauleau, MD, PhD; Yann Philippe Charles, MD, PhD
- 10:36-10:45 **Discussion**
- 10:45-10:49 **Paper #31: Salvaging of Magnetically Controlled Growing Rods in Deep Wound Infections Does Not Lead to Increased Rates of Recurrent Infection in Early Onset Scoliosis**
Krishna Vangipuram Suresh, BS; Majd Marrache, MD; Paul D. Sponseller, MD; Pediatric Spine Study Group
- 10:49-10:53 **Paper #32: Matched Comparison of Growing Rods vs. Primary Posterior Spinal Fusion in “Tweeners” with Early Onset Scoliosis**
Lukas G. Keil, MD; Alysa B. Nash, MD; Til Stürmer, MPH; Yvonne M. Golightly, PT; Feng-Chang Lin, PhD; Joseph D. Stone, MD; James O. Sanders, MD; Craig R. Louer, MD
- 10:53-10:57 **Paper #33: Lung Parenchymal Characterization via Thoracic Dynamic MRI (dMRI) in Pediatric Patients with Early Onset Scoliosis (EOS): A Novel Approach**
Yubing Tong, PhD; Jayaram K. Udupa, PhD; Joseph M. McDonough, MS; Chamith Rajapakse, PhD; Caiyun Wu, MS; Carina Lott, MS; Robert H. Carson, BSRT; Jason B. Anari, MD; Drew A. Torigian, MA; *Patrick J. Cahill, MD*
- 10:57-11:06 **Discussion**
- 11:06-11:10 **Paper #34: Upper Instrumented Vertebra (UIV) Selection Matters: Increased Risk of Proximal Junctional Kyphosis When UIV is Closer to the Apex in Scheuermann’s Kyphosis**
Adam N. Fano, BS; Hiroko Matsumoto, PhD; Lisa Bonsignore-Opp, BS; *Benjamin D. Roye, MD*; Lawrence G. Lenke, MD; Elizabeth Herman, BA; Afrain Z. Bobby, MS, BS; Luzzi J. Andrew, MD; Peter O. Newton, MD; Baron S. Lonner, MD; Michael G. Vitale, MD, MPH; Harms Study Group
- 11:10-11:14 **Paper #35: To Prevent PJK in Scheuermann’s Kyphosis, Restore Kyphosis to Patient’s PI Value and Choose Proximal UIV**
Vishal Sarwahi, MD, MBBS; Jesse Galina, BS; Sayyida Hasan, BS; Aaron M. Atlas, BS; Stephen F. Wendolowski, BS; Jeffrey Goldstein, MD; Thomas J. Dowling III, MD; Jordan Fakhoury, DO; Sean Molloy, MBBS; Adam Benton, MBBS; Sara Khojraty, MBBS; Yungtai Lo, PhD; Terry D. Amaral, MD; Darren F. Lui, FRCS
- 11:14-11:18 **Paper #36: A Normal PI-LL Relationship Is Associated with Pain Improvement following Posterior Spinal Fusion for Scheuermann’s Kyphosis**
Elizabeth Herman, BA; Hiroko Matsumoto, PhD; Adam N. Fano, BS; *Benjamin D. Roye, MD*; Peter O. Newton, MD; Michael Fields, BS; Afrain Z. Bobby, MS, BS; Lawrence G. Lenke, MD; Baron S Lonner, MD; Michael G. Vitale, MD, MPH; Harms Study Group
- 11:18-11:27 **Discussion**
- 11:27-11:31 **Paper #37: Characterization of the Different Spino-Pelvic Profiles of Walking Diplegic Cerebral Palsy Patients**
Kariman Abelin Genevois, MD; Carole Vernez, MD; Emmanuelle Chaleat Valayer, MD, PhD

All times are listed in US Central Time.

*Denotes Non-CME Session

- 11:31-11:35 **Paper #38: Concurrent Scoliosis and Hip Dysplasia in Children with Cerebral Palsy: Should We Fix the Spine or Hip First?**
M. Wade Shrader, MD; Ali Asma, MD; armagan C. ulusaloglu, MD; Kenneth J. Rogers, PhD; Freeman Miller, MD; Jason J. Howard, MD; Mutlu Cobanoglu, MD; Suken A. Shah, MD
- 11:35-11:39 **Paper #39: When is Pelvic Fixation Necessary in Children with Hypotonic Neuromuscular Scoliosis (NMS) Treated with Growing Instrumentation?**
Arya Ahmady, MD; Bianca Parker, MS; Joel Gagnier, PhD; Jaysson T. Brooks, MD; Patrick J. Cahill, MD; Ryan Fitzgerald, MD; John (Jack) M. Flynn, MD; Peter F. Sturm, MD; Michael G. Vitale, MD, MPH; G. Ying Li, MD; Pediatric Spine Study Group
- 11:39-11:48 **Discussion**
- 11:48-11:53 **Harrington Lecture Introduction**
Muharrem Yazici, MD
- 11:53-12:15 **Harrington Lecture: Toward Biologic Treatments Addressing Etiology of Scoliosis**
Charles E. Johnston, MD
- 12:15-12:45 **Presentation of the 2021 Lifetime Achievement Awards**
Introductions by Serena S. Hu, MD & Paul D. Sponseller, MD, MBA
Award Recipients: Donald P. K. Chan, MD & Robert N. Hensinger, MD

12:45-13:30

Lunch Pick-Up

13:30-15:00

Industry Workshops* (Five Concurrent Sessions)

13:30-15:00

DePuy Synthes

PARK VIEW

Optimizing Adult and Pediatric Spinal Deformity Patient Outcomes: Case Discussions

Moderator: Randal Betz, MD

Faculty: Baron S. Lonner, MD; Munish C. Gupta, MD; Suken A. Shah, MD; Michelle C. Welborn, MD; Joshua M. Pahys, MD

Please join our expert surgeon panel for a workshop on Optimizing Adult and Pediatric Spinal Deformity Patient Outcomes.

13:30-15:00

Globus Medical, Inc.

REGENCY DEF

Simplifying Screw Placement for Deformity Correction with ExcelsiusGPS

Faculty: Sravisht Iyer, MD; Virgilio Matheus, MD

In this interactive workshop, Dr. Iyer and Dr. Matheus will discuss clinical applications of ExcelsiusGPS® for deformity correction. Both surgeons will share how the unique features of ExcelsiusGPS, such as integrated navigation capabilities and planning software, have helped them in complex cases. Attendees will gain perspective on how ExcelsiusGPS® can impact deformity procedures.

13:30-15:00

Medtronic

GRAND BALLROOM EFGH

The Value of Incorporating Patient-Specific Technology, Robotics, and Predictive Analytics Into Your Spine Practice

Faculty: Christopher P. Ames, MD; Ronald A. Lehman, MD; Kariman Abelin Genevois, MD

The next disruptive advance in spinal surgery is happening now...the augmentation of surgeon intelligence with artificial intelligence. Medtronic is leading this revolution by integrating powerful complimentary technologies: artificial intelligence-driven surgical planning, personalized spinal implants, navigation, and robotic assisted surgical delivery, which together advance standardization and reduced variability. This workshop will provide a unique opportunity to discover how spine surgeons are incorporating these integrated solutions into their practice, and how Medtronic is accelerating the transition to a new era of personalized medicine to deliver optimal patient care.

13:30-15:00

NuVasive

GRAND BALLROOM ABCD

Advanced Applications of Reline 3D in Treating Complex Spinal Deformity

Faculty: Amer F. Samdani, MD; Amy McIntosh, MD; Stephen Hwang, MD; Hamid Hassanzadah, MD

In this session you will hear from a panel of surgeons on how they have integrated the Reline 3D technique into their practice in order to increase intraoperative efficiency and achieve a more powerful three dimensional correction for their patients. The workshop will also provide a sneak peek into the capacity to integrate Reline 3D within our Pulse platform in order to reproducibly achieve kyphosis restoration and coronal balance in every patient using real-time feedback to objectively measure and dial in correction.

13:30-15:00

Stryker

REGENCY ABC

Facts Not Fiction: What We Know and Don't Know about Tethering vs. Fusion for AIS

Moderator: Peter O. Newton, MD

Faculty: Laurel C. Blakemore, MD; Benny T. Dahl, MD, PhD, DMSci; A. Noelle Larson, MD; Firoz Miyajji, MD, FRCS

Please join our panel as they debate preferred correction methods for treating idiopathic scoliosis, and discuss why vertebral body tethering or posterior spinal fusion may be the right choice for the right patient.

15:00-15:30

Break

15:30-17:30

Half-Day Courses (Two Concurrent Sessions)

The Half-Day Courses are supported, in part, by NuVasive.

15:30-17:30

HDC A. Preoperative Planning for Adult Deformity

REGENCY ABC

Moderators: Ahmet Alanay, MD & Ferran Pellisé, MD, PhD

Part 1. Optimal Patient Selection and When to Say No

- 15:30-15:33 **Case Presentation**
Khaled M. Kebaish, MD
- 15:33-15:38 **Optimal Patient Selection and Timing of Surgery**
Justin S. Smith, MD, PhD
- 15:38-15:43 **Role of Multidisciplinary Team Approach**
Rajiv K. Sethi, MD
- 15:43-15:48 **Role of AI-Based Predictive Models**
Christopher P. Ames, MD
- 15:48-16:00 **Case Resolution & Discussion**

Part 2. Optimal Technique Selection, Pearls & Pitfalls

- 16:00-16:03 **Case Presentation**
Michael P. Kelly, MD
- 16:03-16:11 **Osteoporosis & Blood Management**
David W. Polly, Jr., MD
- 16:11-16:18 **Decompression Only vs. Short Fusion vs. Long Fusion**
Gregory M. Mundis, Jr., MD
- 16:18-16:25 **When and How to Go to Pelvis**
Munish C. Gupta, MD
- 16:25-16:33 **Role of MIS Surgery**
Juan S. Uribe, MD
- 16:33-16:45 **Case Resolution & Discussion**

Part 3. Preoperative Deformity Correction Planning

- 16:45-16:48 **Case Presentation**
Javier Pizones, MD, PhD
- 16:48-16:53 **Coronal Plane Planning**
Ibrahim Obeid, MD
- 16:53-17:03 **Sagittal Plane Planning According to Schwab Classification, Roussouly Types and GAP Score**
Yukihiro Matsuyama, MD, PhD
- 17:03-17:08 **How to Account for Alignment Goals Through the Ages**
Michael P. Kelly, MD
- 17:08-17:13 **How to Assure Intraoperatively that Preoperative Planning Targets are Reached**
Lawrence G. Lenke, MD
- 17:13-17:18 **Intraoperative and Postoperative Preventive Measures to Avoid Mechanical Complications if Planning Targets Are Not Reached**
Khaled M. Kebaish, MD
- 17:18-17:30 **Case Resolution & Discussion**

All times are listed in US Central Time.

*Denotes Non-CME Session

15:30-17:30

HDC B. When New Technology in Pediatric Deformity Grows Up: Lessons Learned

REGENCY DEF

Co-Chairs: Sumeet Garg, MD; Baron S. Lonner, MD; Firoz Miyajji, MD, FRCSC & Amer F. Samdani, MD

Part 1. Magnetically Controlled Growing Rods

Moderator: G. Ying Li, MD

- 15:30-15:35 **MCGR: Optimal Indications and When It Can Fail**
David L. Skaggs, MD, MMM
- 15:35-15:40 **Best Surgical Technique Practices for MCGR Insertion**
Ozgur Dede, MD
- 15:40-15:45 **Discussion**
- 15:45-15:50 **Tips on Running an Expansion Clinic**
Colin Nnadi, FRCS (Orth)
- 15:50-15:55 **Mechanical Complications and Metallosis**
Jwalant S. Mehta, FRCS (Orth)
- 15:55-16:00 **MCGR-HRQoL: Are We Making a Difference?**
Muharrem Yazici, MD
- 16:00-16:05 **Discussion**
- 16:05-16:30 **MCGR Case Discussion Panel**
Moderator: *Suken A. Shah, MD*
Panelists: *Jennifer M. Bauer, MD, MS; Kenny Kwan, BMBCh(Oxon), FRCSEd; Lawrence L. Haber, MD; G. Ying Li, MD; Burt Yazay, MD*

Part 2. Vertebral Body Tethering

Moderator: Amer F. Samdani, MD

- 16:30-16:35 **Optimal Indications and When It Can Fail**
Stefan Parent, MD, PhD
- 16:35-16:40 **Thoracic Tethering: Peals and Complications**
Firoz Miyajji, MD, FRCSC
- 16:40-16:45 **Lumbar and Double Tethers: Peals and Complications**
Per D. Trobisch, MD
- 16:45-16:50 **Discussion**
- 16:50-16:55 **Pushing the Limits of aVBT**
Baron S. Lonner, MD
- 16:55-17:00 **Dealing with VBT Revisions**
Caglar Yilgor, MD
- 17:00-17:05 **Discussion**
- 17:05-17:30 **VBT Case Discussion Panel**
Moderator: *Peter O. Newton, MD*
Panelists: *Robert H. Cho, MD; Daniel G. Hoernschemeyer, MD; A. Noelle Larson, MD; Daniel J. Sucato, MD, MS; Caglar Yilgor, MD*

17:30-17:35

Walking Break

17:35-19:05

Express Yourself: An Early Career Surgeon Session

PARK VIEW

The Early Career Surgeon Session is presented by the SRS Early Career Task Force and is supported, in part, by Globus Medical, Inc.; Medtronic; NuVasive; and Zimmer Biomet.

- 17:35-17:38 **Welcome: Early Career Surgeon Task Force Concept**
Kariman Abelin Genevois, MD, PhD; Kenny Kwan, BMBCh(Oxon), FRCSEd; & Caglar Yilgor, MD
- 17:38-17:41 **Early Career Surgeon Social Details**
The Early Career Surgeon Social is hosted by Medtronic.
- 17:41-17:44 **Launch of the SRS Mentorship Program**
Robert H. Cho, MD & Brian G. Smith, MD

Part 1. My Most Challenging Case within the First 3 Years of Practice

Moderators: Kariman Abelin Genevois, MD, PhD; Jaysson T. Brooks, MD; & Caglar Yilgor, MD

- 17:44-17:49 **Pearls and Pitfalls of Pedicle Subtraction Osteotomy: A Young Surgeon's Perspective**
Owoicho Adogwa, MD, MPH
- 17:49-17:58 **Discussion**
- 17:58-18:03 **Too Big a Curve, Too Early: Challenging Idiopathic Scoliosis**
Kadir Abdul, MD
- 18:03-18:12 **Discussion**
- 18:12-18:17 **Congenital Kyphoscoliosis in the Young Adult**
Alekos A. Theologis, MD
- 18:17-18:26 **Discussion**

Part 2. The Challenges in "Ordinary Cases"

Moderator: Kenny Kwan, BMBCh(Oxon), FRCSEd

- 18:26-18:34 **How to Achieve Spine Fixation/Correction with Poor Bone Quality?**
Jennifer M. Bauer, MD, MS
- 18:34-18:39 **Discussion**
- 18:39-18:47 **Adult Revision Surgery: How I Manage an Adjacent Segment**
Louis Boissiere, MD
- 18:47-18:52 **Discussion**
- 18:52-19:00 **Ideal plan for Cervical Spine Deformity**
Amer Sebaaly, MD, MSc
- 19:00-19:05 **Discussion**

19:05-20:30

Early Career Surgeon Social

PARK VIEW AND PARK VIEW FOYER

The Early Career Surgeon Social immediately follows the Early Career Surgeon Session and is hosted by Medtronic.

7:00-17:00

Registration Open

GRAND FOYER

8:00-9:50

Abstract Session 4. Hibbs Award-Nominated Papers for Best Basic/Translational and Clinical Research

GRAND BALLROOM

Moderators: *Eric O. Klineberg, MD & Suken A. Shah, MD*

- 8:00-8:04 **Welcome**
- 8:04-8:08 **Paper #40: An Algorithm for Using Deep Learning Convolutional Neural Networks with Three-Dimensional Depth Sensor Imaging in Scoliosis Detection†**
Terufumi Kokabu, MD; Noriaki Kawakami, DMSc; Koki Uno, MD, PhD; Toshiaki Kotani, MD, PhD; Teppei Suzuki, MD, PhD; Hiroyuki Tachi, MD; Yuichiro Abe, MD, PhD; Hideki Sudo, MD, PhD
- 8:08-8:12 **Paper #41: Sanders Stage 7b: Using the Ulna Physis Improves Decision-Making for Brace Weaning in Adolescent Idiopathic Scoliosis†**
Prudence Wing Hang Cheung, BSc (Hons); Jason Pui Yin Cheung, MD, MBBS, MS, FRCS
- 8:12-8:16 **Paper #42: Outcomes of Magnetically Controlled Growing Rods (MCGR) in Severe Early Onset Scoliosis†**
Antti J. Saarinen, MD; Paul D. Sponseller, MD; Lindsay M. Andras, MD; David L. Skaggs, MD; John B. Emans, MD; George H. Thompson, MD; Pediatric Spine Study Group; Ilkka J. Helenius, MD, PhD
- 8:16-8:31 **Discussion**
- 8:31-8:35 **Paper #43: Spinal Fusion Leads to Quality Adjusted Life Year Gains in Cerebral Palsy Patients Sustained up to 5 Years after Surgery†**
Krishna Vangipuram Suresh, BS; Paul D. Sponseller, MD; Suken A. Shah, MD; Firoz Miyanji, MD; Amer F. Samdani, MD; Burt Yazsay, MD; Peter O. Newton, MD; Amit Jain, MD; Harms Study Group
- 8:35-8:39 **Paper #44: Mid-Term Health-Related Quality of Life and Caregiver Burden Following Spinal Fusion in Children with Cerebral Palsy†**
Rachel L. DiFazio, PhD, RN; Judith A. Vessey, PhD, RN; Patricia E. Miller, MS; Brian D. Snyder, MD, PhD; Benjamin J. Shore, MPH
- 8:39-8:54 **Discussion**
- 8:54-8:58 **Paper #45: Adverse Events in Multilevel Surgery in Elderly Patients with Spinal Deformity: Report of the Prospective Evaluation of Elderly Deformity Surgery (PEEDS) †**
Sigurd H. Berven, MD; Lawrence G. Lenke, MD; Michael Venezia Venezia, DO; John T. Street, MD; Allan R. Martin, MD, PhD, FRCS(C); Justin S. Smith, MD, PhD; Eric O. Klineberg, MD; Michael P. Kelly, MD; Christopher I. Shaffrey, MD; Benny T. Dahl, MD, PhD, DMSc; Marinus De Kleuver, MD; Maarten Spruit, MD; Ferran Pellisé, MD, PhD; Kenneth MC Cheung, MD, MBBS, FRCS; Ahmet Alanay, MD; David W. Polly, MD; Jonathan N. Sembrano, MD; Yukihiko Matsuyama, MD, PhD; Stephen J. Lewis, MD, FRCS(C)
- 8:58-9:02 **Paper #46: Alterations of Gait Kinematics Depend on the Type of Deformity in ASD†**
Karl Semaan, BS; Eddy Saad, MS; Rami Rachkidi, MD, MS; Abir Massaad, PhD; Georges Kawkabani, MD, MS; Renee Maria Saliby, MD, MS; Mario Mekhael, MD, MS; Krystal Abi Karam, BS; Marc Fakhoury, BS; Elena Jaber, BS; Ismat Ghanem, MD; Khalil Kharrat, MD; gabi kreichati, MD; Wafa Skalli, PhD; Virginie Lafage, PhD; Ayman Assi, PhD
- 9:02-9:06 **Paper #47: Kyphosis and Early Disc Degeneration Induced by Paraspinal Muscle Impairment in Female TSC1mKO Mice***
Hwee Weng Dennis Hey, MD; Wing Moon Raymond Lam, PhD; Kimberly TAN, MBBS; Simon Cool, PhD; Wenhai Zhuo, MD; Elisa Marie Crombie, PhD; Shih-Yin Tsai, PhD
- 9:06-9:21 **Discussion**

Cast your vote for the Hibbs Awards on the Meeting App.

1. Go to "Polls & Voting 2. Select the Hibbs Award Polls 3. Cast your vote!

Key: † = Hibbs Award Nominee – Best Clinical Research Paper * = Hibbs Award Nominee – Best Basic/Translational Paper

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**Denotes Non-CME Session*

- 9:21-9:25 **Paper #48: Comparison of Patient Factors (Frailty) vs. Surgical Factors (Invasiveness) for Optimization of 2-Year Cost-Utility: We Should Focus on the Patient Factors†**
Jeffrey L. Gum, MD; Samrat Yeramaneeni, PhD; Kevin Y. Wang, BS; Richard Hostin, MD; Khaled M. Kebaish, MD; Brian J. Neuman, MD; Amit Jain, MD; Michael P. Kelly, MD; Douglas C. Burton, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Frank J. Schwab, MD; Robert A. Hart, MD; Munish C. Gupta, MD; Alan H. Daniels, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Breton G. Line, BS; Shay Bess, MD; International Spine Study Group
- 9:25-9:29 **Paper #49: Genetic Age Determined by Telomere Length is Significantly Associated with Risk of Complications in Adult Deformity Surgery despite No Significant Difference in Chronological Age: Pilot Study of 43 Patients***
Michael Safaee, MD; Jue Lin, PhD; Christopher P. Ames, MD
- 9:29-9:33 **Paper #50: Cellular Immunophenotyping in Adult Spinal Deformity Surgery: Next Step in Personalized Medicine***
 Annie Hess, MD; Isaiah Turnbull, MD, PhD; Ayu Frazier, PhD; *Michael P. Kelly, MD*
- 9:33-9:49 **Discussion**
Audience Vote

9:50-10:20

Refreshment Break

10:20-12:00

Abstract Session 5. Adult Deformity II

GRAND BALLROOM

Moderators: *Jeffrey Gum, MD & Brian J. Neuman, MD*

- 10:20-10:24 **Paper #51: Complications? Reoperations? Let's Do It Again: Decision Regret after Adult Spinal Deformity Surgery**
Daniel Rubio, MD; Christopher F. Dibble, MD, PhD; Ayu Frazier, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD
- 10:24-10:28 **Paper #52: Would You Do It Again? Discrepancies between Patient and Surgeon Willingness for Adult Spine Deformity Surgery**
Shay Bess, MD; Breton G. Line, BS; Renaud Lafage, MS; Christopher P. Ames, MD; Robert K. Eastlack, MD; Gregory M. Mundis, MD; Virginie Lafage, PhD; Eric O. Klineberg, MD; Alan H. Daniels, MD; Munish C. Gupta, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group
- 10:28-10:32 **Paper #53: The Impact of Unplanned Reinterventions Following ASD Surgery**
Ferran Pellisé, MD, PhD; Alba Vila-Casademunt, MS; Maria Capdevila-Bayo, MS; Susana Núñez Pereira, MD; Aleix Ruiz de Villa, PhD; Sleiman Haddad, MD, PhD, FRCS; Javier Pizones, MD, PhD; Manuel Ramirez Valencia, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Anne F. Mannion, PhD; European Spine Study Group
- 10:32-10:48 **Discussion**
- 10:48-10:52 **Paper #54: Racial Disparities in Presenting Physical Functionality and Mental Distress Characteristics of Patients Undergoing Spine Surgery**
 Sarthak Mohanty, BS; Jenna Harowitz, BS; Thaddeus Woodard, BS; Vincent Arlet, MD; David S. Casper, MD; *Comron Saifi, MD*

Cast your vote for the Hibbs Awards on the Meeting App.

1. Go to "Polls & Voting" 2. Select the Hibbs Award Polls 3. Cast your vote!

Key: † = Hibbs Award Nominee – Best Clinical Research Paper * = Hibbs Award Nominee – Best Basic/Translational Paper

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*Denotes Non-CME Session

- 10:52-10:56 **Paper #55: Preoperative Opioid Use Poorly Correlates with Mental Health in Adult Spinal Deformity: Time to Rethink Foregone Conclusions**
Michael P. Kelly, MD; Lawrence G. Lenke, MD; Breton G. Line, BS; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Munish C. Gupta, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Alan H. Daniels, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Shay Bess, MD; International Spine Study Group
- 10:56-11:00 **Paper #56: Using Patient Reported Outcomes to Counsel Adult Symptomatic Lumbar Scoliosis Patients (ASLS)**
James Wondra, BS; Michael P. Kelly, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Shay Bess, MD; Elizabeth L. Yanik, PhD; Frank J. Schwab, MD; Keith H. Bridwell, MD
- 11:00-11:04 **Paper #57: AO Adult Spine Deformity Patient Profile: A Paradigm Shift In Comprehensive Patient Evaluation In Order To Improve Patient Care**
J Naresh-Babu, MS; Kenny Y. Kwan, MD; Yabin Wu, PhD; Caglar Yilgor, MD; Ahmet Alanay, MD; Kenneth MC Cheung, MD, MBBS, FRCS; David W. Polly, MD; Jong-Beom Park, PhD; Manabu Ito, MD, PhD; Lawrence G. Lenke, MD; Miranda L. Van Hooff, PhD; Marinus De Kleuver, MD; AOSpine Knowledge Forum Deformity
- 11:04-11:23 **Discussion**
- 11:23-11:35 **2022 Meeting Previews: 57th Annual Meeting, 29th IMAST, Global Education on Spine Deformity**
- 11:35-11:40 **Introduction of the President**
Christopher I. Shaffrey Sr., MD
- 11:40-12:00 **Presidential Address**
Muharrem Yazici, MD

12:00-12:30

Lunch Pick-Up

12:30-14:15

Member Business Meeting and Lunch*

GRAND BALLROOM

12:30-14:00

LTS D. Limits of MIS: A SRS-AANS Collaboration

REGENCY DEF

Moderators: Praveen V. Mummaneni, MD; Michael Y. Wang, MD, FACS

12:30-12:35 **Case Presentation Using MISDEF 2 and MIISA Algorithms**

Kai-Ming Gregory Fu, MD, PhD

12:35-12:45 **Panel Discussion: MIS Algorithm**

Panelists: Dean Chou, MD; PhD; Paul Park, MD; Khoi D. Than, MD

Debate: How to Achieve 30 Degrees of Sagittal Balance Restoration

12:45-12:50 **Debate Case Presentation**

Pierce D. Nunley, MD

12:50-12:56 **MIS is Best**

Juan S. Uribe, MD

12:56-13:02 **Open is Best**

David O. Okonkwo, MD, PhD

13:02-13:10 **Rebuttals & Discussion**

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*Denotes Non-CME Session

Debate: How to Prevent and Treat PJK

- 13:10-13:15 **Debate Case Presentation**
Robert K. Eastlack, MD
- 13:15-13:21 **MIS is the Best Way to Prevent PJK**
Neel Anand, MD
- 13:21-13:27 **Open Techniques Work Fine to Prevent PJK**
Justin S. Smith, MD, PhD
- 13:27-13:35 **Rebuttals & Discussion**

Debate: Thoracolumbar Scoliosis in Skeletally Immature Patient - Is Anterior Vertebral Body Tethering the Best Option?

- 13:35-13:40 **Debate Case Presentation**
Mari L. Groves, MD
- 13:40-13:46 **Tethering is Best**
Steven W. Hwang, MD
- 13:46-13:52 **Posterior Approach is Best**
Gregory M. Mundis, Jr., MD
- 13:52-14:00 **Rebuttals & Discussion**

14:15-14:45

Break

14:45-16:10

Abstract Session 6. Miscellaneous (Runs Concurrently to Session 7)

GRAND BALLROOM

Moderators: *Meric Enercan, MD & Khoi D. Than, MD*

- 14:45-14:49 **Paper #58: FDA IDE Study of Decompression and Paraspinous Tension Band Stabilization vs. TLIF for Degenerative Spondylolisthesis: 24-month Outcomes in 98 Patients**
Rick C. Sasso, MD; Barrett Boody, MD; William F. Lavelle, MD; Alan Villavicencio, MD; S. Tim Yoon, MD; Ravi S. Bains, MD; Calvin C. Kuo, MD; Kee D. Kim, MD; Jeffrey Fischgrund, MD; Khalid Sethi, MD; Elizabeth Yu, MD; Harvinder S Sandhu, MD; Michael P. Stauff, MD; W Z. Ray, MD; Dennis G. Crandall, MD; Todd Alamin, MD; Louis C. Fielding, MD
- 14:49-14:53 **Paper #59: The Longitudinal Impact of Intervertebral Disc Distraction on Disc Health : A Preliminary, In Vivo Study Using Magnetic Resonance Imaging in a Rabbit Model**
Hwee Weng Dennis Hey, MD; Wing Moon Raymond Lam, PhD; Kimberly TAN, MBBS; Wenhai Zhuo, MD; Kim Cheng Tan, MS; XiaFei Ren, MD, PhD; Hee Kit Wong, MBBS, FRCS
- 14:53-14:57 **Paper #60: Impact of the Flexibility of Coronal Deformities on Low Back Pain and Disc Degeneration in Adult Patients Nonoperatively Treated for Adolescent Idiopathic Scoliosis with Thoracolumbar/Lumbar Curves**
Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD
- 14:57-15:01 **Paper #61: Autograft Viability and Cellular Contribution to Fusion**
Gregory M. Mundis, MD; Jeremy Lombardo, PhD; Nick Russell, PhD; Jiawei He, PhD; Frank Vizesi, PhD
- 15:01-15:16 **Discussion**
- 15:16-15:20 **Paper #62: Perioperative Complications of Total En bloc Spondylectomy (TES) for Spinal Tumors**
Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noriaki Yokogawa, MD; Takaki Shimizu, MD; Makoto Handa, MD; Ryohei Annen, MD; Yohei Yamada, MD; Motoya Kobayashi, MD; Hiroyuki Tsuchiya, PhD
- 15:20-15:24 **Paper #64: Incidence of Post-spinal Surgery Pulmonary Emboli Over a 12-Year Period in a Specialist Tertiary Referral Centre**
Puneet Tailor, MBBS; Hannah Norman, Medical student; Egidio Da Silva, MD; Jwalant S. Mehta, FRCS (Orth), MCh (Orth), MS (Orth), D Orth

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*Denotes Non-CME Session

- 15:24-15:28 **Paper #65: Early Postoperative Anticoagulation after Spinal Fracture Surgery Decreases Venous Thromboembolism Rates**
Khaled Taghlabi, MBBS; Douglas C. Burton, MD; Brandon B. Carlson, MD; Robert Sean Jackson, MD; Joshua Bunch, MD; Robert Winfield, FACS
- 15:28-15:43 **Discussion**
- 15:43-15:47 **Paper #66: Biomechanical Characterization of Common Thoracolumbar Adult Spinal Deformity Correction Constructs: An Implication for Proximal Junctional Kyphosis Risk Assessment**
Robert Koffie, MD, PhD; Bernardo de Andrada, MD; Jennifer N. Lehrman, MS; Brian P. Kelly, PhD; Juan S. Uribe, MD; Jay D. Turner, MD
- 15:47-15:51 **Paper #67: Biomechanical Investigation of Long Spinal Fusion Model Using the Three-Dimensional Finite Element Analysis**
Norihiro Oku, MD; Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noriaki Yokogawa, MD; Hiroyuki Tsuchiya, PhD
- 15:51-15:55 **Paper #68: Telehealth: Comparison of Physical Exam between Telehealth Visits and In-Person Visit for Patients with Spine Pathology**
Hershil Patel, BS; Zoe Norris, BFA; Kimberly Ashayeri, MD; Nicole Mottole, BS; Eaman Balouch, MD, PhD; Ethan Sissman, MD; Constance Maglaras, PhD; Charla R. Fischer, MD; Themistocles S. Protopsaltis, MD; Aaron J. Buckland, MBBS, FRCSA; *Kola Jegede, MD*
- 15:55-16:10 **Discussion**

14:45-16:10

Abstract Session 7. Cervical Deformity (Runs Concurrently to Session 6)

REGENCY DEF

Moderators: Zeeshan M. Sardar, MD & Caglar Yilgor, MD

- 14:45-14:49 **Paper #69: Cervical Sagittal Alignment Parameters Across Ages**
Yann Philippe Charles, MD, PhD; Sebastien Pesenti, MD, PhD; Benjamin Blondel, MD, PhD; Jean-Charles Le Huc, MD; Vincent Fiere, MD; Louis Boissiere, MD; Vincent Challier, MD; Aymeric Faure, MD; Erik-André Sauleau, MD, PhD; Brice Ilharreborde, MD, PhD
- 14:49-14:53 **Paper #70: Posterior Cervical Spinal Fusion in the Pediatric Population Using Modern Adult Instrumentation: Clinical Outcome and Safety**
Alexander Spiessberger, MD; Peter O. Newton, MD; William G. Mackenzie, MD; Amer F. Samdani, MD; Firoz Miyanji, MD; Joshua M. Pahys, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Mark Abel, MD; Jonathan H. H. Phillips, MD; Burt Yaszay, MD
- 14:53-14:57 **Paper #71: Interval for Repeat Pediatric Trisomy 21 Atlanto-Axial Instability Surveillance**
Jennifer M. Bauer, MD; Virkamal Dhaliwal, BS; Walter F. Krengel III, MD
- 14:57-15:01 **Paper #72: Pediatric Cervical Spine Fusions: Opportunity for Improvement**
Edward Compton, BS; Stephen Stephan, MD; Kenneth D. Illingworth, MD; David L. Skaggs, MD; *Lindsay M. Andras, MD*
- 15:01-15:17 **Discussion**
- 15:17-15:21 **Paper #73: Can Lateral Mass Screw Fixation be Improved with Supplemental Screws?**
Muturi G. Muriuki, PhD; *Robert M. Havey, MS*; Suguna Pappu, MD; Nader Dahdaleh, MD; Kenneth R. Blank, PhD; Sarah Brownhill, PhD; Benjamin Johnston, BS; Sean Selover, MS; Shawn Harris, BS; Robert Carruth, MS; Avinash G. Patwardhan, PhD
- 15:21-15:25 **Paper #74: Medium and Long-Term Sagittal Cervical Spine Alignment and Quality of Life in Adult Patients Receiving Primary Surgery for Recent Cervical Subaxial Injury**
Panagiotis Korovessis, MD; Evangelia Mpountogianni, MD; Vasileios N. Syrimpeis, PhD; Ioannis Papaioannou, MD; Thomas Repantis, PhD; Maria Andriopoulou, Nurse; Alkis Korovessis, Electrical Engineer
- 15:25-15:29 **Paper #75: Outcomes Following Occipitocervical Fusion for Complex Spine Trauma; Optimal Fusion Angle and Construct Design Critical to Prevent Dysphagia and Revision Surgery**
Daniel C. Kim, MD, MS; Richard P. Menger, MD; Anthony Martino, MD; George Rusyniak, MD

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- 15:29-15:45 **Discussion**
- 15:45-15:49 **Paper #76: Surgical and Radiographic Outcomes in Patients with High T1 and C2 Slopes**
 Zoe Norris, BFA; *Themistocles S. Protopsaltis, MD*; Eaman Balouch, MD, PhD; Alex Soroceanu, MPH; Renaud Lafage, MS; Justin S. Smith, MD, PhD; D. Kojo Hamilton, MD; Eric O. Klineberg, MD; Peter G. Passias, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group
- 15:49-15:53 **Paper #77: Evolution of Adult Cervical Deformity (ACD) Surgery Clinical and Radiographic Outcomes Based on a Multicenter Prospective Study: Are Behaviors and Outcomes Changing with Experience?**
Peter G. Passias, MD; Oscar Krol, BS; Virginie Lafage, PhD; Renaud Lafage, MS; Han Jo Kim, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Justin K. Scheer, MD; D. Kojo Hamilton, MD; Eric O. Klineberg, MD; Breton G. Line, BS; Robert A. Hart, MD; Douglas C. Burton, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group
- 15:53-16:10 **Discussion**

16:10-16:40

Refreshment Break

16:40-18:05

Abstract Session 8. Adolescent Idiopathic Scoliosis II (Runs Concurrently to Session 9)

GRAND BALLROOM

Moderators: *Tenner Guillaume, MD & Michelle Welborn, MD*

- 16:40-16:44 **Paper #78: A Randomized Control Trial of Schroth-Based Therapy Fails to Demonstrate a Positive Influence on Curve Progression in Skeletally Immature AIS**
 Karina Zapata, DPT; Rebecca J. Dieckmann, BS; Steven D. Glassman, MD; Michael T. Hresko, MD; Brian G. Smith, MD; Paul D. Sponseller, MD; Michael G. Vitale, MD, MPH; *Daniel J. Sucato, MD, MS*
- 16:44-16:48 **Paper #79: Cost-Utility Analysis of Bracing vs. Observation for Adolescent Idiopathic Scoliosis**
 Ijezie A. Ikwuezunma, BS; Kevin Y. Wang, BS; Paul D. Sponseller, MD; *Amit Jain, MD*
- 16:48-16:52 **Paper #80: Brace Treatment for Scoliosis Associated with Chiari Malformation Type 1 or Syringomyelia without Neurosurgical Intervention: A Matched Comparison with Idiopathic Scoliosis**
Hongda Bao, MD; Shibin Shu, PhD; Benlong Shi, PhD; Xu Sun, MD; Bin Wang, MD; Bangping Qian, MD; Yong Qiu, MD; Zezhang Zhu, MD
- 16:52-17:01 **Discussion**
- 17:01-17:05 **Paper #81: A Modified Enhanced Recovery After Surgery (ERAS) Protocol Reduces Length of Stay and Opioid Consumption in Adolescents after Idiopathic Scoliosis Surgery**
David E. Lebel, MD, PhD; Masayoshi Machida, MD; Fiona Campbell, MD; Natasha Bath, RN; Lisa Isaac, FRCP(C); Martin Koyle, MD, FRCS(C); Danielle Ruskin, CPsych; David Levin, MD, FRCS(C); Jennifer Stinson, PhD, RN
- 17:05-17:09 **Paper #82: AIS Post-Operative Rapid Recovery Program: Liposomal Bupivacaine vs. Epidural**
Amy L. McIntosh, MD; Christopher B. McLeod, MD
- 17:09-17:13 **Paper #83: Short Term Outcomes of 23-Hour Observation Discharge Pathway after Posterior Spine Fusion in Adolescent Patients**
Timothy Oswald, MD; Gilbert Chan, MD; Tonia Dry, PA-C
- 17:13-17:22 **Discussion**
- 17:22-17:26 **Paper #84: Complications after Major Pediatric Surgeries: Comparison with Our Peers**
Shalin Patel, MD; Lawrence G. Lenke, MD; Munish C. Gupta, MD; Peter O. Newton, MD; Daniel J. Sucato, MD, MS; Oheneba Boachie-Adjei, MD; Suken A. Shah, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Patrick J. Cahill, MD; Paul D. Sponseller, MD; Richard E. McCarthy, MD; Fox Pediatric Spinal Deformity Study ; Michael P. Kelly, MD
- 17:26-17:30 **Paper #85: Complications and Additional Procedures after Anterior Vertebral Tethering (AVT) for AIS: A Ten-Year Experience**
John T. Braun, MD; Brian E. Grottkau, MD; David F. Lawlor, MD

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- 17:30-17:34 **Paper #86: Improved Surgical Preparedness with Preoperative Psychology Evaluation Prior to AIS Surgery**
Heather M. Richard, PsyD; Shelby P. Cerza, MA; Kiley F. Poppino, BS; Daniel J. Sucato, MD, MS
- 17:34-17:43 **Discussion**
- 17:43-17:47 **Paper #87: Changing Hand Position on EOS Spinal X-rays Does Not Impact Sagittal and Coronal Parameters**
Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Jesse Galina, BS; Yungtai Lo, PhD; Terry D. Amaral, MD
- 17:47-17:51 **Paper #88: Ultra Low Dose Intra-Operative CT Protocol: Significant Radiation Reduction Without Sacrificing Image Quality in Pediatric Spine Patients**
Derrick A. Henry, MD; Richard E. McCarthy, MD; David B. Bumpass, MD
- 17:51-17:55 **Paper #89: A Modified Position for Optimized Skeletal Maturity Assessment of AIS Patients with Low-Dose Stereoradiography: Results of a Randomized Study on Image Quality and Dosage**
Victoria Blouin; Victor Jullien; Olivier Chémaly, MD; Sylvain Deschenes, PhD; Marjolaine Roy-Beaudry, MSc; Soraya Barchi, BSc; John (Jack) M. Flynn, MD; *Stefan Parent, MD, PhD*
- 17:55-18:05 **Discussion**

16:40-18:05

Abstract Session 9. Pediatric Deformity/Miscellaneous (Runs Concurrently to Session 8)

REGENCY DEF

Moderators: Amy L. McIntosh, MD & Joshua M. Pahys, MD

- 16:40-16:44 **Paper #90: Does Vertebral Body Tethering Cause Disc and Facet Joint Degeneration? An MRI Study with Minimum 2-years Follow-up**
Altug Yucekul, MD; Burcu Akpunarli, MD; Atahan Durbas; Tais Zulemyan, MSc; Irem Havlucu; Gokhan Ergene, MD; Sahin Senay, MD; Pinar Yalinay Dikmen, MD; Sule Turgut Balci, MD; Ercan Karaarslan, MD; Yasemin Yavuz, PhD; Caglar Yilgor, MD; Ahmet Alanay, MD
- 16:44-16:48 **Paper #91: Tether-Based Modulation of Scoliosis Reflects IVD Deformation: Development of Growing Pig Model**
Benjamin Sinder, PhD; Alessandra Fusco, DVM; Jason B. Anari, MD; Edward Vresilovic, MD; Vincent Ruggieri, BS; Sriram Balasubramanian, PhD; Thomas P. Schaer, VMD; Patrick J. Cahill, MD; Brian D. Snyder, MD, PhD
- 16:48-16:52 **Paper #92: Pulmonary Function in Idiopathic Scoliosis after Fusion and Non-Fusion Surgeries: A Matched Cohort Analysis**
Caglar Yilgor, MD; Baron S. Lonner, MD; Burt Yaszay, MD; Dan Hoernschemeyer, MD; Stefan Parent, MD, PhD; Peter O. Newton, MD; Ahmet Alanay, MD; Harms Non-Fusion Study Group
- 16:52-17:01 **Discussion**
- 17:01-17:05 **Paper #93: Quantifying Spine Surgery among Patients with Morquio's Disease: A Report of 12 Consecutive Cases**
Juan S. Uribe, MD; *Fernando Rios, MD*; Oscar Castro, MD; Gregory M. Mundis, MD
- 17:05-17:09 **Paper #94: Spinal Fusion for Spine Deformity in Children with Arthrogyryposis Multiplex Congenita**
Dietrich Riepen, MD; Brian Wahlig, BS; *Karl E. Rathjen, MD*; Kiley F. Poppino, BS
- 17:09-17:13 **Paper #95: Complications of the Magnetically Controlled Growing Rod vs. the Spring Distraction System in the Treatment of Early Onset Scoliosis**
Justin V. Lemans, MD; Casper S. Tabeling, MD; René M. Castelein, MD, PhD; Moyo C. Kruyt, MD, PhD
- 17:13-17:22 **Discussion**
- 17:22-17:26 **Paper #96: Increased Age-Adjusted Body Mass Index (BMI) is Associated with Higher Risk of Postoperative Complications in Neuromuscular Scoliosis (NMS) Surgery**
Chun Wai Hung, MD; Lorenzo Deveza, MD, PhD; Dallas Vanorny, MD, PhD; Frank T. Gerow, MD; William A. Phillips, MD; Darrell S. Hanson, MD; Benny T. Dahl, MD, PhD, DMSc
- 17:26-17:30 **Paper #97: The Influence of Viral Respiratory Season on Perioperative Outcomes in Children Undergoing Spinal Fusion Surgery for Neuromuscular Scoliosis**
Nicholas P. Gannon, MD; *Zachary A. Quanbeck, MD*; Daniel J. Miller, MD

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*Denotes Non-CME Session

Program Agenda

Friday, September 24, 2021

- 17:30-17:34 **Paper #98: Intrusion of the Spine into the Chest Causes Airway Narrowing and Impaired Lung Function in AIS**
James A. Farrell, PhD; Enrique Garrido, MD; Ludvig Vavruch, MD, PhD; Tom P. Schlösser, MD, PhD
- 17:34-17:43 **Discussion**
- 17:43-17:47 **Paper #99: Impact of Low vs. High Implant Density on Perioperative Parameters and Estimated Surgical Cost for Lenke 1A AIS Patients**
A. Noelle Larson, MD; David W. Polly, MD; Paul D. Sponseller, MD; B. Stephens Richards, MD; Sumeet Garg, MD; Stefan Parent, MD, PhD; Suken A. Shah, MD; Stuart L. Weinstein, MD; Charles H. Crawford III, MD; James O. Sanders, MD; Michael P. Kelly, MD; Laurel C. Blakemore, MD; Matthew E. Oetgen, MD; Nicholas D. Fletcher, MD; Ann M. Brearley, PhD; Carl-Eric Aubin, PhD; Daniel J. Sucato, MD, MS; Hubert Labelle, MD; Mark A. Erickson, MD; Minimize Implants Maximize Outcomes Study Group, Study Group
- 17:47-17:51 **Paper #100: Adolescent Athletes Return to Sports Rapidly After Posterior Spine Fusion (PSF) for Idiopathic Scoliosis (AIS)**
Tyler Tetreault, MD; Hannah Darland, BA; Angela Vu, BS; Patrick Carry, MS; Sumeet Garg, MD
- 17:51-17:55 **Paper #101: Pregnancy and Childbirth after Adolescent Idiopathic Scoliosis Surgery: A Study of 80 Pregnancies**
Léonard Chatelain, MD; Laura Marie-Hardy, MD; Marc Khalifé, MD; Glorion Christophe, PhD; Christian Garreau de Loubresse, MD, PhD; Pierre Guigui, MD; Emmanuelle Ferrero, MD, PhD
- 17:55-18:05 **Discussion**

The banner features the SRS logo (Scoliosis Research Society) on the left, with the text 'SRS iExperience' in large white font. Below this, there are several inset images: a diagram of the spine showing the 'Central Sacral Line', 'Significant Vertebra', and 'Stable Vertebra'; a photo of a doctor with a patient; a photo of a surgical team in an operating room; and a photo of a doctor with a patient. The text 'Early Onset Scoliosis' is prominently displayed at the bottom right of the banner.

All times are listed in US Central Time.

*Denotes Non-CME Session

7:30-10:00

Registration Open

GRAND FOYER

8:00-10:05

Abstract Session 10. Adolescent Idiopathic Scoliosis III

GRAND BALLROOM

Moderators: *David E. Lebel, MD, PhD & Vidyadhar V. Upasani, MD*

- 8:00-8:04 **Paper #102: Validation of Patient-reported Outcomes Measurement Information System (PROMIS) Computerized Adaptive Testing (CATs) for Children with AIS**
Stuart L. Mitchell, MD; Kevin McLaughlin, PT, DPT; Keith Bachmann, MD; Reider Lisa, PhD; Paul D. Sponseller, MD
- 8:04-8:08 **Paper #103: Shorter and Sweeter: The 16-Item Version of the SRS Questionnaire Shows Better Structural Validity Than the 20-Item Version in Young Patients with Spinal Deformity**
Anne F. Mannion, PhD; Achim Elfering, PhD; Tamas Fulop Fekete, MD; Ian J. Harding, MD, FRCS; Marco Monticone, MD; Peter M. Obid, MD; Thomas Niemeyer, MD; Alba Vila-Casademunt, MS; Francisco Javier S. Perez-Grueso, MD; Javier Pizones, MD, PhD; Ferran Pellisé, MD, PhD; Sarah Richner-Wunderlin, MS; Laura Zimmerman, BS; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Juan Bago, MD, PhD
- 8:08-8:12 **Paper #104: Actual Condition and Characteristics of Back Pain in Non-Operative Patients with Adolescent Idiopathic Scoliosis**
Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD
- 8:12-8:21 **Discussion**
- 8:21-8:25 **Paper #105: Patient Specific Rods for AIS Surgery Prevent Junctional Decompensation**
Kariman Abelin Genevois, MD; Davide Sassi, MD; Thomas Chevillotte, MD; Pierre Grobost, MD
- 8:25-8:29 **Paper #106: Lowest Instrumented Vertebral Discordance in Adolescent Idiopathic Scoliosis: When Coronal and Sagittal Parameters Conflict**
Dale Segal, MD; Jacob Ball, BS; Eric Yoon, BS; Tracey P. Bastrom, MA; Michael G. Vitale, MD, MPH; Harms Study Group; *Nicholas D. Fletcher, MD*
- 8:29-8:33 **Paper #107: Can Placement of Hook at the Upper Instrumented Level Decrease the Proximal Junctional Kyphosis Risk in Adolescent Idiopathic Scoliosis?**
Mehmet Erkilinc, MD; Melanie Coathup, PhD; Michael G. Liska, MD Candidate; John Lovejoy, MD
- 8:33-8:42 **Discussion**
- 8:42-8:46 **Paper #108: Is Quality of Life Affected by Concomitant Isthmic Spondylolisthesis when Undergoing Surgery for Adolescent Idiopathic Scoliosis and Non-Surgical Management of The Spondylolisthesis?**
Matias Pereira Duarte, MD; Julie Joncas, RN; Stefan Parent, MD, PhD; Hubert Labelle, MD; Soraya Barchi, BSc; Jean-Marc Mac-Thiong, MD, PhD
- 8:46-8:50 **Paper #109: Surgical Strategies and Outcomes of Posterior Lumbar Hemivertebra Resection and Short Fusion in Patients with Lumbosacral Deformity Due to Severe Sacral Tilt**
Shengru Wang, MD; Jianguo Zhang, MD
- 8:50-8:54 **Paper #110: Long-Term Outcome after Surgical Treatment of Scheuermann Kyphosis (SK): Minimum of 10-Year Follow-Up**
Ujjwal Kanti K. Debnath, MD, FRCS; Nasir A. Quraishi, PhD, FRCS
- 8:54-9:03 **Discussion**
- 9:03-9:07 **Paper #111: Distal Adding-on in AIS Results in Diminished Patient Reported Outcomes at 10 Years**
Benjamin D. Roye, MD; Hiroko Matsumoto, PhD; Adam N. Fano, BS; Gerard F. Marciano, MD; Rajiv Iyer, MD; Afrain Z. Bobby, MS, BS; Lawrence G. Lenke, MD; Peter O. Newton, MD; *Michael G. Vitale, MD, MPH*; Harms Study Group
- 9:07-9:11 **Paper #112: Loss of Lumbar Lordosis Below the LIV Occurs Due to an Increased Instrumented Lumbar Lordosis Following Posterior Fusion and Instrumentation for Double Major AIS**
Sai Susheel Chilakapati, MS; Kiley F. Poppino, BS; Daniel J. Sucato, MD, MS

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- 9:11-9:15 **Paper #113: National Trends in Performing Osteotomies for AIS in North America: Greater Incidence Is Associated with Significant Complications and Greater Cost**
Kiley F. Poppino, BS; Chan-Hee Jo, PhD; Daniel J. Sucato, MD, MS
- 9:15-9:24 **Discussion**
- 9:24-9:28 **Paper #114: Does intraoperative Vancomycin Powder affect Postoperative Infections in Adolescent Idiopathic Scoliosis?**
Supriya Singh, MD; Garshana Rajkumar ; Sachini Jayasinghe ; Arvindera Ghag, MD; Michael P. Glotzbecker, MD; Baron S. Lonner, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Harms Study Group; Firoz Miyanji, MD
- 9:28-9:32 **Paper #115: Prophylactic Use of Local Vancomycin Does Not Decrease Acute Surgical Site Infection in Adolescent Idiopathic Scoliosis**
Stephen Stephan, MD; De-An Zhang, MD; Marilan Luong, MPH; Robert H. Cho, MD; Selina C. Poon, MD
- 9:32-9:36 **Paper #116: Intraoperative Navigation for Pedicle Screw Placement in Adolescent Idiopathic Scoliosis: No Clinical Benefit and Increased Cancer Risk**
Peter M. Obid, MD; Sebastian Zahnreich, PhD; Thomas Niemeier, MD; Georgi Wassilew, MD; Tamim Rahim, MD
- 9:36-9:46 **Discussion**
- 9:46-9:50 **Presentation of Award Winners**
Michael P. Kelly, MD
- 9:50-10:05 **Transfer of the Presidency**
Muharrem Yazici, MD and Christopher I. Shaffrey Sr., MD

10:05-10:35

Refreshment Break

10:35-12:30

Abstract Session 11. Adult Deformity III

GRAND BALLROOM

Moderators: *Stuart H. Hershman, MD & Byron F. Stephens, MD*

- 10:35-10:39 **Paper #117: Comparison of Degenerative Lumbar Scoliosis Correction and Risk for Mechanical Failure Using Posterior 2-Rod Instrumentation vs. 4-Rod Instrumentation and Interbody Fusion**
Yann Philippe Charles, MD, PhD; Vincent Lamas, MD; Jean-Paul Steib, MD, PhD
- 10:39-10:43 **Paper #118: Rod Failures Continue to Plague the Surgical Treatment of Adult Spinal Deformity (ASD)**
Munish C. Gupta, MD; Renaud Lafage, MS; Sachin Gupta, MD; Alan H. Daniels, MD; Alex Soroceanu, MPH; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Virginie Lafage, PhD; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Gregory M. Mundis, MD; D. Kojo Hamilton, MD; Michael P. Kelly, MD; Douglas C. Burton, MD; Richard Hostin, MD; Robert A. Hart, MD; Frank J. Schwab, MD; Shay Bess, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; International Spine Study Group
- 10:43-10:47 **Paper #119: Multiple Rod Constructs and use of BMP2 Results in Lower Rod Fracture Rates in Adult Spine Deformity Patients Who Undergo Lumbar Pedicle Subtraction Osteotomy: Series of 141 Patients with 2-Year Follow-Up**
Darryl Lau, MD; Qiunan Lyu, MD; Vedat Deviren, MD; Alexander Haddad, BS; Christopher P. Ames, MD
- 10:47-10:56 **Discussion**
- 10:56-11:00 **Paper #120: Assessing Pain as a Primary Factor in the Surgical Treatment of Adult Spinal Deformity Surgery in Patients over 60 Years of Age**
Colby Oitment, MD, FRCS(C); Stephen J. Lewis, MD, FRCS(C); Anna Rienmüller, MD, MS; Thorsten Jentzsch, MD, MS; Hananel Shear-Yashuv, MD; Allan R. Martin, MD, PhD, FRCS(C); Christopher J. Nielsen, MD; Sigurd H. Berven, MD
- 11:00-11:04 **Paper #121: Comparing the Modified 5-item Frailty Index vs. Chronological Age in Predicting Perioperative Complications and Discharge Disposition for Patients undergoing Adult Spinal Deformity Surgery**
Rahul Sachdev, BS; Kevin Y. Wang, BS; Richard L. Skolasky, PhD; Khaled M. Kebaish, MD; Brian J. Neuman, MD

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*Denotes Non-CME Session

- 11:04-11:08 **Paper #122: Matched Analysis Demonstrates Acute Rehabilitation or Skilled Nursing Facility Care Does Not Reduce Readmissions, Return to Surgery or Improve Outcomes Compared to Home Discharge Following Adult Spine Deformity Surgery**
Shay Bess, MD; Breton G. Line, BS; Renaud Lafage, MS; Pierce D. Nunley, MD; Christopher P. Ames, MD; Robert K. Eastlack, MD; Gregory M. Mundis, MD; Virginie Lafage, PhD; Eric O. Klineberg, MD; Munish C. Gupta, MD; Michael P. Kelly, MD; Robert A. Hart, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group
- 11:08-11:17 **Discussion**
- 11:17-11:21 **Paper #123: Adults with Scoliosis, Curve Progression is Faster after Age 50: Results from a Longitudinal Collection of Radiographical Data**
Sabrina Donzelli, MD; Fabio Zaina, MD; Giulia A. Rebagliati, MD; Massimiliano Vanossi, PhysiOtherapist; Greta Jurenaite, MD; Stefano Negrini, MD
- 11:21-11:25 **Paper #124: Adult Spinal Deformity Surgery Is Associated with Increased Productivity and Decreased Absenteeism from Work and School**
Wesley M. Durand, BS; Jacob Babu, MD; D. Kojo Hamilton, MD; Peter G. Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Michael P. Kelly, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Alan H. Daniels, MD; International Spine Study Group
- 11:25-11:29 **Paper #125: Gain in HRQL after ASD Surgery is Maintained Between 2 and 5 Years' Follow-Up**
Ferran Pellisé, MD, PhD; Alba Vila-Casademunt, MS; Maria Capdevila-Bayo, MS; Susana Núñez Pereira, MD; Aleix Ruiz de Villa, PhD; Sleiman Haddad, MD, PhD, FRCS; Frank S. Kleinstueck, MD; Javier Pizones, MD, PhD; Manuel Ramirez Valencia, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Anne F. Mannion, PhD; European Spine Study Group
- 11:29-11:38 **Discussion**
- 11:38-11:42 **Paper #126: Neurologic Complications after Adult Spinal Deformity Surgery**
 Karnmanee Srisanguan, BS; Michael Dinizo, MD; Thomas J. Errico, MD; *Tina Raman, MD*
- 11:42-11:46 **Paper #127: Assessing Key Functional Outcomes after Multilevel Fusion for Adult Spinal Deformity in Patients Over Sixty Years of Age: A Prospective, Observational, Multicenter Study with 2-Year Follow-Up**
 Hananel Shear-Yashuv, MD; *Stephen J. Lewis, MD, FRCS(C)*; Thorsten Jentzsch, MD, MS; Colby Oitment, MD, FRCS(C); Anna Rienmüller, MD, MS; Allan R. Martin, MD, PhD, FRCS(C); Christopher J. Nielsen, MD; Marinus De Kleuver, MD; Yong Qiu, MD; Yukihiro Matsuyama, MD, PhD; Lawrence G. Lenke, MD; Ahmet Alanay, MD; Ferran Pellisé, MD, PhD; Kenneth MC Cheung, MD, MBBS, FRCS; Maarten Spruit, MD; David W. Polly, MD; Jonathan N. Sembrano, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Benny T. Dahl, MD, PhD, DMSc; Sigurd H. Berven, MD
- 11:46-11:55 **Paper #128: Complication Rates with MIS Deformity Surgery Depend More on Number of Posterior Levels Fused than Number of Interbody Grafts**
 Juan S. Uribe, MD; *Shashank V. Gandhi, MD*; Michael Y. Wang, MD; Gregory M. Mundis, MD; Adam S. Kanter, MD; Robert K. Eastlack, MD; Neel Anand, MD; Paul Park, MD; Justin S. Smith, MD, PhD; Douglas C. Burton, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Lawrence G. Lenke, MD; Virginie Lafage, PhD; Praveen V. Mummaneni, MD; International Spine Study Group
- 11:55-12:05 **Discussion**
- 12:05-12:30 **56th Annual Meeting Highlights Summary**
- 12:30 **Adjournment**

Abstract Session 12. COVID-19 Impact on Spine Deformity

Moderators: Jeffrey Gum, MD & Michael P. Kelly, MD

Paper #129: COVID-19 Significantly Impacted Hospital Length of Stay and Discharge Patterns for ASD Surgery

Kevin Y. Wang, BS; Emmanuel McNeely, MS; Suraj Dhanjani, BS; Micheal Raad, MD; Varun Puvanesarajah, MD; Brian J. Neuman, MD; Jay Khanna, MD; Floreana N. Kebaish, MD; Hamid Hassanzadeh, MD; Khaled M. Kebaish, MD

Paper #130: The Lessons Learned from the COVID Pandemic Will Improve the Patient Experience in the Outpatient Setting

Kiley F. Poppino, BS; Charu Sharma, MS; Lindsay Phillips, MS; Daniel J. Sucato, MD, MS

Paper #131: Effect of COVID-19 on Spine Deformity Care and Patient-Reported Outcome Measures

Suken A. Shah, MD; Michelle Claire Marks, PT; Maty Petcharaporn, BS; Petya Yorgova; Irene Li, MS

Paper #132: Are AIS Patients Good Candidates for Telemedicine Consultation?: A Comparison of Satisfaction Scores between AIS and Non-AIS Patients During the COVID-19 Pandemic

Gabriel KP Liu, MD; Jun Hao Tan, MBBS; Leok-Lim Lau, FRCS; Hee-Kit Wong, FRCS

Paper #133: Impact of COVID-19 on Pediatric Spine Patients: Post Traumatic Stress and Coping Responses

Emily Gale, PhD; Whitney M. Herge, PhD; Emily Stapleton, PsyD; Kiley F. Poppino, BS; Shelby P. Cerza, MA; Daniel J. Sucato, MD, MS

Paper #134: A Dangerous Curve: Impact of the COVID-19 Pandemic on Brace Treatment in Idiopathic Scoliosis

Matias Pereira Duarte, MD; Julie Joncas, RN; Stefan Parent, MD, PhD; Olivier Chémaly, MD; Felix L. Brassard, MD; Jean-Marc Mac-Thiong, MD, PhD; Soraya Barchi, BSc; Hubert Labelle, MD

Abstract Session 13. Machine Learning and Advanced Analysis

Moderators: Marinus de Kleuver, MD, PhD & Zeeshan M. Sardar, MD

Paper #135: Identification of Anterior Cervical Spinal Instrumentation Using a Smartphone Application Powered by Machine Learning

John Schwartz, BS; Aly A. Valliani, BS; Brian H. Cho, BS; Varun Arvind, BS; Eric Geng, BS; Samuel K. Cho, MD; Jun S. Kim, MD

Paper #136: The Utility of Surgeon-Directed DICOM Manipulation Software as a Preoperative Surgical Planning Tool in Pediatric Craniovertebral Anomalies

Kshitij Chaudhary, MD; Arjun Dhawale, MD; Avi P. Shah, MD; Abhay Nene, MD

Paper #137: Automated Clustering of Early Onset Scoliosis Patients Using Pre-Operative Clinical Indices

Girish Viraraghavan, MS; Patrick J. Cahill, MD; Jason B. Anari, MD; Sriram Balasubramanian, PhD

Paper #138: Development and Validation of a Model to Predict X-ray Progression at a Follow-Up Visit Based on Ultrasound and Clinical Parameters for Adolescent Idiopathic Scoliosis (AIS)

Mahdieh Khodaei, PhD; Eric C. Parent, PhD; Lawrence H. Le, PhD; Sarah Southon, Nurse Practitioner; Doug L. Hill, MS; Kyle Stampe, MD; Eric M. Huang, MD; Edmond H. Lou, PhD

Paper #139: Automatic Measurement of Cobb Angle Based on Artificial Intelligence Key Point Detection Technology

Xianglong Meng, MD, PhD; Yaozhong Xing, PhD; Yu Sun, PhD; Zian Zhao, PhD

Paper #140: Cluster Analysis to Identify Deformity and Disability Patterns in ASD Patients: A Step Toward a Clinically Relevant ASD Classification

Renaud Lafage, MS; Justin S. Smith, MD, PhD; Shay Bess, MD; Christopher I. Shaffrey, MD; Han Jo Kim, MD; Khaled M. Kebaish, MD; Douglas C. Burton, MD; Richard Hostin, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Munish C. Gupta, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

Paper #141: The Use of Predictive Modeling to Determine Post-operative Thoracic Kyphosis and Pelvic Tilt in Adult Spinal Deformity Surgery

Mellissa R. Delcont, MD, MS; David C. Ou-Yang, MD; Evalina L. Burger, MD; Vikas V. Patel, MD; Nolan M. Wessell, MD; Christopher J. Kleck, MD

Paper #142: Can Machine Learning Improve Our Ability to Predict Reoperations in Adult Spinal Deformity Surgery: A Leap Forward in Predictive Modeling

Joseph M. Lombardi, MD; Scott Zuckerman, MD; Meghan Cerpa, MPH; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Paper #143: Predicting Readmission Following Fusion for Scoliosis in Pediatric Patients: A Machine Learning Approach

Alan H. Daniels, MD; Ashwin Veeramani

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Abstracts

Case Discussion Abstracts	78
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The Scoliosis Research Society gratefully
acknowledges Medtronic for their
exclusive support of the Annual
Meeting Beverage Breaks.



Case Discussion Abstracts

1A. Hemodynamic Instability from Patient Positioning with Pectus Excavatum Leading to Procedural Discontinuance

Terry D. Amaral, MD; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Vishal Sarwahi, MD, MBBS

Summary

15-year-old syndromic female underwent posterior spinal fusion for AIS. Intraoperatively, compression of the mediastinum resulted in hemodynamic instability and eventual surgery discontinuance.

Hypothesis

Padding should be placed along areas with less chest compliance in patients with pectus excavatum

Design

Case Report

Introduction

Likely syndromic 15 yo female with micro duplication of 11P15.5 and pectus excavatum undergoing posterior spinal fusion. Cleared preoperatively by cardiology, neurology and pulmonology.

Methods

Patient placed in prone position and padded and blood pressure dropped as thoracic chest pad was pressing directly on chest. Jelly rolls placed bilaterally along chest wall preventing direct compression of sternum; blood pressure returned to baseline. Segmental fixation was uneventful. Upon attempted pedicle screw fixation of high thoracic spine, hemodynamic instability noted and pressor support was required. When patient lifted to decompress anterior chest wall, pressor support was alleviated. Surgical procedure continued and screws placed uneventfully. Upon rod placement, pressor support not proving effective, so rods removed and decision made to abort surgery. At this time, hemodynamic stability became labile, prompting rapid closure. When patient positioned supine, blood pressure unable to be obtained and code was called. Patient transfused with 300 mL RBC's and 50 mEq of sodium bicarbonate due to blood acidity. Once stabilized, patient was transported to PICU for recovery.

Results

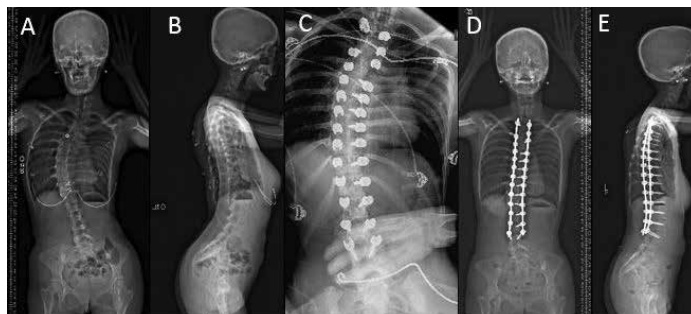
CT scans of screw placements taken on POD 2 to ensure ideal positioning due to drift during code from spinal cord ischemia. Given patient's normal chest compliance, at time of following operation, jelly bumps placed further lateral along chest, where ribs had less compliance and would not result in central chest compression. Rod placement done from cephalid to caudad, as opposed to index surgery, to avoid shunting of extremities and pressure buildup on chest. Blood pressure and neuromonitoring stable for surgery duration and patient discharged POD 4.

Conclusion

In patients with sunken chest, jelly bumps should be placed along areas with less compliance to alleviate potential hemodynamic instability and low blood pressure.

Take Home Message

In patients with sunken chest, jelly bumps should be placed along areas with less compliance to alleviate potential hemodynamic instability and low blood pressure.



(A,B) Preop AP and Lateral (C) Index Postop AP (D,E) Subsequent Surgery Postop AP and Lateral

1B. The Use of D-Waves as a Prognostic Tool after Signal Loss in Complex Spinal Deformity Surgery

Gulsen Oztosun; Altug Yucekul, MD; Irem Havlucu ; Tais Zulemyan, MSc; *Caqlar Yilgor, MD*; Elif Ilgaz Aydinlar, MD; Ahmet Alanay, MD; Pinar Yalinay Dikmen, MD

Summary

Intraoperative neurophysiologic monitoring (IONM) is a valuable tool to avoid neurological injury in spinal surgery. Use of D-wave in deformity surgery is limited due to reported high false negativity when used alone, and technical difficulty of continues recording. D-wave is generally used to detect the location of a signal drop that does not recover, generally in an osteotomy case. This case report displays another important use of D-wave; predicting motor outcome similar to its use in intramedullary tumor surgery.

Hypothesis

D-wave can be used as a prognostic tool when MEPs are lost during complex spine surgeries

Design

Case Report

Introduction

IONM provides information about the real-time status of the nervous system and gives the surgeon a chance to avoid complications via modifying the surgical steps. Different modalities such as TcMEP, SSEP and free-run EMG provide different types of feedback regarding the motor pathway, the dorsal column and individual nerve roots. Direct wave (D-wave) recorded from epidural or subdural space represents the synchronous activity of the fast-conducting corticospinal tract axons. The combined use of MEP and D-wave is reported to predict outcome in intramedullary tumor surgery. This is a report of a case with complete IONM loss in a failed back deformity surgery.

Methods

A 65-years-old patient with a history of multiple myeloma had 2 operations in an outside institute. She was undertaken a third surgery due to pseudoarthrosis, PJF, cement breakdown and retropulsion to spinal canal with a marked myelopathy in physical examination. TcMEP, SSEP and free-run EMG were used for IONM.

Case Discussion Abstracts

Results

During exposure, while retracting skin and paraspinal muscles, tent appearance of the skin and its compressive effects were disrupted, which caused the implants to incrementally pull-out. Bilateral TcMEP signals in the lower extremities were totally lost. After decompression, re-implantation and reduction of the acute kyphotic deformity, loss did not recover. Epidural-recording electrodes were placed over the spinal cord. D-wave recording was possible throughout the laminectomy and conductivity between proximal and distal side still existed. Although TcMEP did not recover until anesthetic discontinuation, D-wave amplitude difference was 67%. The patient woke up with a partial neurological deficit. Her neurological condition improved while her muscle strength was back to its normal state within two months of physical therapy.

Conclusion

D-wave can be used to predict outcome when MEP loss does not recover. In the absence of TcMEP guidance, intact D-wave conductivity gives the surgeon a chance to complete instrumentation and reduction more securely.

Take Home Message

In addition to its use a tool to detect the location of injury, D-wave can be used as a prognostic tool when TcMEPs are lost and did not recover.

1C. Delayed Post-operative Spinal Cord Ischemia after Posterior Spinal Fusion in a Pediatric Patient with Syring and Decompressed Chiari

Jennifer M. Bauer, MD; Sebastian E. Welling, BS

Summary

A 12-year-old female with a progressive 88* thoracic scoliosis after prior Chiari decompression underwent a T2-12 posterior spinal fusion without initial complication. Despite normal function post-operatively, she was noted to have delayed lower extremity motor and sensory deficits 18 hours later. Urgent rod removal led to full recovery with staged completion. No further complications at 2 years post-op. Patients with a history of Chiari or syring may be more sensitive to aggressive deformity correction including in a delayed fashion.

Hypothesis

An abnormal spinal cord with syring or decompressed Chiari may be more sensitive to scoliosis deformity correction and present with a delayed deficit.

Design

Case Report

Introduction

Spinal cord injuries due to deformity correction are normally discovered intra-operatively with neuromonitoring or more immediately post-operatively, but delayed neurologic postoperative deficits (DNPD) have an estimated incidence of 0.01%- 0.18%, 63% occurring within 24 hours. An inherent difference in the spinal cord physiology or response to the stress of deformity correction may exist in patients with Chiari or syring. At least one

prior study found that patients with a history of Chiari or syring who underwent surgical scoliosis correction had an 11% risk of neurologic deficit compared to 0% in idiopathic scoliosis, though none were delayed. We present a patient with normal preoperative neurologic function, prior Chiari decompression, with neurologic deficits the day after scoliosis deformity correction without marked EBL or hypotension.

Methods

A 12-yo female presented with an 88* thoracic scoliosis with Chiari and syring. After Chiari decompression, she was treated with T2-12 posterior spinal fusion. There were no neuromonitoring alerts, EBL was 300cc, and she had a normal post-operative neurologic exam. 18 hours later she was first noted to have progressive motor and sensory deficits of bilateral lower extremities. Urgent rod removal and ICU monitoring with MAP goals resulted in complete recovery within 48 hours. 6 days later the surgical treatment was conservatively completed.

Results

At 2-year follow-up, the patient continues to do well without deficit.

Conclusion

Patients with scoliosis and Chiari or syring may have a cord that is more sensitive to the effects of aggressive deformity correction than an idiopathic patient. They may benefit from a more conservative spinal surgery correction or close ICU monitoring with MAP goals post-operatively, even despite initial normal intraoperative neuromonitoring. Important corrective steps in the setting of DNPD include elevated MAP control and relieving tension from the cord.

Take Home Message

Patients with syring and history of Chiari decompression may have spinal cords more sensitive to injury including delayed ischemia after deformity treatment and should be paid extra perioperative attention.



1D. Delayed Presentation of Quadriplegia Due to Cervical Cord Ischemia Following Posterior Scoliosis Correction and Thoracolumbar Spinal Instrumentation for Lenke Type 1AR Adolescent Idiopathic Scoliosis

Vigneshwara M. Badikillaya, MD; Keyur Akbari, MD; Muralidharan Venkatesan, MD; Pramod Sudarshan, MD; Sajjan K. Hegde, MD

Summary

Case of delayed quadriplegia in a 16-year-old girl who underwent PSF from D2 to L4 for idiopathic scoliosis. Preoperative

Case Discussion Abstracts

MRI was normal without any cord abnormality. She had modest correction with minimal bleeding, with normal intraoperative motor evoked and somatosensory evoked potentials. Delayed quadriplegia developed 41 hours post-surgery due to cervical cord injury cranial to the level of surgery. Surgeons and patients should be aware of risk of neural injury remote of surgical site despite normal intra op neuromonitoring.

Hypothesis

We present a case of delayed quadriplegia in a patient after unremarkable posterior thoracolumbar instrumented spinal fusion for Lenke Type 1AR adolescent idiopathic scoliosis

Design

Case Report

Introduction

Segmental Instrumentation and Spinal fusion for adolescent idiopathic scoliosis (AIS) can have many potential complications, including spinal cord injury. Most often, spinal cord injury occurs in the region of surgery due iatrogenic direct mechanical trauma or Vascular compromise secondary to high degree of correction forces across the deformed spine. In these cases, the impairment of spinal cord function is often detected intraoperatively with spinal cord monitoring and confirmed in the immediate postoperative period. Injury to the spinal cord distant from instrumented surgical level is extremely rare.

Methods

Review of medical record. Our patient is a 16-year-old female who underwent PSF for AIS from D2 to L4 for progressive scoliosis main thoracic curve measuring over 80 degrees. Pre-operative MRI was normal without any cord abnormality. During surgery, she had modest correction with minimal blood loss and with normal intraoperative motor evoked and somatosensory evoked potentials. Immediate Post-operative period patient had intact neurology

Results

Delayed quadriplegia developed 41 hours post-surgery after uneventful D2-L4 posterior spinal fusion. MRI demonstrated evidence of cervical cord ischemia at levels C4-6. Subsequent spinal angiogram was normal without any evidence of arteriovenous shunting. At 3 months post-surgery patients upper limb function improved, lower limbs remained same.

Conclusion

Cervical spine cord injuries are very rare following lower-level fusions. We report first case where pre-operative MRI is normal and post op cervical spinal cord ischaemia is unexplained by normal spinal angiogram. The exact mechanism is unknown and may include a combination of hypoperfusion due to stretch injury of Spinal cord and its vascular supply.

Take Home Message

Unique case with preoperative MRI and postoperative spinal angiogram normal, cervical cord ischemia is unexplainable. Surgeons should be aware of risk of neural injury CRANIAL to instrumentation despite normal neuromonitoring.

2A. Surgical Management of Cervicothoracic Lordoscoliosis in an Emery-Dreifuss VI Muscular Dystrophy Patient: A Case Discussion

Brandon A. Ramo, MD; Daniel J. Sucato, MD, MS; Devan J. Devkumar, BSA

Summary

A 19-year-old male with extreme cervicothoracic hyperlordosis secondary to Emery-Dreifuss Type VI Muscular Dystrophy presented with inability to see the horizon due to his cervical deformity and extreme sagittal imbalance (SVA +21.8cm), as well as a progressive 75° thoracolumbar scoliosis. He was successfully treated via a staged procedure: posterior cervical muscle Z-plasty lengthening with halo application, followed by 6 weeks of halo gravity traction to achieve neutral horizontal gaze, then C2-L4 instrumented posterior spinal fusion with multiple posterior column osteotomies.

Hypothesis

N/A

Design

Case Report

Introduction

Emery-Dreifuss Muscular Dystrophy (EDMD) is a rare genetic disorder with a common manifestation of joint contractures, muscle weakness, and cardiac abnormalities. We report the case of a 19-year-old male with EDMD subtype VI (EDMD6), an X-linked recessive disorder with mutations in the FHL1 gene. The patient presented with severe extension contracture of his cervical spine and a compensatory positive sagittal balance due to his inability to forward gaze horizontally. He had also developed a progressive thoracolumbar scoliosis with concomitant restrictive lung disease and right elbow contracture. Currently, there has been very minimal literature on the management of a highly progressed and involved spinal deformity in a patient with EDMD6.

Methods

A chart review was performed to illustrate the patient's clinical course prior to HGT and following PSF.

Results

The patient initially underwent posterior cervical muscle release in a Z-plasty fashion to correct his cervical extension contracture and six-week halo gravity traction (HGT) to ameliorate his cervicothoracic lordosis. Restoration of normal spinal alignment was achieved via C3-L4 PSF, posterior-column (Ponte) osteotomies at 8 levels between T1 and L3 with postoperative halo vest immobilization for 10 weeks. Two-year post-operative radiographic parameters include correction of positive sagittal alignment (SVA: +21.8 cm to -2.4 cm), lumbar hypo-lordosis (1° to 52°), thoracic hypo-kyphosis (-20° to +9°), and major thoracolumbar Cobb angle (75° to 30°). Patient's gait demonstrated slight Trendelenburg due to subtle residual pelvic obliquity (7°) but his stride, coordination, and balance are normal as is his gaze. He has since attended college and also started his own YouTube channel.

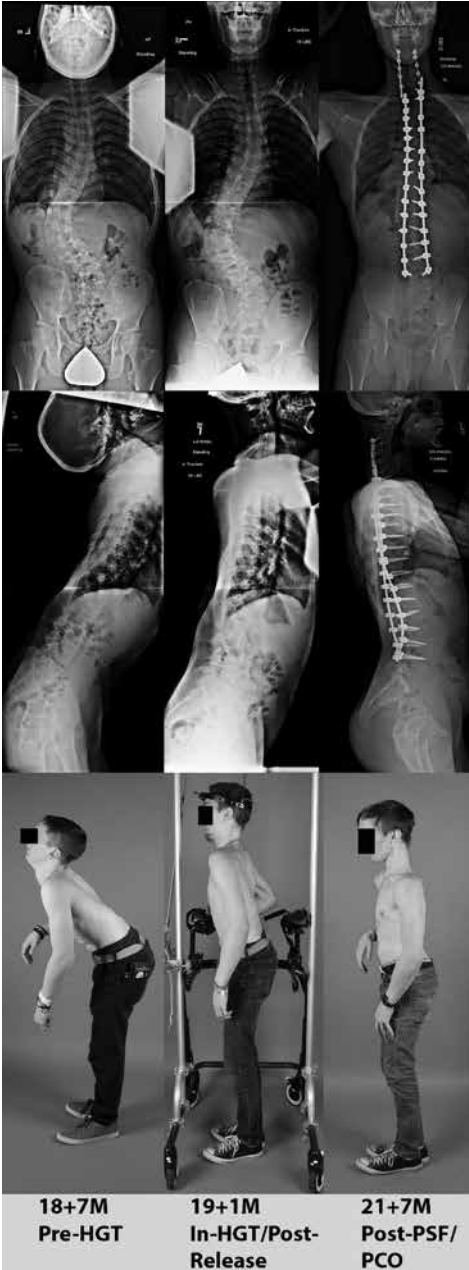
Case Discussion Abstracts

Conclusion

HGT has been utilized in many severe spinal deformities (usually kypho-scoliosis) to provide safe, gradual correction. In this instance, we demonstrate its use in severe lordo-scoliosis along with a staged muscle release and posterior spinal fusion with osteotomies to dramatically improve sagittal balance.

Take Home Message

Halo gravity traction is a useful instrument to achieve safe, gradual correction of severe cervico-thoracic lordoscoliosis in rare spinal deformities (Emery Dreifuss MD patients) using a staged muscle release-fusion approach.



Post-PSF/PCO- 2.5 year follow-up radiographs

2B. Vertebral Column Resection for Correction of Right Bronchus Occlusion from Thoracic Lordosis

Richard E. McCarthy, MD; David B. Bumpass, MD

Summary

A 10 yo female with Multiple Pterygium Syndrome presented with severe rigid thoracic lordosis causing occlusion of the right bronchus. This led to collapse of the right lung middle and lower lobes, and preoperative PFTs 25% of normal. Intra-bronchial markers allowed for visualization using navigation to accurately localize a VCR to correct the lordosis and open the occlusion. Intraoperative bronchoscopy during deformity correction demonstrated relief of the airway obstruction. Postop PFTs improved dramatically and were maintained at eight months postop.

Hypothesis

Bronchial occlusion by a vertebral body in the setting of severe thoracic lordosis can be relieved by vertebral column resection (VCR).

Design

Case Report

Introduction

A 10 yo female with Multiple Pterygium Syndrome (Escobar type) presented with worsening respiratory function. Workup demonstrated that her rigid thoracic lordosis was occluding the right bronchus, causing collapse of the middle and lower lobes with atelectasis. Baseline percent-predicted pulmonary function tests (PFTs) were 25% (FVC) and 26% (FEV1).

Methods

Using bronchoscopy, a radiopaque marker was placed within the airway at the site of the bronchial stenosis. After posterior spinal dissection, intraoperative CT-based spinal navigation was used to identify the vertebral body adjacent to the bronchial marker, confirming that T7 was causing the airway compression. A T7 vertebral column resection was then performed in two stages in an opening-wedge technique, with a T1-L1 instrumented fusion. During the osteotomy correction, bronchoscopy was again used to directly visualize the opening of the airway as kyphosis was created in the thoracic spine.

Results

Patient was discharged home in good condition on post-operative day 6 after osteotomy completion. She experienced no neurologic complications and healed her wound appropriately. Postoperative PFTs had improved to FVC 50% and FEV1 45% at just two months postop. Her weight improved by 3 kg in the first two months after surgery, with return to ambulation. She remains in excellent condition 8 months post-surgery.

Conclusion

VCR is an effective technique to improve pulmonary function caused by severe thoracic lordosis. Use of preoperative and intraoperative bronchoscopy can better inform the surgeon as to proper localization of osteotomies.

Take Home Message

Bronchial compression can be caused by severe thoracic lordosis resulting in thoracic insufficiency. Direct airway compression can

Case Discussion Abstracts

be evaluated with bronchoscopy and treated with a three-column osteotomy.



Before right bronchi decompression

After right bronchi decompression

2C. Don't Underestimate Preoperative Kyphosis in Cerebral Palsy

Margaret Baldwin, MD; Julieanne P. Sees, MD; Suken A. Shah, MD

Summary

Thoracic kyphosis is a common finding in children with GMFCS V cerebral palsy with associated scoliosis. This can lead to an increased incidence of proximal junction kyphosis and failure and subsequently to a vicious cycle of prominent and exposed implants, infection and need for multiple revision surgeries, iatrogenic deformity correction and extension of the fusion and instrumentation. This case presentation highlights the need to recognize and appropriately treat preoperative hyperkyphosis in cerebral palsy.

Hypothesis

This case report will illustrate multiple important principles in the management of spinal deformity in cerebral palsy (CP).

Design

Case Report

Introduction

Hyperkyphosis is commonly associated with scoliosis in patients with CP who are non-ambulatory (GMFCS V). Proximal junctional kyphosis (PJK) and failure (PJF) are recognized postoperative complications and the management of these problems are challenging. There are several postulated risk factors for developing PJK or PJF and these can be used for prevention. Furthermore, PJK can be the start of a vicious cycle of implant prominence, deep infection, PJF and need for re-operation. What are some best practices for managing these problems and what are some options for reconstruction?

Methods

Case Report

Results

A 12-year-old male with GMFCS V CP and scoliosis underwent surgery for thoracolumbar scoliosis (T6-L3) of 64 deg and had 57

deg of kyphosis (T2-T12). He underwent PSF from T1 to sacrum with a unit rod and sublaminar wiring. At his 3-month follow-up appointment, he developed PJK with pullout of his proximal wires. At 6 months post-op, he developed a pressure wound over his proximal implants with exposed rod and connector and treated with local wound care. Due to his progressive deformity and PJF, he underwent re-operation for infection and implant removal. He was found to have deep MRSA infection and pseudoarthrosis between T1 and T2 and the proximal portion of his instrumentation was removed. After successful treatment for MRSA with IV antibiotics and local antibiotic beads, he returned to the operating room for revision instrumentation C6 to T8 with posterior column osteotomies to restore appropriate sagittal alignment. He is currently doing well with no evidence of PJK.

Conclusion

Thoracic kyphosis is a common finding in children with GMFCS V CP and scoliosis and is risk factor for PJK and subsequent cycle of prominent/exposed implants, infection, PJF and need for multiple revision surgeries. This case presentation highlights the need to recognize and appropriately treat preoperative hyperkyphosis in cerebral palsy and strategies for management of PJF.

Take Home Message

Hyperkyphosis is a common finding in patients with CP and neuromuscular scoliosis which should be appreciated and addressed to avoid PJK and a cycle of re-operation in these fragile patients.



Index surgery, progression of PJK and PJF and revision, PCO and extension of fusion to C6.

2D. Shorter Fusion in Neuromuscular Scoliosis Patients Give Rise to Long-term Problems

Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Jesse M Galina, BS; Aaron M. Atlas, BS; Terry D. Amaral, MD

Summary

42 year old female with Friedrich's ataxia and neuromuscular scoliosis underwent a revision surgery for progression of deformity/adding on and pelvic obliquity. Use of multiple level posterior based osteotomies is safe, effective, and can achieve desired results.

Hypothesis

Shorter fusions in neuromuscular scoliosis lead to significant adding on and pelvic obliquity which require extensive revision surgery.

Design

Case Report

Introduction

Patient is a wheelchair-bound 42 year old female with Friedrich's ataxia, neuromuscular scoliosis, and multiple joint contractures. At 13, she underwent PSF with instrumentation using Drummond wires, multiple segmental fixation with distal level

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fixation at L4. Patient developed significant adding on and pelvic obliquity after the index procedure.

Methods

At presentation, patient has pain due to coastal pelvic impingement and sitting imbalance. Radiographic films showed 58° T10-L5 curve, 38° T4-T10 curve, 31° pelvic obliquity, and 156.8mm coronal imbalance. Patient underwent implant removal and revision with extension of fusion to S1, sacral pelvic fixation and osteotomies with an L5-S1 bilateral TLIF and cage insertion.

Results

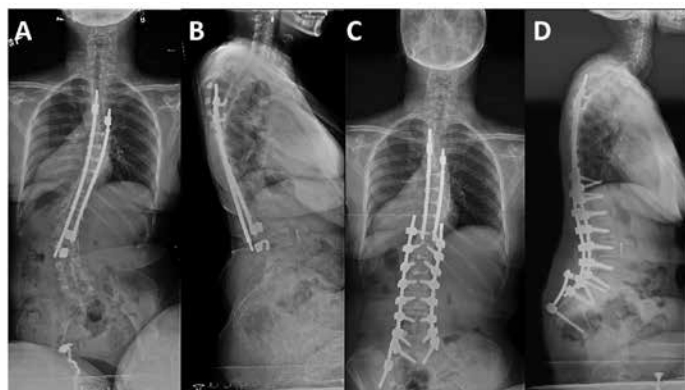
There were no complications. Estimated blood loss was 700ml and required 1 unit of PRBCs intraoperatively. Surgical duration was 612min and anesthesia time was 974min. Neurological status is unchanged. Patient had improved sitting balance and restored to normal coronal alignment.

Conclusion

In neuromuscular scoliosis, fusion to S1 or at least L5 will prevent decompensation at a later date. In patients needing extension of fusion to improve balance later on, good results can be achieved by multi-level posterior based osteotomies.

Take Home Message

Multiple level posterior based osteotomies are safe, effective and can achieve desired results.



(A,B) Preoperative; (C,D) Postoperative

3A. The First MCGR in the World: Lessons Learned Over the Past 10 Years from Implantation to Graduation

Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Teng Zhang, PhD; Kenneth MC Cheung, MD, MBBS, FRCS

Summary

The first magnetically controlled growing rod (MCGR) was implanted in a 5-year-old girl with Ehlers-Danlos syndrome in 2009. In the past decade, her successes and failures have shaped the development of the MCGR. These include loss of distraction, intraoperative implantation protocol, ideal distraction technique, dealing with proximal junctional kyphosis, clunking episodes and rod fracture.

Hypothesis

There are various complications associated with MCGRs that are related to rod design and surgical inexperience.

Design

Case Report

Introduction

The MCGR has been in use for a decade. This report highlights the patient journey and how that has helped drive changes in MCGR design and surgery.

Methods

A 5-year-old girl with MCGR implanted in 2009 had generalized hypotonia and flail right upper limb. She had a curve of 58.5 degrees at T1-9 and 72.8 degrees at T9-L4 with single MCGR inserted at 5-years old anchored at T3-4 and L3-4. Soon thereafter, interval loss of distraction was found to be related to unwinding of the internal magnet, which was subsequently prevented by a change in design and addition of a keeper plate. With subsequent follow up, proximal junctional kyphosis developed.

Results

At 9-years old, dual MCGRs were inserted with extension to C7-T1. Her spinal balance improved and distractions continued. Add-on below developed with frequent clunking. A crooked rod sign [Cheung et al. The Crooked Rod Sign: A New Radiological Sign to Detect Deformed Threads in the Distraction Mechanism of MCGRs and a mode of distraction failure. Spine 2019) developed whereby the extendable portion of the rod was misaligned as a result of deformed threads. Final fusion surgery performed at the age of 15 from C7-L4 with observed autofusion of the lumbar spine. A residual tilt was left below to avoid fusion to the pelvis as she is a candidate for the para-Olympics table tennis team.

Conclusion

The first patient with MCGR implanted provided the platform to learn from technical errors. Several complications such as clunking and deformed threads still require a solution. Deformed threads is a complication only identified with long-term follow-up.

Take Home Message

Only long-term follow-up can identify issues related to the MCGR that could not anticipated at the design stage.



MCGR through the decade illustrated by the first patient with MCGR implanted. Images from left to right: 1st generation MCGR with loss of distraction between lengthenings; 2nd generation MCGR with a keeper plate inserted to prevent loss of distractions; dual rods inserted and extension of instrumentation for PJK; developed add-on below and an angulated rod indicating a skipped thread complication; final fusion procedure

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3B. The Iliac Kickstand Screw: A Novel Pelvic Screw for Correction of Coronal Spinal Imbalance

James D. Lin, MD; Joseph M. Lombardi, MD; Jun Kim, MD; Joseph A. Osorio, MD, PhD; Meghan Cerpa, MPH; Melvin C. Makhni, MD; Lawrence G. Lenke, MD

Summary

The “iliac kickstand screw” is a novel pelvic screw that facilitates correction of coronal spinal imbalances. It has a uniquely lateral starting point which creates a longer lever arm for distraction. It was placed in 24 consecutive patients using the free hand technique with no neurovascular or visceral complications. The mean starting point is 6cm lateral to midline on the iliac crest. The screw trajectory is approximately 10 degrees of lateral angulation and 60 degrees cephalocaudal angulation.

Hypothesis

The iliac kickstand screw can be placed safely and reliably

Design

Retrospective radiographic study.

Introduction

The goal of spinal deformity surgery is to restore spinal alignment in both sagittal and coronal planes. While there has been significant emphasis placed on sagittal plane correction, coronal imbalance can also be debilitating. However, correction of large coronal deformities is challenging. We recently described the “kickstand rod” technique for correction of coronal imbalance. This technique utilizes powerful “construct-to-construct” distraction between a fixed multi-screw thoracic construct and the ilium, facilitated by a novel “iliac kickstand screw”. The technique for freehand placement of the “iliac kickstand screw”, as well as screw trajectories and parameters, have not been previously described.

Methods

Consecutive adult patients who underwent spinal deformity surgery and coronal imbalance correction using the “kickstand rod” by the senior surgeon were identified. All screws were placed using the free hand technique. The starting point for the screw is near the most cephalad surface of the iliac crest, approximately 6cm lateral to midline. Screw accuracy was assessed using intra-operative O-arm imaging and screw trajectories and breaches were analyzed using 3D visualization software.

Results

24 consecutive screws were analyzed. The mean patient age was 50.1 years. 20 were female. 12 were left sided screws and 12 were right sided screws. The mean starting point was 59.5 mm lateral to midline. The mean horizontal angle was 10.8 degrees, and the mean caudal angle was 57.9 degrees. The mean screw size was 7.88 mm (range 7.5-8.5mm) and screw length was 74.2mm (range 70-90mm). 6 of 24 screws had cortical breaches, 5 of which perforated medially and 1 of which perforated inferiorly. There were zero clinically notable neurovascular or visceral complications.

Conclusion

The “iliac kickstand screw” is a novel pelvic screw that facilitates

correction of coronal spinal imbalances. It was placed in 24 consecutive patients using the free hand technique with no neurovascular complications.

Take Home Message

We describe a novel “iliac kickstand screw” which facilitates correction of coronal imbalance.



Figure: Iliac Kickstand Screw (arrow) used to correct coronal imbalance.

3C. Tether Breakage in a Mature Thoracolumbar Double Row Vertebral Body Tethering Patient

Altug Yucekul, MD; Gokhan Ergene, MD; Ipek Ege Gurel; Atahan Durbas; Caglar Yilgor, MD; Irem Havlucu; Tais Zulemyan, MSc; Pinar Yalinay Dikmen, MD; Binnaz Ay, MD; Sahin Senay, MD; Ahmet Alanay, MD

Summary

VBT is a growth modulation technique that allows surgical and gradual spontaneous follow-up curve correction as the patient grows. However, in mature patients, the lack of remaining growth and effort to adapt upper uninstrumented curvature to lower levels may overload the tether after correction. Although, double row tethering could be an option to resist these forces, it may not be helpful to prevent early tether breakage and implant failure.

Hypothesis

Double row tethering may not prevent early tether breakage in mature patients

Design

Case Report

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Introduction

VBT is primarily used as a growth modulation technique in growing children. With the increasing use of the technique, indications began to widen to use this technique in more mature patients. Increased loads on the tether, due to the small amount of growth remaining, may lay the ground for implant complications. The aim is to report a failed case of thoracolumbar double row tethering.

Methods

A 15-years-old Lenke 5C(N), Sanders 7, Risser 5 AIS patient had selective T10-L3 left thoracoscopic and mini open lumbar double row VBT due to 45° thoracolumbar and 41° thoracic curve. Bending radiographs displayed 80% and 96% flexibility for thoracolumbar and main thoracic curves, respectively. Surgical correction was -7° in the intra-postoperative supine radiograph. In the first erect radiograph, the tethered segment was 22° and the compensatory thoracic curve was 24°.

Results

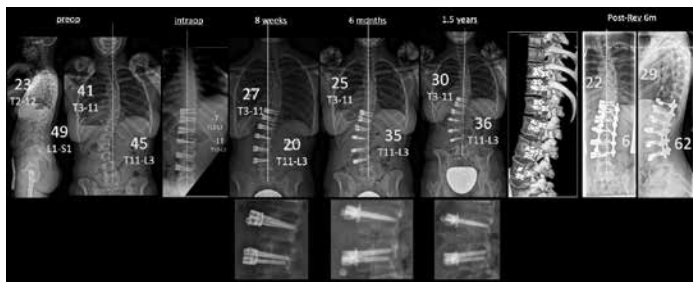
During the follow-ups the patient began to describe back pain without an history of trauma. Radiographs showed set screw dislodgement with increase in the tethered curve to 35° which was marked at 6 months. CT scan at 1 year follow-up demonstrated tether breakage on both tethers. A revision surgery was suggested due to increased curve magnitude and back pain. Selective T10-L3 posterior instrumentation and fusion was performed at 18 months of follow-up. Post-revision first erect thoracic and lumbar curves were 26° and 8°, respectively.

Conclusion

Although a double row configuration may be used to create a more durable construct, the effort of the tethered region to adapt to the upper curvature and the magnitude of surgical correction may result is tether breakage.

Take Home Message

Double row configuration may not be enough to prevent tether breakage in mature thoracolumbar VBT applications.



3D. Management of AIS with Double Major Curves with Combination of Posterior Pedicle Screw Fixation-Fusion for Thoracic and Vertebral Body Tethering for Thoracolumbar/Lumbar Curves (Hybrid Technique)

Meric Enercan, MD; Mustafa Eltayep, MD; Huseyin Ozturk, MD; Seray G. Gur, MD; Ayhan Mutlu, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

Summary

Hybrid technique including posterior pedicle screw fixation-fu-

sion for thoracic curve with hypokyphosis/lordosis and Vertebral Body Tethering (VBT) with double screw double cord (DS-DC) fixation for thoracolumbar/lumbar (TL/L) curve provided satisfactory corrections on both planes. Thoracic kyphosis was restored with posterior surgery. The cervical sagittal alignment improved following restoration of TK in pts with preop hypokyphosis/lordosis. VBT with DS-DC fixation preserved spine flexibility and motion in in lumbar spine without any cord rupture at the end of 2 years f/up.

Hypothesis

VBT is not powerful enough to restore ideal thoracic sagittal alignment in pts with thoracic hypokyphosis/lordosis (HK/L). We planned posterior pedicle screw fixation-fusion for thoracic scoliosis with HK/L & VBT with DS-DC to correct TL deformity, preserve spinal flexibility & motion of the lumbar spine.

Design

Retrospective

Introduction

We combined two techniques for management of the double major curves. Posterior surgery was performed to correct thoracic coronal and sagittal deformity & VBT with DS-DC fixation was performed for TL deformity. The aim of this study to evaluate the preliminary results of hybrid technique for the surgical treatment of AIS with double major curves.

Methods

21(18F,3M) pts, mean age 14,5(11-18) years were included. Indication for posterior surgery was presence of thoracic HK/L or upper trunk shift/shoulder asymmetry occurred following TL/L curve correction with VBT. Coronal and sagittal parameters were measured on preop, first erect & f/up x-rays. Preop & f/up lumbar ranges of motion were compared. SRS-22r was used for clinical assessment.

Results

Mean f/up was 28,4(26-32) months. Mean MT curve 45,1° was corrected to 7,8° & 7,2° at f/up (84% correction). Mean TL/L curve of 53,2° was corrected to 9,9° & 8,8° at f/up (83,5% correction). Preop TK of 21,4° improved to 33° at f/up. In 11 pts with preop thoracic HK/L of 9,1° improved to 29,3°. Preop cervical kyphosis of 9,8° improved to 7° lordosis following restoration of TK. 17 pts with TL kyphosis of 12,4° was restored to 2,3°. 4 pts with TL hyperlordosis of 6,7° was restored to 1,8°. There was no neurological deficit or cord rupture. Preop lumbar ROM was preserved at f/up.

Conclusion

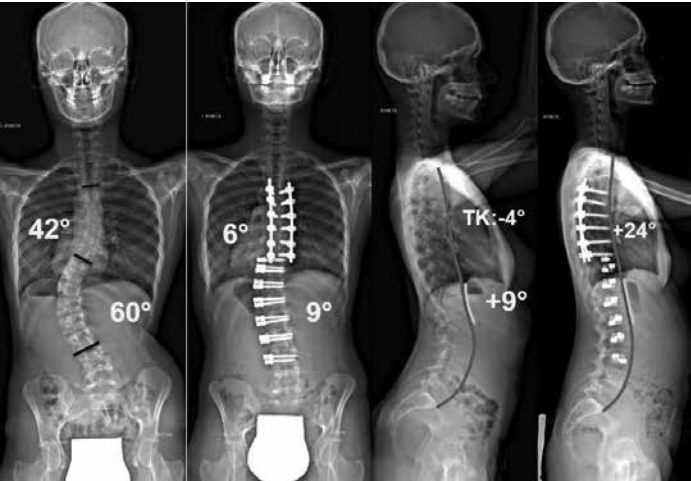
Posterior surgery enables restoration of TK in pts with thoracic HK/L. The sagittal cervical alignment improved following restoration of TK. VBT with DS-DC fixation provides satisfactory correction of TL deformity. According to TL sagittal alignment, anterior or posterior cord was tightened first to restore TL alignment. VBT with DS-DC fixation preserved spinal flexibility and motion of mobile TL spine.

Take Home Message

Hybrid technique, including posterior pedicle screw fixation-fusion for thoracic curve with hypokyphosis/lordosis & Vertebral

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Body Tethering with Double Screw-Double Cord fixation for thoracolumbar/lumbar deformity provided satisfactory corrections without any cord rupture.



Hybrid Technique

1. Retrospective Matched Comparison Study on Anterior Vertebral Body Tethering (AVBT) vs. Posterior Spinal Fusion (PSF) for Primary Thoracic Curves

Peter O. Newton, MD; Firoz Miyajani, MD; Ahmet Alanay, MD; Dan Hoernschemeyer, MD; Stefan Parent, MD, PhD; Baron Lonner, MD; Kevin M. Neal, MD; Laurel C. Blakemore, MD; Tracey P. Basstrom, MA; Harms Non-Fusion Study Group

Summary

241 thoracic AVBT patients were matched to 241 PSF for idiopathic scoliosis utilizing a multicenter database. Curve correction was greater for the PSF cohort (62% vs. 43%) as was the proportion of cases with a >2yr main thoracic Cobb <35° (98% vs. 76%) compared to the AVBT group. The reoperation rate was >10-fold higher in the AVBT group (1.2% vs. 15.8%). Both cohorts were highly satisfied. This may help inform families when considering AVBT vs. PSF.

Hypothesis

The outcomes of Anterior Vertebral Body Tethering (AVBT) will be comparable when propensity matched to Posterior Spinal Fusion (PSF) cases.

Design

Retrospective, multi-center study

Introduction

Understanding the outcomes of AVBT relative to the gold standard PSF is critical in presenting the options to patients.

Methods

A retrospective comparison of 482 main thoracic IS patients, 241 treated with thoracic AVBT and 241 treated with PSF, each with a min follow-up of 2yrs was performed. PSF cases were selected from a prospective database by propensity matching based on age, sex, Risser, and Cobb angle (w/o caliper limits). For AVBT cases, 2+yr outcomes up to the point of PSF if such occurred are reported.

Results

Despite “nearest neighbor” matching, AVBT patients were less mature (12.1±1.6 vs. 13.4±1.4yrs, $p<0.001$, and 80% vs. 43% Risser 0-1, $p<0.001$) compared to PSF patients. The mean follow-up was similar: 2.2±0.5 (2-5) yrs for AVBT vs. 2.3±0.5 (2-5) yrs for PSF. Slightly smaller thoracic curves for AVBT: 48±9° (range 30-74°) vs. PSF: 53±8° (range 40-78°), $p<0.001$ were corrected to 27±11° (43%) and 20±7° (62%), respectively ($p<0.001$). 24% of AVBT vs. 2% of PSF patients had 2+yr Cobb >35°, $p<0.001$. Revision procedures (14 PSF, 15 loosen/remove tether, 10 replace/add tether) were performed on 38 (15.8%) AVBT patients vs. 3 (1.2%) PSF patients, $p<0.001$. Median SRS-22 Total scores were not different preop (4.1 vs. 4.0) or postop (4.5 vs. 4.6) for AVBT and PSF respectively, with median SRS-22 Satisfaction high at 5.0 for both.

Conclusion

Thoracic idiopathic scoliosis patients treated with AVBT had similar SRS-22 improvement, less curve correction, and higher rates of reoperation compared to PSF. However, the majority (94%) have “avoided” spinal fusion (a goal for those who choose

AVBT) at just over 2 years postop, although longer follow-up will be required to understand the mid and long-term outcomes of this non-fusion treatment strategy. These initial results may help in counseling families regarding these 2 options while realizing we are early in the evolution of AVBT treatment and decision making.

Take Home Message

This multicenter study demonstrates greater residual curve and higher revision rates in patients with thoracic scoliosis treated with AVBT compared to the gold standard PSF at min 2yr follow-up.

2. Unsuccessful Vertebral Body Tethering: Incidence and Predictive Factors

Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Alejandro Quinonez, BS; Erica Johnson, BS; Hannah Miravich, BS; Ross Chafetz, PhD; Steven W. Hwang, MD

Summary

Vertebral body tethering is a viable option for a select group of patients. We sought to identify how often and in whom unsuccessful outcomes occur. A single center dataset of 171 thoracic VBT patients was analyzed and any last visit Cobb angle of 40 degrees (or spinal fusion) was deemed unsuccessful. Larger (>55°), stiffer (bends>35°) preoperative curves with a first erect (>30°) portends an unsuccessful result, with the latter increasing the chances of an unsuccessful outcome 8-fold.

Hypothesis

Unsuccessful outcomes following VBT occur in children with less growth potential and larger, stiffer curves.

Design

Single center retrospective review

Introduction

Vertebral body tethering is a viable option for select patients. To date, unsuccessful outcomes have not been adequately studied. We sought to determine how often an unsuccessful outcome occurs following VBT and which factors are predictive.

Methods

From a single center dataset of 171 patients s/p thoracic VBT with minimum 2-year f/u, we identified those with an unsuccessful result (U group= Cobb angle greater than 40° at last visit or fusion performed). Clinical and radiographic data were compared between the U patients and the rest of the cohort (R Group) utilizing univariate and odds ratio analysis to determine predictive factors.

Results

27 patients (16%) had an unacceptable result. The two groups were similar with respect to preoperative age (U = 12.82 ± 1.3, R = 12.56 ± 1.4, NS), median Sanders (U = 3, R = 3, NS), and percentage of open triradiates (U = 33.3%, R = 36.1%, NS). Follow-up was also similar (U = 43.2 ± 19.6, R = 42.1 ± 17.1 months, NS) and vast majority were skeletally mature at last visit (% Risser 4 or 5, U = 83.3%, R = 83.7%, NS). In comparison to the R group, the U patients had larger preoperative Cobb angles (U

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= 55.7 ± 10.35, R= 50.9 ± 10.1, p=.03), less curve flexibility on bending (U= 30.9 ± 10.2, R= 21.9 ± 11.8, p=.03), and larger first erect Cobb angles (U = 34.5 ± 10.5, R = 25.4 ± 8.6, <.01). Both groups grew a similar amount (change in height pre to last visit in cm U = 10.3 ± 5.8, R = 9.5 ± 6.7, p =0.54). The odds ratio for failure was greatest for FE Cobb angle greater than 30° (8-fold), and less so for preoperative cobb greater than 55° (3.2) and bends greater than 35° (3.8).

Conclusion

Unsuccessful outcomes occur in 16% of patients undergoing VBT. Curves greater than 55° that do not bend under 35° should be approached thoughtfully as they may lead to a greater than 30° cobb angle on first erect which dramatically increases the chances of an unsuccessful outcome. Regardless of growth potential, it appears the goal of surgical intervention should be a curve less than 30° on first erect.

Take Home Message

In patients with aVBT, larger, stiffer curves with less correction on first erect x-ray portend an unsuccessful outcome. Intraoperative correction should aim for a less than 30° cobb on FE.

	U Group (N=27)	R Group (N=144)	P
Age at Surgery (Years)	12.82 ± 1.3	12.56 ± 1.4	0.36
Follow-up (Months)	43.2 ± 19.6	42.1 ± 17.1	0.8
Pre-op Thoracic Cobb (°)	55.7 ± 10.35	50.85 ± 10.14	0.03
Pre-op Thoracic Bend (°)	30.9 ± 10.2	21.9 ± 11.8	0.03
Pre-op Risser (Range)	0 (0 - 3)	0 (0 - 4)	NS
Pre-op Sanders (Range)	3 (1 - 5)	3 (1 - 6)	NS
% Triradiate Open	33%	36%	1
% Female	74%	91%	0.021
Levels Tethered	7.78 ± 0.51	7.83 ± 0.71	0.67
Change in Height (cm)	10.3 ± 5.8	9.5 ± 6.7	0.54
First Erect Cobb Angle (°)	34.5 ± 10.5	25.4 ± 8.6	0.0002
% Risser 4 or 5 at Last Visit	83.3%	83.7%	1
Cobb at Last Visit (°)	45.9 ± 4.7	24.9 ± 8.9	0.0001

3. Does LIV Selection Affect Radiographic Outcomes in Vertebral Body Tethering? Analysis of a Prospective Case Series of 102 Patients from the PSSG Database

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Summary

VBT surgery for the thoracic AIS curves results in curve correction whilst maintaining spinal motion, but the optimal LIV selection is unknown. The current radiographic review of 102 prospectively enrolled AIS patients from the PSSG database showed that selecting the lower end vertebra (LEV) as the LIV yielded the best improvement in truncal shift compared with LEV-1 or LEV+1. Distal adding-on was significantly higher if LEV-1 was chosen as LIV, but no difference was observed between LEV and LEV+1.

Hypothesis

LIV selection in vertebral body tethering (VBT) does not affect radiographic outcomes at 2-year.

Design

Radiological analysis of prospectively collected data.

Introduction

The optimal instrumented level selection in VBT surgery is currently unknown. The purpose of this study was to determine the effects of selecting different LIVs. in VBT surgery for AIS patients with Lenke 1 and 2 curves on 2-year radiographic outcomes.

Methods

Radiographic review of patients prospectively collected in the PSSG database who had Lenke 1 and 2 curves and minimum of 2-year follow-up. Coronal, sagittal parameters and distal adding-on were documented, and analysed according to whether the lower end vertebra (LEV), LEV+1 or LEV-1 was chosen as the LIV. Adding-on was defined as increased in vertebrae in the primary curve distally combined with increase >5mm deviation from CSVL or >5deg increase in angulation distal to LIV.

Results

102 patients were included, and the LIV were at LEV (n=77), LEV+1 (n=11) and LEV-1 (n=14). Baseline characteristics between groups such as age (p=0.06), gender (p=0.24), initial body height (p=0.70), initial body weight (p=0.59) and initial Cobb angle (proximal thoracic, p= 0.36; main thoracic, p=0.87; lumbar, p=0.24) were similar. At 2-year follow-up, there was significant correction of the thoracic and lumbar curves, radiographic shoulder height, T1-S1 height, in all groups. However, truncal shift correction was better in the LEV group (p<0.01) than the LEV+1 (p=0.087) or LEV-1 (p=0.051) groups, and LEV-1 group had significantly higher number of adding-on (42.9%, n=6) than the other 2 groups (LEV group: 9.1% (n=7), LEV+1 group: 9.1% (n=1) (p<0.01).

Conclusion

Choosing the LEV as the LIV in VBT surgery for thoracic AIS patients yielded the best improvement in truncal shift, but no significant improvement in LEV-1 or LEV+1. Choosing LEV-1 was associated with significant higher frequency of distal adding-on compared with LEV or LEV+1 at 2-year follow-up.

Take Home Message

LIV selection is important in determining radiographic outcomes at 2 years. Choosing the LEV yielded the best improvement in truncal shift and the least frequency of distal adding-on.

4. Predicting Overcorrection in AVBT: Can We Improve Patient Selection?

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Summary

AVBT is being increasingly recognized as a possible option in patients with idiopathic scoliosis as proof of concept and early favorable clinical results have been reported. The complication profile however is not insignificant and a better understanding of patient selection is critical. Our study determined an 8.7% overcorrection rate of which 45.5% required revision surgery in a cohort of 253 patients. Risser 0, greater initial curve correction and shorter preop height were significant predictors of overcorrection.

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Hypothesis

Initial curve correction and skeletal age are best predictors of overcorrection (OC) in anterior vertebral body tethering (AVBT)

Design

Retrospective multicenter review

Introduction

The high complication profile and revision surgery rate in AVBT due to OC suggests a better understanding of patient selection is needed. Our aim was to determine variables that were associated with OC and secondarily to identify predictors of OC in patients treated with AVBT.

Methods

A multicenter AVBT database identified consecutive patients with ≥ 2 -yr f/u. Patients were divided into 2 groups: overcorrection group (OCG) defined as $\geq 10^\circ$ of primary tethered Cobb in opposite direction at MRF; and non-overcorrection group (NOCG) having no radiographic complication or revision procedure by MRF. Univariate analysis explored the association between OC and variables of interest while multivariate regression analysis identified potential predictors of OC.

Results

253 patients were analyzed with mean f/u of 38mths [24-102]. OC rate was 8.7% with 10 patients (45.5%) requiring revision surgery. There was no statistical difference in preop coronal Cobb ($p=0.11$), flexibility ($p=0.054$), or sex distribution ($p=0.22$) between the groups. OCG had significantly smaller curves on FE x-ray ($p=0.007$), were younger by mean 1.5yrs ($p<0.001$), and were shorter on avg by 9.3cm ($p<0.001$). A statistically significant proportion of patients were Risser 0 in OCG (95%) compared to NOCG (58.6%) ($p<0.001$). OCG on avg had significantly more patients with open TRC compared to NOCG ($p=0.023$). Significantly more patients were Sanders <3 in OCG compared to NOCG ($p<0.001$). Regression analysis identified Risser 0 ($p=0.038$), FE Cobb ($p=0.001$), and preop height ($p<0.001$) to be predictors of OC with Risser 0 patients having an 11.6-fold greater chance of OC. Every degree improvement in FE Cobb increased rate of OC by 17.4%; for every cm decrease in preop height OC rate increased by 16.6%.

Conclusion

We found Risser 0, smaller FE Cobb, and shorter preop height to be predictors of OC in patients following AVBT. Although AVBT has shown efficacy in skeletally immature patients, this study suggests that patients that are too immature with significant initial curve correction are at a heightened risk of OC.

Take Home Message

Risser 0 patients with greater initial Cobb correction and smaller preop height are at significant risk of overcorrection possibly warranting revision surgery following AVBT.

Univariate Analysis

Variables of Interest	OCG n=22	NOCG n=231	p-value
Preop Primary Coronal Cobb [Range] ($^\circ$)	45.2+/-10 [30-81]	48.5+/-9.1 [30-73]	0.11
Flexibility (%)	54.6	45.4	0.054
T2-T12 Kyphosis ($^\circ$)	23.6+/-13.7	26.5+/-12.1	0.28
Gender (%)	F=95.4%; M=4.5%	F=82.6%; M=17.3%	0.22
FE Cobb ($^\circ$)	22.1+/-8	27.4+/-8.7	0.007*
Age(yrs)	11.1+/-1	12.5+/-1.7	<0.001*
Preop Height(cm)	147.6+/-7.9	156.8+/-10	<0.001*
Sanders <3 (%)	40	7.4	<0.001*
Open TRC (%)	77.3	47.2	0.023*
Risser 0 (%)	95	58.6	<0.001*
Thoracic/Lumbar Tether (%)	8/13.8	92/86.2	0.295

*p-value denotes significant difference

Multivariate Logistic and Linear Regression

	Odds Ratio Exp(B)	95% C.I. for Exp(B)	p-value	
Risser 0 vs ≥ 1	0.086	0.009	0.869	0.038*
FE Cobb	0.852	0.777	0.934	0.001*
Preop Height(cm)	0.858	0.788	0.935	<0.001*

*p-value denotes significant difference

5. Operative Differences for PSF after VBT: Are We Fusing More Levels in the End?

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Summary

This is a multicenter analysis of 15 cases requiring posterior spinal fusion (PSF) after failed vertebral body tethering (VBT). Compared to a matched cohort of PSF-Only patients, we found no differences in operative time (OT), postoperative length of stay (LOS), or type of instrumentation used. A greater number of levels were fused when VBT was chosen as the index procedure.

Hypothesis

We hypothesized that there would be: (1) no difference in OT, estimated blood loss (EBL), or postoperative LOS for PSF after VBT, and (2) a difference in instrumentation type and the number of levels fused for PSF after VBT.

Design

Retrospective, multicenter.

Introduction

VBT is recognized as a non-fusion alternative for idiopathic scoliosis in the skeletally immature patient. If the deformity progresses despite VBT, a PSF may result. To date, little has been published on the outcomes of these secondary procedures following a failed VBT.

Methods

We reviewed outcomes of VBT patients in the Harms Non-Fusion Registry and identified those that received a PSF following a failed VBT. A cohort of PSF patients were matched for age, pre-operative Cobb, and instrumented levels. OT, EBL, and postoperative LOS for PSF-VBT and PSF-Only patients were collected. Surgeons were asked about fusion levels prior to VBT, which were

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compared to the final number of levels fused. Instrumentation type was also evaluated. Significant differences were determined using paired t-tests.

Results

Of the 301 patients assessed, 15 received a PSF as a secondary procedure after VBT. The mean preoperative thoracic and lumbar Cobb angles were similar in both PSF-VBT (45.0±17.3° and 31.1±16.8°) and PSF-Only (47.0±15.7° and 32.6±15.0°) patients. We observed no difference in OT or postoperative LOS, but EBL was nearly double, on average, in PSF-Only patients (Table 1). In 10 PSF-VBT patients, the levels instrumented were 2.1 (range: 1 to 5; 7 of which added distally) levels longer, on average, than if they had received a PSF instead of VBT for their index procedure. Instrumentation for the PSF-VBT patients were 53% hybrid vs. the PSF-Only group where instrumentation was 47% hybrid.

Conclusion

We observed no difference in OT or postoperative LOS in patients that received a PSF after VBT. EBL was significantly greater in PSF-Only patients. No difference was observed in type of instrumentation between the two groups, but a greater number of levels were fused when VBT was chosen as the index procedure for most patients.

Take Home Message

We are more likely to fuse additional levels if VBT was chosen as the index procedure.

Variable	PSF-VBT	PSF	Paired T-Test P-Value
	Mean (SD)	Mean (SD)	
Preoperative Thoracic Cobb	45.0±17.3°	47.0±15.7°	---
Preoperative Lumbar Cobb	31.1±16.8°	32.6±15.0°	---
Operative Time (OT)	298.13 (111.6)	324.47 (111.2)	0.532
Estimated Blood Loss (EBL)	586.3 (521.9)	1075.3 (708.2)	0.037
Postoperative Length of Stay (LOS)	4.5 (1.6)	5.8 (4.0)	0.277
Instrumentation Type	All-Screw – 7 Hybrid – 8	All-Screw – 8 Hybrid – 7	---
Difference in Levels Fused	Less (5): 3.0 (range: 1-5) More (10): 2.1 (range: 1-5)	---	---

Table 1. Preoperative and Operative Variables, Instrumentation Type, and Levels Fused for PSF Procedure.

6. Results of Fusion after Failed Anterior Vertebral Body Tethering

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Summary

Some patients will require fusion after a failed anterior vertebral body tethering (aVBT). On average, fusion occurs 3 years after the index procedure. Excellent radiographic correction is attained, with similar implant density, estimated blood loss (EBL), and operative time as for those without a previous tether. However, the fusion after tethering extends 2 additional distal levels longer than the original tether, implying that a shorter fusion may have sufficed as the initial treatment.

Hypothesis

Fusion after aVBT will provide inferior outcomes compared to patients undergoing fusion without a previous aVBT.

Design

Single-center retrospective review.

Introduction

In some patients, aVBT will fail and require fusion. The outcomes of fusion in these patients have not previously been reported.

Methods

From a data set of 215 patients who had undergone aVBT, 7 (3.3%) subsequently underwent posterior spinal fusion. Clinical and radiographic data were collected pre tether, pre fusion, and post fusion. Patients who underwent aVBT followed by fusion (F) were compared with those who did not (NoF) using paired T-tests.

Results

Both groups were similar preoperatively, although the F group trended towards a larger Cobb angle (F=56.1 ± 18.5°, NoF=50.5 ± 11.3°, NS). Fusion was performed at age 15.7 ± 1.5 years and occurred a mean 35.3 ± 10.9 months after initial tether. The mean thoracic Cobb angle was 43.1 ± 10° and lumbar 24.6 ± 11.5°, with T5-12 measuring 20 ± 12°. Post fusion the thoracic Cobb angle measured 9.7 ± 4.2° and lumbar 14.7 ± 5.4°. On average, 8.1 ± 1.5 levels were fused, which was 2.8 ± 1 levels longer than the original tether. On average, the patients were fused 2 additional distal levels than if they had a fusion as their primary intervention. The implant density (1.92 ± 0.11), OR time (324.5 ± 48.2 minutes), EBL (501 ± 195 mL), and hospital stay (4.8 ± 0.8 days) were comparable to our institutional averages. There were no intraoperative neuromonitoring events.

Conclusion

A subset of patients will require posterior spinal fusion after aVBT. These failures typically occur 3 years after the index procedure. Fusion can be performed safely with similar radiographic and clinical results to those who did not have a previous tether. However, if fusion was performed as the initial surgical intervention these patients would have been fused 2 fewer levels distally.

Take Home Message

Fusion can be performed safely with similar results to those without a previous tether, but patients are fused longer than if they were fused as the index procedure.

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	Fusion (N=7)	No Fusion (N=208)	P
Age at Initial Procedure (Years)	13.3 ± 2	12.6 ± 1.3	NS
% Female	86	89	
% Premenarchal	100	59	
% Triradiates Open	29	34	
Thoracic Cobb (°)	56.1 ± 18.5	50.5 ± 11.3	NS
Pre-op Lumbar Cobb (°)	41.4 ± 18.1	33 ± 11.6	NS
Flexibility % Correction	54.7 ± 21.6	50.1 ± 21.3	NS
T5-T12 Kyphosis (°)	20.7 ± 9.5	20.4 ± 10.6	NS
T12-L5 Lordosis (°)	43.0 ± 11.4	46.6 ± 13	NS
Number of Levels Tethered	8.1 ± 1.5	8.2 ± 1.4	NS
Fusion			
Age (Years)	15.7 ± 1.5		
Risser	4.14 ± 0.9		
Thoracic (°)	43.1 ± 10		
Lumbar (°)	24.6 ± 11.5		
T5-12 Kyphosis (°)	20 ± 12		
Post Fusion			
Thoracic (°)	9.7 ± 4.2		
Lumbar (°)	14.7 ± 5.4		
T5-12 Kyphosis (°)	21.8 ± 9.8		

7. Estimating the Risk of Scoliosis Progression in Adolescent Idiopathic Scoliosis Based on Skeletal Maturity

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Summary

While skeletally immature patients and patients with larger curves are at greater risk of progression to surgical range, the exact risk for combinations of curve size and skeletal maturity is unclear. Although Sanders provided an accurate method of predicting peak height velocity using hand radiographs, a small sample size limited accurate predictions of curve progression. We examine a large cohort of patients with AIS treated with current standard of care to assess risk of progression to surgical range.

Hypothesis

Skeletally immature patients with larger presenting curves have a significantly greater risk of progression to surgical range compared to mature patients with smaller curves.

Design

Retrospective

Introduction

The use of hand radiographs for skeletal maturity staging is now frequently used to evaluate growth potential for adolescent idiopathic scoliosis (AIS) patients. Our aim was to evaluate a large cohort of AIS patients and use skeletal maturity and curve

magnitude to predict the likelihood of a patient requiring surgical intervention.

Methods

All patients with AIS treated at a large pediatric spine center with an initial visit from 2017-2019, a major curve <50°, and available hand radiographs were included. Patients underwent rigid bracing for curves >25°. Treatment success was defined as reaching skeletal maturity with a major curve <50°. Ranges of treatment success for major thoracic curves based on curve size and skeletal maturity were estimated using a normal approximation of the binomial function.

Results

Of 612 AIS patients (75% female) who were treated at our institution and had reached skeletal maturity at most recent follow up, 508 (83.0%) had major thoracic curves (Lenke type 1-4). 18% (86/508) of patients' curves progressed into surgical treatment range. Patients presenting with a major curve between 10-29°, had a 97% (286/295) rate of nonoperative treatment success across all skeletal maturity categories, compared to 64% (136/213) of patients with curves >30° (p<0.001). Relative to low-risk patients (no shading), intermediate-risk patients (grey shading) are 10.3 times (CI: 4.9-21.5) and high-risk patients (dark shading) are 88.8 times (CI: 42.1-187.2) more likely to progress to surgical range (Table 1).

Conclusion

Skeletal maturity and curve magnitude have strong predictive value for curve progression. The table presented here reinforces the work of Sanders et al regarding curve progression and may help set expectations for success of non-operative therapy.

Take Home Message

Increased skeletal maturity and smaller curve magnitude at presentation decrease the risk of curve progression. The table presented here represents a valuable resource for surgeons regarding patient's risk of progression.

	Skeletal Immaturity (S1-2)	Peak Height Velocity (S3-4)	Late Adolescence (S5-6)	Early Maturity (S7-8)
10-19°	100% (86-100%)	97% (84-100%)	100% (90-100%)	100% (54-100%)
20-29°	82% (56-96%)	94% (85-94%)	99% (93-100%)	100% (89-100%)
30-39°	22% (6-48%)	76% (60-88%)	90% (79-96%)	100% (86-100%)
40-49°	14% (0-58%)	21% (6-45%)	30% (14%-50%)	56% (30-80%)

Table 1. Chance of successful non-operative treatment with 95% confidence intervals for AIS patients with major thoracic curves based on Cobb angle and Sanders maturity score

8. Could Have Tethered, Glad We Didn't: A Review of AIS Patients Meeting Anterior Vertebral Body Tethering Criteria While Bracing

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Summary

As indications for anterior vertebral body tethering (AVBT) are being refined, understanding the success of rigid bracing for those who cross into AVBT surgical range ($>30^\circ$) is essential. We found that brace treatment allowed 43% of AIS patients meeting our institution's Investigational Device Exemption (IDE) AVBT criteria to reach skeletal maturity with a major curve less than 45° . Patients with a curve $<38^\circ$ at brace-tether overlap had an 80% chance of reaching skeletal maturity without needing surgery.

Hypothesis

Half of AIS patients meeting AVBT criteria during rigid brace treatment will reach skeletal maturity without progressing into surgical range.

Design

Retrospective review

Introduction

AVBT has become a popular growth modulation technique for correcting spinal deformity in AIS. AVBT is FDA approved for use in skeletally immature patients with major curves from 30 - 65° who have failed or are intolerant to rigid bracing. This range overlaps with traditional bracing indications (25 - 45°), creating a population who qualify for both AVBT and bracing. Our study was designed to determine the proportion of patients meeting our institution's IDE AVBT criteria while undergoing rigid bracing who reached skeletal maturity without needing surgery.

Methods

126 AIS patients with final outcomes (either had a PSF or reached skeletal maturity without surgery) who presented with a Sanders score ≤ 4 and underwent rigid bracing at a single pediatric spinal center from 2016 to 2019 were included. Patients with Lenke 3 and 4 curves were excluded. All patients were evaluated for measurements that overlapped (Sanders score ≤ 4 with a major curve from $\geq 35^\circ$ to $\leq 45^\circ$) with our institution's more stringent IDE AVBT criteria (major curve 35 - 60°). A patient was deemed to have unsuccessfully braced if their primary curve progressed past 45° . ROC analysis was performed to identify the ideal overlapping curve cutoff. Logistic regression to determine likelihood of progression was then performed using this cutoff.

Results

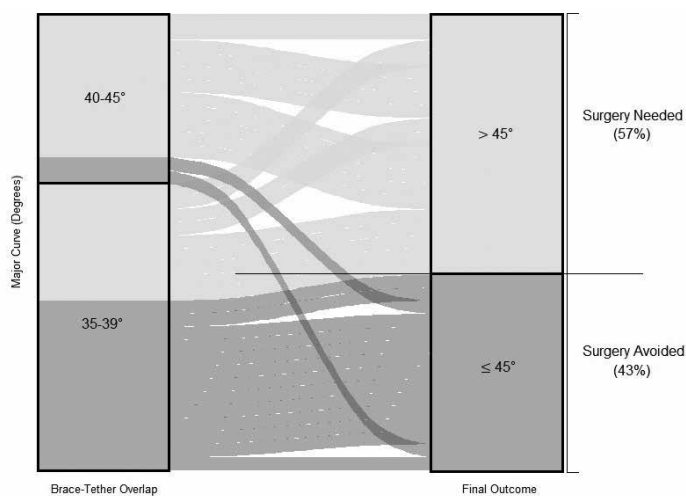
35 patients (74% female) had a Sanders score of ≤ 4 with a major curve from 35° to 45° during brace treatment. 43% (15/35) were successfully braced (Figure 1). Patients with curves $<38^\circ$ at brace-tether overlap had an 80% chance of successful bracing ($p < 0.001$). Patients with curves $\geq 38^\circ$ at overlap had a 16% chance of successful bracing ($p < 0.001$).

Conclusion

43% of patients who met indications for AVBT while bracing reached skeletal maturity without needing surgical intervention. Patients with curves less than 38° had an 80% chance of successful non-operative treatment.

Take Home Message

Bracing failure should be an important consideration before offering AVBT as almost half of immature bracing AIS patients with a curve in AVBT range may avoid surgery.



Change in curve magnitude from time of brace-tether overlap to final outcome.

9. 2 to 5-Years Follow-Up Results after Thoracoscopic VBT: A Single Surgeon's Experience

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Summary

This study reports a single European center experience on 42 consecutive patients with ≥ 2 -years follow-up who had undergone thoracic-only Vertebral Body Tethering (VBT) surgery. Surgical correction was followed by growth-dependent correction attained during follow-up. Spontaneous correction in the non-operated upper thoracic and thoracolumbar levels were also noted. VBT improved pulmonary function. Overall pulmonary, mechanical and curve behavior complications rates were 12%, 19% and 33%, respectively. 95% patients avoided fusion, of whom 92% had $\leq 30^\circ$ residual curve at final follow-up.

Hypothesis

VBT is a safe and effective procedure

Design

Retrospective analysis of prospectively collected data

Introduction

There is a paucity of information on clinical and radiographic outcomes of VBT surgery. Current information is not yet strong enough to convince surgeons to include this surgical technique to their armamentarium.

Methods

Data were collected preoperatively, at 6-weeks, 1-year, 2-years and latest follow-up. Demographic, perioperative, clinical, radiographic data and complications were analyzed. Curve sizes at each follow-up were compared using repeated measures ANOVA. Respiratory function was compared between preop, 1-year and 2-years postop. Clinical outcome was assessed by using SRS-22r.

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Results

42 AIS pts (40F, 2M; 12.1±1.5 years) with a mean follow-up of 33 (24-62) months were included. 95% were Lenke 1 (21A, 4Ar, 11B and 1C) and 5% were Lenke 2. Preoperatively, 25 (62.5%) patients were premenarchal (median Sanders: 3 (1-7), median Risser: 1 (0-5)). A median of 7 (6-9) levels were tethered. Mean surgical time was 240±70 (123-360) minutes. Patients grew 8cm on average; height measurements showing significant increase at each follow-up time point (p<0.001) (Fig). 88% of the patients reached skeletal maturity at final follow-up. Upper Thoracic (UT), Main Thoracic (MT) and Thoracolumbar/lumbar (TLL) curves showed significant decrease in each follow-up time point. No significant changes were noted in kyphosis and lordosis (p<0.05) (Fig). FVC% and FEV1% showed significant increase from preop to 1 year, as well as from 1 to 2 years (p<0.001) (Fig). Pulmonary, mechanical and curve behavior complications rates were 12%, 19% and 33%, respectively (Fig). 2 (4.8%) patients were converted to fusion (Fig). At final follow-up, 92% patients had ≤30° residual curve. SRS-22 MH, SI and subtotal scores increased significantly (Fig).

Conclusion

Thoracoscopic VBT surgery prevented fusion in 95% of patients of whom 92% had good radiographic and clinical outcomes; however, it is not without complications. Pulmonary function showed a gradual increase. Some complications may be avoided with a better understanding of the growth modulation and advancement of technical skills and technology.

Take Home Message

VBT is a safe and effective procedure for children with remaining growth potential. Satisfactory clinical and radiographic results may be achieved in growing adolescents.

	Pre-Operative		6 weeks		12 months		24 months		Last follow-up	
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
Height, cm	42	154.6 ± 8.6	42	156 ± 8.5	42	160 ± 7.6	42	161.8 ± 7	42	152.5 ± 7.3

	Pre-Operative		6 weeks		12 months		24 months		Last follow-up	
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max	Mean ± SD	Min-Max
UT, Degree	28.1 ± 8.4	14 - 55	19.5 ± 7.3	8 - 37	16.5 ± 6.9	3 - 35	15.3 ± 7.1	1 - 36	16.1 ± 9.0	1 - 49
TLL, Degree	30 ± 7.9	12 - 48	18.4 ± 8.4	3 - 39	15 ± 9.9	0 - 43	12.6 ± 10.9	-10 - 44	15.3 ± 11.4	-18 - 44
MT, Degree	48.4 ± 8.9	35 - 73	25.9 ± 6.8	15 - 40	19.9 ± 7.7	0 - 35	17.7 ± 10.1	-16 - 36	20.0 ± 10.9	-11 - 49
Kyphosis, Degree	29 ± 9.5	15 - 59	26.8 ± 9.5	6 - 47	28.3 ± 8	9 - 41	28.9 ± 8.6	13 - 48	29.3 ± 8.5	13 - 52
Lordosis, Degree	60.3 ± 10.9	37 - 91	55.3 ± 10.3	35 - 90	57.6 ± 10.3	34 - 88	56 ± 8.6	39 - 74	55.5 ± 8.9	36 - 75

	Pre-Operative		6 weeks		12 months		24 months	
	n	Mean ± SD	n/a	n/a	n	Mean ± SD	n	Mean ± SD
PVOC Predicted	41	80.5 ± 15.6			38	85.2 ± 15.3	23	90.4 ± 10.4
FEV1% Predicted	41	80.5 ± 15.4			38	87.8 ± 15.5	23	90.4 ± 10.4
FEV1/ FVC	41	85.5 ± 5.3			38	88.6 ± 5.7	23	88.7 ± 6.6

	Pre-Operative		6 weeks		12 months		24 months		Last follow-up	
	n	Mean ± SD	n/a	n/a	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
SRS-22r: F	35	4.5 ± 0.6			38	4.6 ± 0.4			42	4.6 ± 0.4
SRS-22r: P	35	4.4 ± 0.7			38	4.5 ± 0.5			41	4.5 ± 0.5
SRS-22r: SI	35	3.4 ± 0.4			38	4.2 ± 0.7			41	4.1 ± 0.7
SRS-22r: MH	35	3.7 ± 0.5			38	4.0 ± 0.7			41	3.9 ± 0.8
SRS-22r: Subtotal	35	4.0 ± 0.4			38	4.3 ± 0.5			41	4.3 ± 0.5
SRS-22r: Satisfaction	n/a	n/a			38	4.7 ± 0.5			41	4.7 ± 0.6

	n (%)		n (%)		n (%)		n (%)
Curve Behavior Complications	14 (33.3)	Overcorrection	9 (21.4)	Distal adding on	4 (9.5)	Worsening	1 (2.4)
Mechanical Complications	8 (19)	Broken Tether	5 (11.9)	LIV migration	3 (7.1)	LIV Migration	1 (2.4)
Pulmonary Complications	5 (11.9)	Atelectasis	3 (2.4)	Pleural Effusion	1 (2.4)	Chylothorax	1 (2.4)
Readmission	1 (2.4)						
Revised Patients	3 (7.1)						
Reoperations	4 (11.9)	Tether Release	2 (4.8)	Conversion to Fusion	2 (4.8)		

10. Thoracolumbar Curve Behavior after Selective Thoracic Anterior Vertebral Body Tethering in Lenke 1A vs. Lenke 1C Curve Patterns

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Summary

Lenke 1C curves treated w/ selective thoracic AVBT demonstrate equivalent thoracic (T) curve correction and reduced thoracolumbar (TL) curve correction compared to Lenke 1A curves. Additionally, at most recent follow-up, both curve types demonstrate equivalent coronal alignment at C7 and the apex, though 1C curves have better alignment at the LIV and both have equivalent rates of revision surgery.

Hypothesis

The purpose of this study is to evaluate changes in T/TL curves and truncal balance in pts treated w/ AVBT w/ Lenke 1A vs. 1C curves at min of 2 yr fu

Design

Retrospective review of prospective database

Introduction

There remains significant debate on the ideal treatment of Lenke 1C curves, including whether they are appropriate for selective thoracic AVBT, if they should undergo a double AVBT or if they should be treated w/ selective thoracic fusion. Effect of AVBT on the uninstrumented TL curve and trunk balance in Lenke 1C curves has not been investigated, nor has it been compared to the results of Lenke 1A curves

Methods

A matched cohort of 43 Risser 0-1, Sanders 2-5 AIS pts with Lenke 1A and 19 pts with Lenke 1C treated with selective thoracic AVBT and a minimum of 2 yr fu were included. Digital radiographic software was used to assess Cobb angle, coronal alignment on preop, postop and subsequent follow-up radiographs. Coronal alignment was assessed by measuring the distance from the CSVL to the midpoint of the LIV, curve apex and C7

Results

There was no diff in the T Cobb preop, 1st erect pre-rupture or at most recent follow-up, nor was there a diff in C7 alignment p=.057 nor apical alignment p=.272 between the 1A and 1C groups. There was a diff in TL curve w/ the 1A curves being smaller at all time points, preop p<.00001, 1st erect p=.00367 and most recent follow-ups p=.000124. The Lenke 1C curves in contrast had improved alignment at the LIV at most recent follow-up p=.0355. At most recent follow-up there was no diff in the number of pts with both the T/TL curves ≤35, 33/43 Lenke 1A and 14/19 Lenke 1C curves, between the groups p=.80. There was no diff in the rate of revision surgery p=.546

Conclusion

This is the first study to look at the impact of curve type on outcomes in AVBT. We found that Lenke 1C curves treated w/ selective thoracic AVBT demonstrate less correction of the TL curve at all time-points, but have equivalent alignment at C7 and the curve apex at most recent follow-up compared to 1A curves and better alignment at the LIV. Furthermore, they have an equivalent rate of revision surgery compared to Lenke 1A curves

Take Home Message

Selective thoracic AVBT is a viable option for Lenke 1C curves, despite equivalent correction of the thoracic curve, there is less correction of the thoracolumbar curve at all-time points

Preoperative					2-Year Follow-Up				
Parameter	Mean	SD	Range	P value	Parameter	Mean	SD	Range	P value
Age	14.3	1.4	11-19	<0.001	Age	16.3	1.4	11-19	<0.001
TK	34.9	13.2	18-68	0.04	TK	38.5	12	20-68	0.04
LL	54.7	10.9	38-78	0.3	LL	52.5	11.1	38-78	0.3
PT	6.3	6.4	0-25	0.7	PT	8.9	15.2	0-25	0.7
PI	48.5	10.6	30-68	-	PI	-	-	-	-
SVA	1.4	34.4	-25-68	0.8	SVA	-1.2	25.7	-25-68	0.8
LL in lumbar VBT	53.4	12.1	38-78	0.8	LL in lumbar VBT	52.4	11	38-78	0.8
TK in 2a/2b/3 patients	25.4	12.2	10-58	0.05	TK in 2a/2b/3 patients	31	8.9	10-58	0.05

11. Sagittal Alignment after Vertebral Body Tethering: 2 Years Follow-Up

Alice Baroncini, MD, PhD; Filippo Migliorini, MD; Per D. Trobisch, MD

Summary

Data on the effects of Vertebral Body Tethering (VBT) on sagittal parameters are scarce. In our experience on 30 patients with a 2-years follow-up, VBT allowed for an improvement of thoracic kyphosis without reducing lumbar lordosis, even in patients with lumbar instrumentation. 57% of patients had a physiological sagittal profile after VBT, while 37% had a physiological profile before VBT. Age and curve magnitude did not influence postoperative thoracic kyphosis and lumbar lordosis.

Hypothesis

Vertebral Body Tethering (VBT) improves sagittal parameters and does not have a kyphotic effect on the lumbar spine.

Design

Retrospective

Introduction

VBT is able to achieve coronal curve correction in patients with AIS. Curve correction is based on a combination of immediate intraoperative correction and, to a smaller amount, on growth modulation. Sagittal alignment has shown to correlate with quality of life but data on the effect of VBT on sagittal parameters are limited.

Methods

Analysis of all skeletally immature patients with minimal follow-up of 2 year after VBT. Thoracic and lumbar Cobb angles, TK, LL, pelvic tilt (PT), pelvic incidence (PI), and sagittal vertical alignment (SVA) before and 2 years after VBT were compared. The sagittal profile was evaluated with the Abelin-Genevois (AG) classification. A multivariate analysis was used to assess the influence of baseline data (age, radiographic parameters) on postoperative TK and LL.

Results

Data from 30 patients were available (age 14.3±1.4 years), 8 thoracic, 3 thoracolumbar/lumbar and 19 double instrumentations. There was a significant increase in TK; LL, PT and SVA remained stable. Patients after TL/L VBT also had no change of LL (Table 1). Pre-op, 11 patients were AG type 1, 4 type 2a, 9 type 2b, 6 type 3. Post-op, TK improved for most patients (Table 2) and 17 patients obtained a normokyphotic profile. TK and LL at 2 years correlated with preoperative TK and LL (r=0.76 and r=0.46), but not with other baseline data.

Conclusion

VBT has a positive effect on sagittal parameters by increasing TK and not reducing LL. Most AG type 1/2a patients became type 1, which is considered physiologic. Most type 2b/3 maintained the preoperative alignment, with an increase in TK.

Take Home Message

Vertebral Body Tethering has a positive effect on sagittal parameters, in particular allowing for an improvement in thoracic kyphosis. No kyphotic effect on the lumbar lordosis was observed.

	Preoperative	2-years	P
Cobb T°	55.1 ± 14.1	35.6 ± 16.9	< 0.0001
Cobb L°	51.3 ± 14.6	30.5 ± 12.6	< 0.0001
PI°	48.5 ± 10.6	-	-
TK°	34.9 ± 13.2	38.5 ± 12	0.04
LL°	54.7 ± 10.9	52.5 ± 11.1	0.3
SVA mm	1.4 ± 34.4	-1.2 ± 25.7	0.8
PT°	6.3 ± 6.4	8.9 ± 15.2	0.7
LL° in lumbar VBT	53.4 ± 12.1	52.4 ± 11	0.8
TK° in 2a/2b/3 patients	25.4 ± 12.2	31 ± 8.9	0.05

Table 1

		Sagittal profile			
		2-years			
		1	2a	2b	3
Preoperative	1	10		1	
	2a	4			
	2b	3	1	5	
	3		1		5

Table 2

Table 1: Summary of radiographic parameters; Table 2: Overview of the changes in the sagittal profile

12. 10-Year Follow-Up of Lenke V Curves in Patients with Adolescent Idiopathic Scoliosis

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Summary

54 patients with spinal fusion for Lenke V thoracolumbar curves were reviewed at ten year follow up. Curve correction was stable in 80% of patients however a loss of correction was seen in 20% at final follow up. Disc wedging and lumbar apical translation was also stable. Clinical outcomes were excellent and did not differ from normative data on 20-40 year olds without scoliosis.

Hypothesis

Spinal fusion of Lenke V curves will be radiographically stable at 10 years follow up with no decline in clinical outcome scores

Design

Retrospective review of prospectively collected database

Introduction

Patients with surgically treated Lenke V curves require at least partial fusion of the lumbar spine. Longer term outcomes evaluating clinical and radiographic results are lacking.

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Methods

A review of a prospectively collected database of patients with Lenke V curves treated with spinal fusion was performed. Clinical and radiographic outcomes were collected at 10 year follow up. Normative data was used for comparison of clinical outcomes.

Results

54 patients (26 PSF and 28 ASF) with 10 year follow up. 33.4% were treated with long fusion (above T9) and 66.6% with short fusion (T9 and below). Preoperative curve magnitude was $45.1 \pm 8.4^\circ$ and corrected to $14.0 \pm 7.2^\circ$ ($p < 0.001$). A $3.3 \pm 7.3^\circ$ increase in curve was noted at follow up ($p < 0.008$) with 20.3% of patients having a loss of correction (LOC) $> 10^\circ$. Thoracic curve correction and T5-T12 kyphosis were stable at 10 years. LIV angulation improved from $11.2 \pm 23.2^\circ$ to $0.96 \pm 6.4^\circ$ ($p = 0.004$) and translation from 2.5 ± 2.9 cm to 0.92 ± 1.5 cm ($p = 0.008$) with no LOC. Similarly, C7-CSVL and apical lumbar translation improved significantly on first erect radiograph with no LOC at final follow up. Disc wedging below the LIV increased from $0.3 \pm 4.9^\circ$ to $2.8 \pm 4.4^\circ$ ($p < 0.001$) with no subsequent change at 10 years. There was no increase in SRS pain scores (4.3 ± 0.7 preop vs. 4.2 ± 0.6 10-year, $p = 0.53$). Using normative data for adults aged 20-40, there was no correlation between pain scores 2-standard deviations below normal and LOC $> 10^\circ$ ($p = 0.99$), L3 vs. L4 as LIV ($p = 0.34$), or thoracic vs. lumbar fusion ($p = 0.14$). There were three complications using the Clavien-Dindo classification greater than grade II (2 CDS III and 1 CDS IVa) in the ASF group and none in the PSF group. No patient required a second operation.

Conclusion

Spinal fusion was durable at 10 year follow up but 20% of patients had a loss of correction $> 10^\circ$; this did not correlate with worse pain or need for revision surgery. Disc wedging was stable. Selection of LIV did not correlate with pain scores.

Take Home Message

Results of spinal fusion at ten-year follow up are very good and outcomes are stable without a high risk of revision surgery.

13. Fixed Coronal Malalignment (CM) Independently Impacts Disability in Adult Spinal Deformity (ASD) Patients when Considering the Obeid-CM (O-CM) Classification

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Summary

We analyzed a large Adult Spinal Deformity (ASD) database and included patients who underwent a lumbar fusion of more than 3 levels. Patients were classified according to the 6 modifiers of the O-CM classification and compared to coronally aligned patients. Multivariate analysis, considering age and sagittal alignment as cofounding factors, showed an independent correlation between CM and PROMs. Results showed that the severity of symptoms increases with progressive postoperative coronal imbalance.

Hypothesis

Fixed CM independently correlates with PROMs.

Design

A retrospective review of a prospective multicenter ASD database with patients who underwent lumbar fusion of more than 3 levels.

Introduction

The correlation between post-operative sagittal imbalance and disability is now accepted. However, fixed CM has been less described and some authors report no significant association with clinical outcomes. The O-CM classification analyses CM and incorporates specific modifiers for each curve type. This study evaluates these modifiers according to age, sagittal alignment and PROMs.

Methods

We included 743 ASD patients with long lumbar fusion (more than 3 levels), with at least two years of follow-up. Patients were classified according to O-CM classification. The impact of increasing Central Sacral Vertical Line (CSVL) malalignment above 2cm on PROMs was analyzed. Multivariate analysis was performed on the relationship between PROMS and age, global tilt (GT) and CM modifiers.

Results

Controlling for age and GT the multivariate analysis showed that CM above 2cm independently affects PROMs. Disability increases linearly with CSVL. Patients classified in 2B (curve with L5 oblique take-off) modifier have the worst SRS-22 total score, social life and self-image.

Conclusion

In the fused spine, CM independently affects disability in ASD patients. Disability increases linearly with CSVL. Despite previous reports failing to find a correlation between CM and PROMs, our study showed that when each modifier is considered a clear correlation exists.

Take Home Message

Fixed postoperative coronal malalignment, according to the O-CM classification, correlates independently from sagittal plane and age with PROMs. 2B modifier (L5 oblique take-off) is associated to worst SRS-22 total score.

Main types	Subtypes	Main features	Number of patients included
Type 0 No CM		CSVL < 2 cm	551
Type 1 Concave CM		Coronal malalignment towards the concavity of the main curve	
	Type 1A2 Main L/TL curve	Main curve with apex between T12 and L4	68
Type 2 Convex CM		Coronal malalignment towards the convexity of the main curve	
	Type 2a2 Main L/TL with rigid lumbar sacral junction	L4-S1 degenerated or stiff	94
	Type 2B Main lumbar sacral curve	Main curve apex below L4	30

1a1, 1b and 2a1 types are not represented because they consider flexible lumbar spines

O-CM modifiers and patient distribution

14. Postoperative Coronal Malalignment after Adult Spinal Deformity Surgery: Incidence, Risk Factors, and Impact on 2-Year Outcomes

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Summary

Postoperative coronal malalignment (CM) occurred in 18% of 243 patients undergoing adult spinal deformity (ASD) surgery. The strongest risk factors for postoperative CM were: preoperative coronal/sagittal malalignment, pelvic obliquity, lumbosacral fractional (LSF) curve concavity to the same side of the coronal vertical axis (CVA), and max cobb angle concavity opposite the CVA. Postop CM was associated with increased complications but not reoperation or 2-year patient reported outcomes (PROs).

Hypothesis

A subset of pts undergoing adult spinal deformity (ASD) surgery will have postop coronal malalignment (CM) with suboptimal outcomes.

Design

Retrospective cohort

Introduction

Little is known regarding the incidence and risk factors for postop CM after ASD surgery.

Methods

A single-institution database was queried for ASD pts undergoing ≥ 6 level fusions from 2015-19. Postop CM was defined as C7 coronal vertical axis (CVA) > 3 cm. Iatrogenic CM was defined as postop CVA > 3 cm in pts without preop CM. Demographic, radiographic, & surgical variables were collected. 2-year outcomes included: complications, readmissions, reoperations, & ODI/SRS-22r. Logistic regression was performed.

Results

243 ASD pts had preop and immediate postop measurements; 174 pts (72%) had 2-year f/u. Mean age was 50.9 ± 17.6 & mean instrumented levels was 13.5 ± 3.9 . Mean preop CVA was 2.9 ± 2.7 cm, and 90 (37%) had preop CM. Postop CM was seen in 43 (18%) pts, 13 (5%) of which were iatrogenic. Significant risk factors for postop CM were: EBL (OR 1.00; $p=0.026$), operative time (OR 1.16; $p=0.045$), preop CVA (OR 1.21; $p=0.001$), preop SVA (OR 1.05; $p=0.046$), pelvic obliquity (angle between horizontal & iliac crests) (OR 1.21; $p=0.008$), lumbosacral fractional (LSF) curve concavity to the same side as the CVA (OR 2.31; $p=0.043$), & max cobb angle concavity opposite the CVA (OR 2.10; $p=0.033$). The single significant risk factor for iatrogenic postoperative CM was a LSF curve concavity to the same side as the CVA (OR 11.39; $p=0.020$). Patients with postop CM were more likely to sustain a postop complication (31.0% vs. 14.3%; $p=0.009$), yet no differences were seen in readmissions ($p=0.743$) or reoperations ($p=1.000$). No significant differences were seen in 2-year PROs according to postop CM.

Conclusion

Postop CM occurred in 18% of ASD patients and was most associated with preop CVA, pelvic obliquity, LSF curve to the same side as the CVA, and max cobb angle to the opposite side of the CVA. Though postop CM was significantly associated with increased complications, surprisingly, readmission, reoperation, & 2-year PROs were similar in those with and without CM.

Take Home Message

Postop CM occurred in 18% of ASD-patients. Risk factors were preop malalignment, pelvic obliquity, lumbosacral fractional curve to same side of the CVA, and max cobb angle opposite the CVA.

Table 1. Significant risk factors for postoperative coronal malalignment (CM).

	Postop CM		Iatrogenic Postop CM	
	OR, 95% CI	p-value	OR, 95% CI	p-value
Estimated blood loss (EBL, mL)	1.04 (1.01, 1.08)	0.026	--	--
Operative time (minutes)	1.16 (1.00, 1.35)	0.044	--	--
Preop CVA (cm)	1.21 (1.08, 1.35)	0.001	--	--
Preop SVA (cm)	1.05 (1.00, 1.09)	0.048	--	--
Pelvic Obliquity ($^{\circ}$)	1.21 (1.05, 1.40)	0.008	--	--
Lumbosacral fractional (LSF) curve same side CVA	2.06 (1.02, 4.15)	0.043	11.39 (1.46, 89.04)	0.020
Max cobb angle opposite CVA	2.10 (1.06, 4.18)	0.033	--	--

15. Comparative Effectiveness of Ant-IF vs. Post-IF in ASD Surgery: A Propensity Score Based Analysis

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Summary

Interbody Fusion (IF), performed anteriorly (Ant-IF) or posteriorly (Post-IF), is frequently employed in ASD surgery. Recent technological advances have boosted the use of Ant-IF. Evidence needed for accurate surgical decision making is still lacking. Our study shows, in propensity score (PS) matched patients followed-up prospectively for > 2 -years, that Ant-IF allows for better sagittal correction and may protect against mechanical complications and reinterventions. Ant-IF could be a better option in patients at risk for mechanical complications needing larger sagittal corrections.

Hypothesis

Compared with Post-IF, Ant-IF improves ASD deformity correction, fusion rate and clinical outcomes

Design

Comparison of Ant-IF vs. Post-IF in comparable PS-matched ASD patients

Introduction

IF is commonly used in ASD surgery to promote fusion and restore sagittal alignment. Posterior-only approaches were predominant for years. Technological advances and deficiencies of posterior-only approaches have boosted the use of anterior-posterior surgeries. There is no definitive evidence describing the benefits of Ant-IF vs. Post-IF in ASD. The objective of this study

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was to assess surgical outcomes in comparable ASD patients treated with Ant-IF vs. Post-IF

Methods

We identified all patients included in an international prospective ASD database, operated before Dec 2018, receiving IF and having 2YFU data. A PS analysis was performed to adjust Ant-IF and Post-IF attributes making the populations comparable. The PS was built using 21 confounding variables defined by a multicentre team of surgeons through 2 rounds of consensus. To guarantee a high overlap of treatment distributions, PS area 0-0.5 was selected. We compared 6w and 2y radiographic outcomes, 2y HRQL gain and incidence of postoperative adverse events. Differences among groups were assessed with average treatment effects (ATEs) based on PS. Statistical significance was set in $ATE > 2SE$ (Standard error)

Results

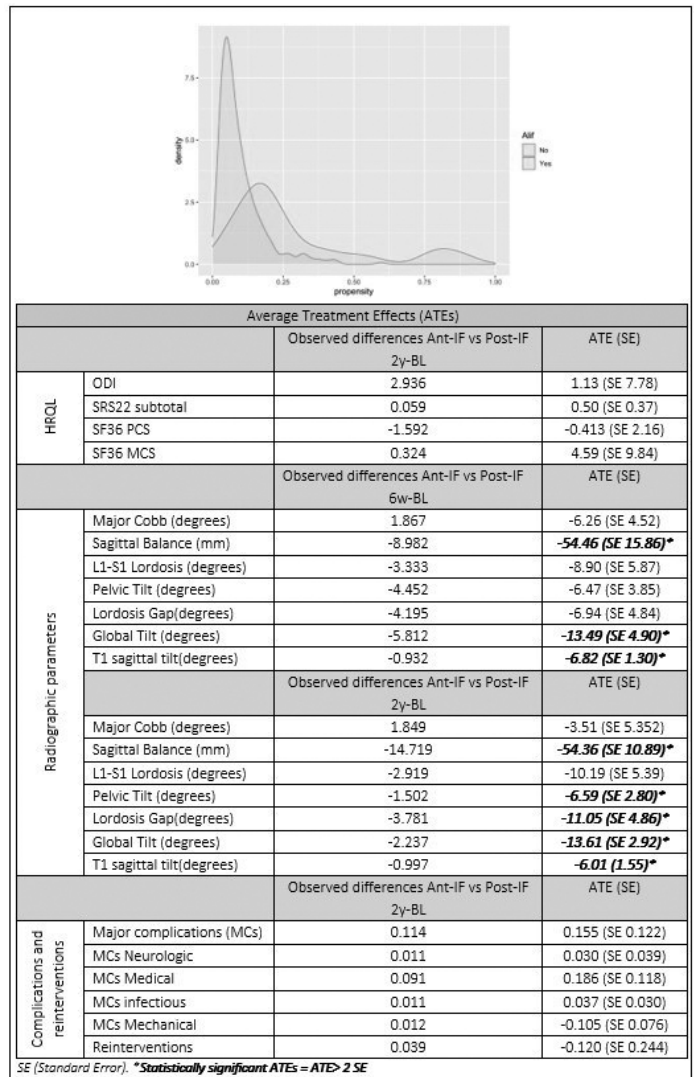
431 patients were treated with IF before Dec2018. 369 (93.3%) had 2yFU data and were included in the study (79.4% females, mean age 62.9, coronal cobb 33.7, SVA 60.8). 47 (12.7%) received Ant-IF and 322 (87.3%) Post-IF. Before PS-matching, Ant-IF population was younger (58.6vs63.6y, $p < 0.05$), more frequently fused to ilium (80.9%vs51.2%, $p < 0.05$) and had a higher rate of IF per patient (2.8vs1.6, $p < 0.05$). ATEs showed that Ant-IF was associated with greater sagittal correction. No significant differences in 2y HRQL were found. A trend towards fewer mechanical complications and reinterventions associated with Ant-IF was identified (Table)

Conclusion

In matched ASD patients, Ant-IF is associated with better sagittal correction and possibly also a reduced risk of postop mechanical complications and reinterventions

Take Home Message

In comparable, PS-matched ASD patients, Ant-IF is associated with better sagittal alignment and perhaps a reduction in mechanical complications and unplanned reoperations, compared with Post-IF



16. Fractional Curve Correction Using TLIF vs. ALIF in Adult Scoliosis

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Summary

Few reports focus on fractional curve correction with transforaminal (TLIF) vs. anterior lumbar interbody fusion (ALIF) for adult symptomatic thoracolumbar/lumbar scoliosis (ASLS). This study assessed 106 ASLS patients and demonstrated similar fractional curve correction using L4-S1 TLIF vs. ALIF. TLIF cage height had significant impact on leveling L4 coronal tilt; ALIF cage lordosis had significant impact on lumbosacral lordosis restoration.

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TLIF was associated with reduced operative duration, but HRQL was inferior and more rod fractures were detected compared to ALIF.

Hypothesis

Long fusions with TLIF vs. ALIF are associated with similar fractional correction, but HRQL and complications may differ.

Design

Prospective multicenter observational series

Introduction

Few ASLS studies investigate fractional correction with TLIF vs. ALIF.

Methods

Prospective multicenter data was reviewed. Inclusion required fractional curve $\geq 10^\circ$, thoracolumbar/lumbar curve $\geq 30^\circ$, index TLIF vs. ALIF at L4-L5 and/or L5-S1, and min 2y fu.

Results

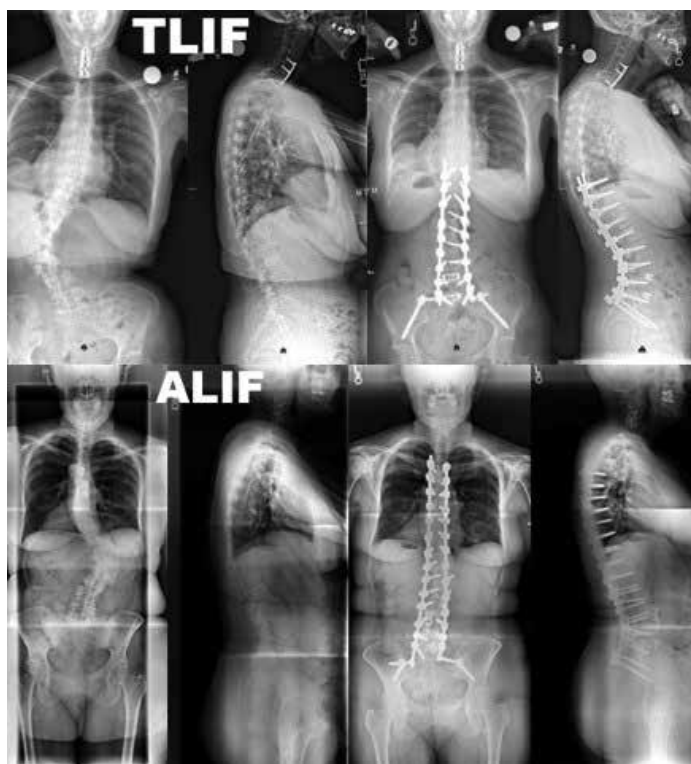
Of 135 consecutive pts, 106 (79%) achieved 2y fu (age=61±9yrs, women=86%, TLIF=44%, ALIF=56%). Index ops had 12±4 posterior levels, iliac fixation=87%, and TLIF/ALIF at L4-L5 (67%) and L5-S1 (84%). ALIF had greater cage height (11±2 vs. 15±3mm, $p=0.001$) and lordosis ($6^\circ \pm 2^\circ$ vs. $17^\circ \pm 10^\circ$, $p=0.001$) and longer op duration (7±2 vs. 9±3hrs, $p<0.001$). Final alignment improved significantly ($p<0.05$): fractional curve ($20^\circ \pm 7^\circ$ to $7^\circ \pm 5^\circ$), max cor Cobb ($55^\circ \pm 15^\circ$ to $24^\circ \pm 14^\circ$), SVA (5±6 to 2±5cm), PT ($25^\circ \pm 8^\circ$ to $23^\circ \pm 10^\circ$), and LL ($32^\circ \pm 19^\circ$ to $51^\circ \pm 14^\circ$). Fractional correction was similar (TLIF= $-14^\circ \pm 7^\circ$ vs. ALIF= $-14^\circ \pm 8^\circ$, $p=0.982$). Final HRQL improved significantly ($p<0.05$): Oswestry Disability Index (ODI, 42±16 to 24±20), Short Form-36 Physical Component Summary (PCS, 33±9 to 41±12), Scoliosis Research Society-22r (3±1 to 4±1). TLIF had worse ODI (31±21 vs. 18±17, $p=0.017$) and PCS (38±12 vs. 45±10, $p=0.020$) at last follow-up. Total complication rate per pt was not different (TLIF=77% vs. ALIF=71%, $p=0.530$), but significantly more TLIF pts had rod fractures (RF) (TLIF=29% vs. ALIF=7%, $p=0.036$). Multiple regression demonstrated 1-mm increase in L4-L5 TLIF cage height lead to 2.2° reduction in L4 coronal tilt ($p=0.011$), and 1° increase in L5-S1 ALIF cage lordosis lead to 0.4° increase in L5-S1 segmental lordosis ($p=0.045$).

Conclusion

Operative ASLS treatment with TLIF vs. ALIF demonstrated comparable fractional correction (67% vs. 65%) despite significantly larger, more lordotic ALIF cages. TLIF cage height had significant impact on leveling L4 coronal tilt, whereas ALIF cage lordosis had significant impact on lumbosacral lordosis restoration. Advantages of TLIF may include reduced operative duration; however, associated HRQL was inferior and more RFs were detected in this study.

Take Home Message

Fractional correction was similar for TLIF vs. ALIF in long fusions for ASLS. TLIF was associated with reduced operative duration, but there was inferior HRQL more RFs (compared to ALIF).



17. Central Sacral Pelvic Line (CSPL) is a Useful Radiographic Parameter that Correlates with Clinical Outcomes of Coronal Alignment after Spine Deformity Surgery

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Summary

The relationship between adequate coronal alignment and patient reported outcomes in spine deformity surgery have yet been clearly identified. The lack of correlation may be due to the inadequate assessment of coronal spinal alignment based on the central sacral vertical line (CSVL). We established the first radiographic parameter, central sacral pelvic line (CSPL), that evaluates coronal alignment and correlates with ODI and SRS scores.

Hypothesis

CSPL is a better clinical predictor of coronal alignment than CSVL based on ODI/SRS scores.

Design

Prospectively collected cohort

Introduction

There is a paucity of literature demonstrating a reliable relationship between radiographic coronal malalignment and patient reported outcome scores, potentially due to the inadequacy of CSVL to appropriately represent the coronal alignment. CSPL is a novel radiographic parameter that portrays coronal alignment after spine deformity surgery.

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Methods

We reviewed 93 deformity patients from 2015-2018. The CSPL bisects the sacrum and is perpendicular to the line connecting the superior aspects of the acetabuli. We derived two radiographic metrics describing coronal alignment: (1) the horizontal distance between the C7 plumb line and the CSPL (C7-CSPL) and (2) the horizontal distance between the C7 plumb line and the CSVL (C7-CSVL). We divided patients into coronally aligned (CA) and malaligned (CM) groups based on a) CM as C7-CSVL>4cm and b) CM as C7-CSPL>4cm in 2yr follow up. Logistic regression and Chi-square analyses evaluated the relationship between the postop C7-CSVL and C7-CSPL with Δ ODI/SRS (difference between pre and 2 yr postop) scores.

Results

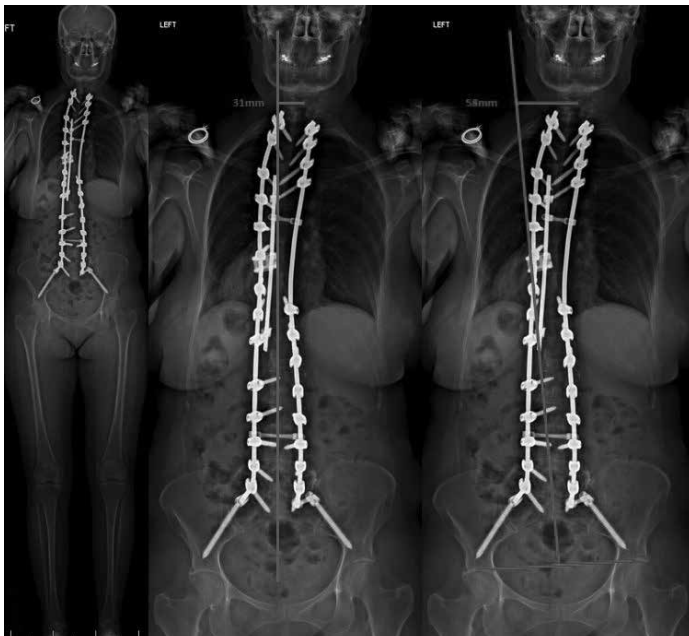
Of the 93 patients, there were 7 with CM when it was defined as postop C7-CSVL>4cm. There were statically insignificant and minimal differences between the Δ ODI scores (-13.9 vs. -10.4, $p=0.45$) and the Δ SRS total scores (20.5 vs. 9.7, $p=0.03$) in the CA and CM group when it was defined based on CSVL. When CM was defined as postop C7-CSPL>4cm, there were 10 patients with CM. There were statistically significant and larger differences between the CA and CM group for both Δ ODI (-15.0 vs. -2.6, $p=0.03$) and Δ SRS total scores (21.3 vs. 6.8, $p=0.002$) when CM was defined as CSPL>4cm.

Conclusion

CSPL is a superior radiographic representation of coronal alignment after spine deformity surgery that directly correlates with Δ SRS and Δ ODI scores. C7-CSPL>4cm is the critical distance that corresponds with clinical coronal malalignment.

Take Home Message

CSPL is the first, coronal measurement that radiographically represents coronal alignment and clinically correlates with patient reported outcome scores (SRS and ODI).



Same patient with appropriate coronal alignment based on CSVL and coronal malalignment based on CSPL

18. Radiographic Malalignment Has a Far Greater Impact on Clinical Outcomes than Perioperative and Postoperative Complications in ASD Surgery

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Summary

Corrective surgery for adult spinal deformity (ASD) is known to carry a high likelihood of complications including surgical site infection, mechanical failure and loss of correction. Despite a significant portion of patients experiencing intraoperative/perioperative, medical, mechanical, and many neurological complications, the most detrimental contributors to poor long-term outcomes were almost exclusively related to poor radiographic correction, loss of correction post-operatively, and mechanical failure.

Hypothesis

To investigate what complications most impacted HRQLs at two-years (2Y) post-op.

Design

Retrospective cohort study of a multi-center database of ASD patients.

Introduction

Corrective surgery for adult spinal deformity (ASD) is known to carry a high risk of complications yet it is unclear which complications have the greatest impact on outcomes.

Methods

Operative ASD patients ($\text{scoliosis} \geq 20^\circ$, $\text{SVA} \geq 5\text{cm}$, $\text{PT} \geq 25^\circ$, or $\text{TK} \geq 60^\circ$) with available BL and 2Y radiographic and HRQL data were included. Complications grouped as: intraoperative/perioperative, medical, mechanical, or neurological. Multivariable analysis (MVA) controlling for age, CCI, baseline deformity, invasiveness, and baseline disability assessed impact of complications on HRQL outcomes. A conditional inference tree (CIT) stratified complications in a hierarchal manner based on impact on HRQLs.

Results

762 ASD patients (59.9yrs \pm 14.0, 79%F, BMI: 27.7 kg/m 2 \pm 6.0, CCI: 1.8 \pm 1.7) with a mean level fused of 11.1 \pm 4.4. 6 categories were included: 245 (32.2%) medical complications, 135 (17.7%) neurological, 545 (71.5%) mechanical after discharge 248 (32.5%) intra/perioperative, 317 (42%) radiographic unrelated to PJF, and 17 (2.2%) surgical infection related complications Table 1. MVA and CIT ranking showed radiographic complications had the most impact on ODI and SRS, followed by neurological complications. None of the other 4 categories led to significant long-term effects. For individual complications, CIT ranked re-

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maining severe in any SRS-Schwab modifier by 2Y as the largest contributor to worse outcomes in ODI and SRS, followed by implant failure, development of a motor deficit, and PJF for ODI, and implant failure, PJF, and worsening in PILL postoperatively for SRS. Table 1.

Conclusion

Despite a significant portion of patients experiencing intraoperative/perioperative, medical, mechanical, and many neurological complications, the most detrimental contributors to poor long-term outcomes were almost exclusively related to poor radiographic correction, loss of correction post-operatively, and mechanical failure.

Take Home Message

The most detrimental contributors to poor long-term outcomes were almost exclusively related to poor radiographic correction, loss of correction post-operatively, and mechanical failure, among many categories of complications.

Table 1. Complication and complication categories ranked by degree of negative impact on ODI and SRS

Complications	ODI	SRS-Total
Neurological:	Overall Complication by Groups:	Overall Complications by Group:
<ul style="list-style-type: none"> • Bowel Bladder Deficit • Epidural Hematoma • Mental Stat • Motor Deficit • Nerve Root Injury • Ophtho • Radiculopathy • Myelopathy • Sensory Deficit • Stroke 	<ol style="list-style-type: none"> 1. Radiographic 2. Neurologic 	<ol style="list-style-type: none"> 1. Radiographic 2. Neurologic
Intra-/Perioperative:	Individual Complications:	Individual Complications
<ul style="list-style-type: none"> • Prolonged Stay • Dual Tear • Prolonged Op Time • Prolonged SICU 	<ol style="list-style-type: none"> 1. Remained Severe in Schwab 2. Implant Failure 3. Motor Deficit 4. PJF 5. Worsening in SVA 6. Worsened in PILL 7. Rod Breakage 8. Screw Breakage 	<ol style="list-style-type: none"> 1. Remained Severe in Schwab 2. PJF 3. Implant Failure 4. Worsened in PILL 5. Worsened in SVA 6. Hardware Dislocation 7. Rod Breakage 8. Screw Breakage
Radiographic:		
<ul style="list-style-type: none"> • Schwab Remain Severe • Worsened in PILL • Worsened in SVA • Worsened in PT 		
Medical:		
<ul style="list-style-type: none"> • Cardiopulmonary • Musculoskeletal • Renal • Neuro • GI • Non- Surgical Infection 		
Surgical Infection:		
<ul style="list-style-type: none"> • Deep infection with re operation 		
Mechanical after discharge:		
<ul style="list-style-type: none"> • Implant Failure • Implant Malposition • Implant Dislocation • Painful Implant • Prominence • Rod Breakage • Screw Breakage • Screw Loose • PJF • PJK 		

19. Preoperative Paraspinal Fat Atrophy of the Upper Instrumented Vertebrae Musculature in Spine Deformity Surgery is a Risk Factor for Proximal Junctional Kyphosis and Sagittal Malalignment

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Summary

Proximal junctional kyphosis (PJK) after spine deformity surgery is a frequent complication with multiple etiologies ranging from patient factors to surgical techniques. The paraspinal musculature at the upper instrumented vertebrae (UIV) is an understudied potential risk factor for PJK. This study classifies the paraspinal fat atrophy at the UIV into 3 different grades and correlate with postoperative sagittal alignment and PJK.

Hypothesis

A higher grade of preoperative paraspinal fat atrophy at the UIV musculature will lead to higher risk of PJK and sagittal malalignment

Design

Prospectively collected cohorts

Introduction

The paraspinal musculature quality at the UIV is an understudied risk factor for PJK. We propose an easily distinguishable classification to categorize the different grades of preoperative paraspinal fat atrophy and correlate that with postoperative radiographic outcomes.

Methods

A radiographic review was performed on 116 deformity patients from 2015-2018. The paraspinal muscle at the UIV were assessed using the preoperative axial MRI. Grade 1 was defined as fatty infiltrate between 0-10%, grade 2 between 10-50%, and grade 3 over 50%. Pre, immediate postop and 2yr postop spine films were assessed. PJK was defined as PJA > 15°. Logistic regression and Chi-square analyses were performed to study the relationship between the different UIV paraspinal muscle fat atrophy grades and postoperative sagittal balance.

Results

Of the 116 patients, 74 had grade 1, 34 had grade 2, and 8 had grade 3 fat atrophy. The immediate postop T1PA for grade 1,2, and 3 were 11.85, 14.8, and 17.7°. The 2 yr postop T1PA for grade 1,2, and 3 were 9.5, 16.9, and 19.6°. The immediate postop PJA for grade 1,2, and 3 were 8.1, 8.7, and 15.0°. The 2 yr postop PJA for grade 1,2, and 3 were 7.7, 16.9, and 25.2°. For grade 1 patients, 7 had PJK immediate postop and 14 had PJK at 2 yr postop. Grade 2 patients had 7 immediate postop PJK and 20 at 2 yr postop. Grade 3 patients had 4 immediate postop PJK and 7 at 2 yr postop. The odds ratio of developing PJK for grade 2 was 6.1 and for grade 3 was 30.0.

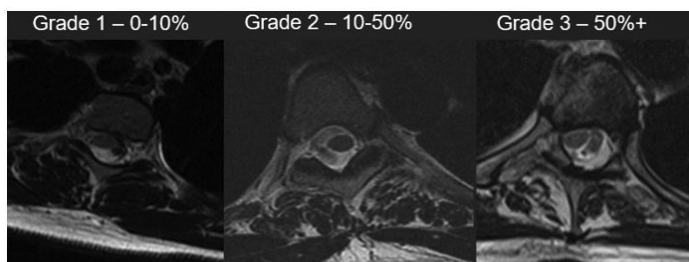
Conclusion

Higher grades of preoperative paraspinal fat atrophy in the UIV musculature in spine deformity cases is a risk factor for PJK, with the odds ratio of developing PJK for grade 2 fat atrophy at 6.1 and for grade 3 an astounding 30.0. Also, there is greater progression of sagittal malalignment with higher paraspinal fat atrophy grades.

Take Home Message

Paraspinal muscular fat atrophy at the UIV in spine deformity patients is a risk factor for PJK and progression of postoperative sagittal malalignment.

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Odds Ratio of Developing PJK				
Effect	Point Estimate	95% Wald Confidence Limits		
Fat Atrophy Grade 1 vs 2	6.1	2.496	15.016	
Fat Atrophy Grade 1 vs 3	30.0	3.410	263.846	
Paraspinal Fat Atrophy Grades	Grade 1 (n=74)	Grade 2 (n=34)	Grade 3 (n=8)	p-value
T1PA (°)				
Preop	8.45	26.2	21.1	<0.0001
Immediate postop	11.85	14.8	17.7	0.064
2yr postop or prior to RTOR	9.5	16.9	19.6	0.001
SVA (mm)				
Preop	31.5	54.3	13.3	0.046
Immediate postop	27.7	32.9	24.9	0.80
2yr postop or prior to RTOR	33.3	14.1	27.9	0.015
PJA (°)				
Preop	6.2	6.7	6.8	0.60
Immediate postop	8.1	8.7	15.0	0.021
2yr postop or prior to RTOR	7.7	16.9	25.2	<0.0001
Number of patients with PJK				
Immediate postop	7	7	4	
2yr postop or prior to RTOR	14	20	7	

Odd ratio of developing PJK and radiographic parameters based on UIV fat atrophy grading scale

20. Dynamic Assessment Sagittal Spinal Parameter after 10 Minutes of Walking Predicts Mechanical Failure and Revision of PJK

Junseok Bae, MD; Sang-Ho Lee, MD, PhD

Summary

In ASD, daily activity such as walking is often interrupted by progressive decompensation from fatigue causing sagittal malalignment. Preoperative dynamic assessment after 10 minutes walking reflects fatigue of extensor muscles. SVA after walking showed significant correlation of revision surgery of PJK and development of mechanical failure after corrective surgery of ASD than a static radiography. Preoperative dynamic assessment of sagittal parameters is important in prediction of post-surgical outcomes.

Hypothesis

Dynamic assessment of sagittal parameter is more influential in the development of sagittal decompensation after ASD correction.

Design

Retrospective review

Introduction

In ASD, daily activity such as walking is often interrupted by progressive decompensation from fatigue causing sagittal malalignment. Preoperative dynamic assessment after walking reflects fatigue of extensor muscles. There's limited understanding of how preoperative dynamic assessment predict in development of surgical outcomes.

Methods

Consecutive ASD patients (FU > 2yrs) who underwent spinal deformity correction (UIV at L1 above) with lumbosacral fusion were reviewed. All patients were initially evaluated with full-length standing spinal radiography and then asked to walk in the clinic for 10 minutes. Subsequently, all were re-evaluated with second full-length radiography. Spinal deformity parameters were measured on each radiograph. PJK, revision surgery of PJK, mechanical failure including screw pull-out, spondylolisthesis, and fracture were evaluated. HRQoLs were assessed with VAS, ODI, and SRS-22.

Results

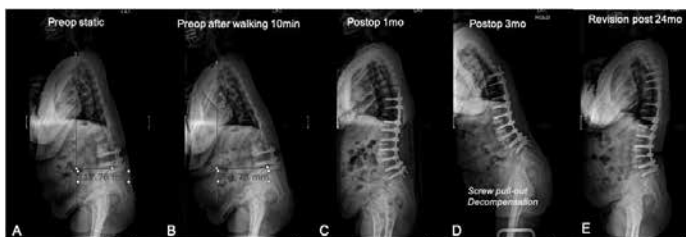
Seventy-five patients (68 females, 67.8 years, 25.6 months FU) met inclusion criteria. The initial average SVA was 129mm. After walking 10 minutes, average SVA were significantly deteriorated to 187mm. PJK was diagnosed in 12 patients. 6 patients underwent revision surgery for PJK. Mechanical failure was developed in 7 patients. SVA after walking showed a significant correlation with revision surgery of PJK (p=0.038) and mechanical failure (p=0.009), while no correlation with the diagnosis of PJK (p=0.821). Initial SVA (p=0.029) and PI-LL mismatch (p=0.049) showed a correlation of the development of mechanical failure. Revision surgery of PJK showed strong negative impact on HRQoLs.

Conclusion

After 10 minutes of walking, a compensatory mechanism to maintain sagittal balance are less pronounced to result in significant sagittal decompensation. As we postulate that loss of compensatory mechanism is due to fatigue on extensor muscles, postsurgical mechanical failure and revision surgery of PJK is related to SVA after walking.

Take Home Message

Dynamic assessment of sagittal balance is important in the development of revision surgery of PJK and mechanical failure after ASD correction.



Screw pull out w/ sagittal decompensation

21. C2 Pelvic Angle (C2PA) is a Useful Intraoperative Radiographic Parameter that Correlates with the Risk of Developing Proximal Junctional Kyphosis Postoperatively

Alex Ha, MD; Justin Mathew, MD; Xavier E. Ferrer, MD; Josephine R. Coury, MD; Luzzi J. Andrew, MD; Daniel Hong, MD; Gerard F. Marciano, MD; Scott Zuckerman, MD; Ian A. Buchanan, MD; Mena G. Kerolus, MD; Meghan Cerpa, MPH; Joseph M. Lombardi, MD; Marc D. Dyrszka, MD; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

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Summary

We established the first intraoperative parameter that directly correlates with postoperative proximal junctional kyphosis (PJK). C2PA is a novel, intraoperative radiographic parameter used to assess for potential development of PJK. Intraoperative C2PA > 15° is a critical angle with 2.5 times the relative risk for developing PJK. No patient with intraoperative C2PA < 15° developed PJK.

Hypothesis

Spine deformity patients with high intraoperative C2PA will have higher risks of PJK.

Design

Prospectively collected cohorts

Introduction

PJK is a postoperative complication of adult spinal deformity surgery that leads to poorer patient clinical outcomes. There is no literature on intraoperative assessment of sagittal alignment to prevent PJK. Intraoperative C2PA is a novel, radiographic parameter derived from the difference between global spinal alignment and the alignment proximal to the uninstrumented spine. The goal of this study is to demonstrate a positive relationship between the intraoperative C2PA and PJK.

Methods

We performed radiographic analysis on 60 deformity patients from 2015- 2018. Of the 60 patients, 35 were fused to the sacrum/pelvis. C2PA is defined as the angle between the posterior superior sacrum, C2 centroid and upper instrumented vertebrae (UIV) centroid and measured in the pre, intra, and postop setting (immediate and 2 year or prior to return to OR). PJK was defined as postop PJA > 15°. Logistic regression and Chi-square analyses evaluated the relationship between the postop PJA and intraop C2PA/PJA

Results

Of the 60 pts, 20 had PJK at the 2 yr postop X-ray or prior to return to OR films. The intraop C2PA for the non-PJK and PJK group were 12.5° and 21.2°, respectively ($p < 0.0001$). The intraop PJA for the non-PJK and PJK group were 5.6° and 7.4°, respectively ($p=0.04$). The relative risk ratio of developing PJK for patients with intraop C2PA > 15° was 2.43, and no one with intraop C2PA < 15° developed PJK in the 2 yr follow up.

Conclusion

This is the first intraoperative measurement that demonstrates a direct correlation with PJK. Intraoperative C2PA > 15° is a critical angle with 2.5 times the relative risk for developing PJK. No patient with intraoperative C2PA < 15° developed PJK.

Take Home Message

Intraoperative C2PA > 15° directly correlated with development of postoperative PJK. This should be used as an intraoperative measure to assess appropriate sagittal alignment.



An example of a patient who developed PJK. The intraop PJA and C2PA were 5.8° and 19.7°, respectively (left). The immediate postop PJA and C2PA were 6.1° and 25.1°, respectively (middle). The final film prior to returning to OR shows PJA and C2PA of 28.7° and 33.9°, respectively (right).

22. Using Normal to Find Normal: Identifying Individualized Lordosis Alignment Targets

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Summary

We conducted an international cross-sectional study of 256 volunteers 40 years of age or younger to define normative alignment in a population without deformity or degenerative disc disease. Pelvic incidence alone was insufficient to define a normal lumbar lordosis. By estimating the L1 pelvic angle as a function of lumbar lordosis and pelvic incidence, an individualized and normal lumbar alignment can be identified. This measure accounts for both magnitude of lordosis and lumbar spinal shape.

Hypothesis

Analysis of non-degenerated spines will offer more physiologic lumbar lordosis (LL) targets

Design

International Cross-Sectional Study

Introduction

Currently accepted sagittal alignment targets were developed using correlations between radiographic and health-related quality of life measures in asymptomatic patients with spinal

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deformity, rather than degeneration-free samples. We evaluated the accuracy of pelvic incidence alone in predicting lumbar lordosis and established normative lumbar alignment values by adjusting for pelvic incidence, lumbar lordosis, and the L1 pelvic angle in a disease-free population sample.

Methods

Asymptomatic volunteers ages 18-40 with no degeneration or spinal deformity were included. Radiographic parameters were obtained from full spine radiographs (EOS Imaging, SA, France), including LPA (angle subtended from femoral heads to L1 centroid and center of S1 endplate). Linear regression estimated the L1-S1, L2-S1, L3-S1, and L4-S1 lordosis by pelvic incidence alone. Multivariable nonlinear regression estimated the L1 pelvic angle as a function of lumbar lordosis and pelvic incidence. The L1 pelvic angle's effect on sagittal balance (defined by 0.05 to 0.95 quantiles of T1 tilt) was simulated.

Results

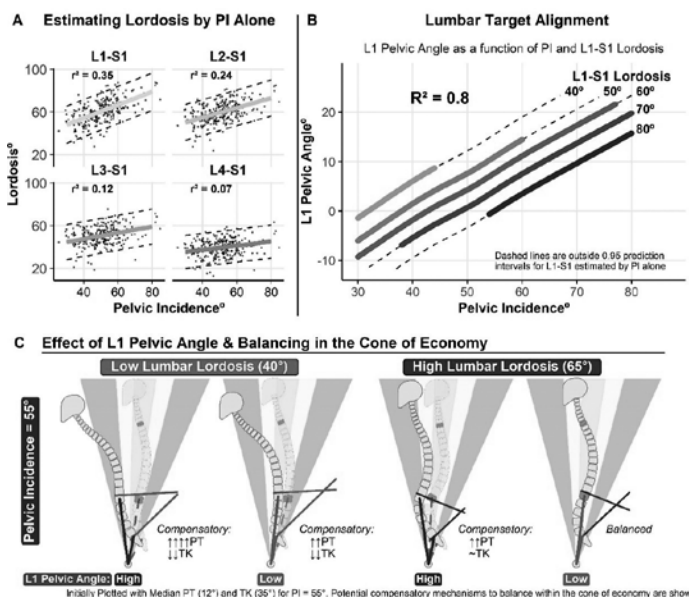
Among 256 volunteers included from 4 continents, median age was 29 and 56% were female. Estimating lumbar lordosis by pelvic incidence alone resulted in wide prediction intervals and high unexplained variance (L1-S1, $r^2 = 0.35$; L4-S1, $r^2 = 0.07$; Fig 1A). Estimating a normal L1 pelvic angle as a function of lumbar lordosis and pelvic incidence resulted in high explained variance ($R^2 = 0.8$; Fig 1B). An abnormal L1 pelvic angle requires compensatory mechanisms to maintain sagittal balance (Fig 1C).

Conclusion

We analyzed normal spinal alignment from an international sample without signs of disc degeneration or deformity and found pelvic incidence alone was insufficient for estimating a normal lumbar lordosis. A normal lumbar alignment is better identified by estimating the L1 pelvic angle as a function of lumbar lordosis and pelvic incidence ($R^2 = 0.8$).

Take Home Message

Lumbar lordosis, the L1 pelvic angle, and pelvic incidence should be considered together when establishing normative lumbar alignment targets.



23. The Clinical Benefit of Addressing the Malalignment in Revision Surgery for Proximal Junctional Kyphosis Following ASD Surgery

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Summary

Proximal junctional kyphosis is a common cause of revision surgery for ASD patients. Surgeons may elect to perform a proximal extension of the fusion, or, also correct the source of the lumbo-pelvic mismatch. Our findings suggest addressing the root cause of surgical failure in addition to proximal extension of the fusion may be beneficial. Future studies with a larger cohort should be done to further investigate.

Hypothesis

To investigate the clinical benefit of addressing malalignment in revision surgery for PJK.

Design

Retrospective cohort study of a prospective multicenter ASD database.

Introduction

The benefit of correcting alignment in PJK revision surgery remains understudied

Methods

Adult spinal deformity patients undergoing revision surgery for PJK with fusion to ilium and a upper instrumented vertebrae at C5 or below. Correction in sagittal alignment was identified by patients who went from undercorrected (UC) or overcorrected (OC) pre-revision in PI-LL, SVA or PT to an ideal matched alignment in the Schwab age-adjusted parameters by Lafage et al. Improvement in PI-LL was defined by a decrease in SRS-Schwab deformity category.

Results

137 ASD pts undergoing revision surgery for PJK. 12.6% (19) were anterior and 84% (127) were posterior approaches. Average levels fused was 11±5, 33% had three-column osteotomies. 46% of pts with revision surgery for PJK had sagittal alignment correction. Pts corrected in SVA vs. only fusion extension had similar rates of PJK by 2 years, and higher HRQL scores. Pts UC in SVA and OC post-op had a greater recurrence of PJK (73% vs. 58%, $p=.144$). Pts UC/OC in PILL and matched post-operatively, due to surgical realignment at revision, had a lower NSR 2Y back pain (2.4 vs. 3.9, $p=.20$). pts who improved in PI-LL had lower rates of PJF (8% vs. 17%, $p=.4$) and reoperation (21% vs. 32%, $p=.4$) than patients who only had an extension of fusion. Pts who were UC/OC and matched in T1PA showed lower rates of post-operative PJK (44% vs. 55%, $p=.6$), 2Y PJK (67% vs. 74%,

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p=.6) and proximal junctional failure (11% vs. 15%, p=.7).

Conclusion

In revision surgery for proximal junctional kyphosis, patients who maintained poor sagittal alignment had worse clinical outcomes compared with patients with abnormal lumbo-pelvic mismatch corrected as well. While limited by sample size, these findings suggest addressing the root cause of surgical failure in addition to proximal extension of the fusion may be beneficial. Future studies with a larger cohort should be done to further investigate.

Take Home Message

In revision surgery for proximal junctional kyphosis, it may be beneficial to address the root cause of surgical failure in addition to proximal extension of the fusion.

24. Correcting ASD Patients to Normative Alignment Results in No Functional Benefit but More PJK and PJF

Themistocles S. Protopsaltis, MD; Alex Soroceanu, MPH; Renaud Lafage, MS; Han Jo Kim, MD; Eaman Balouch, MD, PhD; Zoe Norris, BFA; Justin S. Smith, MD, PhD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Lawrence G. Lenke, MD; Virginie Lafage, PhD; Munish C. Gupta, MD; International Spine Study Group

Summary

Recent studies have used normative alignment to guide surgeons in adult spinal deformity (ASD) surgery while other studies have recommended alignment targets that optimize physical function in line with age-matched asymptomatic peers. A component angle of T1-pelvic-angle (TPA) within the fusion was used to determine age- and PI-optimal alignment targets. Correcting patients to normative alignment resulted in higher rates of proximal junctional kyphosis (PJK) and proximal junctional failure (PJF) without HRQL improvements compared with PI- and age-optimal alignment.

Hypothesis

Normative alignment is too rigorous a target for ASD patients

Design

Retrospective analysis of a prospective multicenter ASD database and a database of asymptomatic subjects

Introduction

A previous study utilized normative alignment to determine overcorrections and predict mechanical complications in ASD surgery. Other studies have recommended alignment targets that optimize age-appropriate physical function. The difference in functional outcomes and mechanical complications between these prescribed alignment targets has not been explored.

Methods

Baseline relationships between Age, PI and a component angle of TPA within the fusion were analyzed in ASD patients and compared to asymptomatic subjects. Linear regression modeling was used to determine alignment based on PI and age in asymptomatic subjects (normative alignment), and in ASD

patients, alignment corresponding to age-appropriate functional status (optimal alignment). ASD patients with UIV above T4 were grouped based on their corrections: normative and optimal. Extreme over or undercorrected patients were excluded (> or < 2SD from mean). The rate of PJF was determined for each group using a definition that includes severe PJK, UIV olisthesis and/or fracture.

Results

1916 ASD patients were included in the optimal formula development. In the 288 ASD patients included in the pre- to post-op analysis, there was no difference in baseline alignment or HRQL between the normative-aligned (Norm) and the optimally-aligned (Optimal) groups. At 6 weeks, Norm pts had smaller TPA (4.45 vs. 14.1), PI-LL (-7.24 vs. 7.4), all p<.0001. Norm pts had the higher PJK rate (40 vs. 27.2%, p=.03) compared with optimal; and a higher PJF rate (17% vs. 6.8%, p=.008). PJF pts had a mean T4PA offset of -1.2° from normative alignment and -5.2° offset from optimal alignment. Both Norm and Optimal improved in outcomes from baseline to 2y (p<.001) with no difference in 2y HRQL.

Conclusion

Correcting ASD patients to normative alignment resulted in higher rates of PJK and PJF without improvements in HRQL. Correcting patients to optimal alignment that matches their physical function with their age-matched asymptomatic peers is recommended.

Take Home Message

Correcting ASD patients to normative alignment resulted in no functional benefit but more PJK/PJF compared to PI and age-optimal alignment that matches their physical function to their age-matched peers.

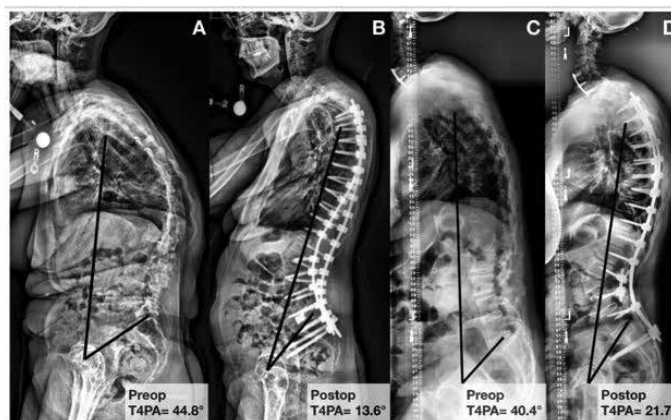


Figure: A. Preoperative and B. Postoperative radiographs of a 63-year-old patient who underwent T3-S1/iliac fusion with correction close to normative alignment (T4PA offset from normative= -0.48°), resulting in PJF. C. Preoperative and D. Postoperative radiographs of a 65-year-old patient who underwent T3-S1/iliac fusion with correction close to optimal alignment (T4PA offset from optimal=0.11°), resulting in no PJF.

25. Comparison of Sagittal Vertical Axis Correction after L4 vs. L3 Pedicle Subtraction Osteotomies

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Srivastava; Rafael Guizar III; Xiao Tan, BS; Jeremy Huang, BS; John K. Yue, MD; Vivian Le, MPH; Shane Burch, MD; Sigurd H. Berven, MD; *Dean Chou, MD*

Summary

Pedicle subtraction osteotomies are performed at L4 because of possible increased sagittal vertical axis (SVA) correction and more natural lordosis position. Advantages of L4 over L3 are not clearly known.

Hypothesis

L4 PSO leads to increased correction of SVA over L3 PSO.

Design

Retrospective study

Introduction

Historically, the pedicle subtraction osteotomy (PSO) has been done at L3, but are increasingly performed at L4 because of possible increased sagittal vertical axis (SVA) correction and lordosis position.

Methods

Patients with L3 or L4 PSO by 4 surgeons from 2005-2019 were retrospectively studied. Inclusion criteria were single-level L3 or L4 PSO, minimum 2-year follow-up, and comparison 36" films. Demographic variables, operative factors, and radiographic measurements were collected. Univariate analysis using was used to determine any baseline differences. Multivariate regression was performed to identify possible confounding variables.

Results

Ninety-two patients (56 female) met inclusion criteria. The mean age was 65.3 years, and mean follow-up was 3.17 years (2.01-8.09). PSO at L3 was performed in 75 patients and at L4 in 17 patients. Univariate analysis demonstrated significant differences in sacral slope (SS) ($p = 0.02$). There were no baseline differences in sex ($p = 0.85$), body mass index ($p = 0.62$), age ($p = 0.43$), estimated blood loss ($p = 0.85$), surgical time ($p = 0.94$), levels of fusion ($p = 0.56$), non-PSO osteotomies ($p = 0.32$), or number and types of interbody fusion ($p = 0.91, 0.26$). Pre-operative SVA, central sacral vertical line (CSVL), pelvic incidence (PI), lumbar lordosis (LL), and PI-LL were not different between groups (all p values >0.05). Multivariate regression showed no differences with respect to changes from pre-op to post-op L3 vs. L4 SVA (-46.80 mm, -53.10 mm, $p = 0.33$), CSVL (-15.62 mm, -16.91 mm, $p = 0.82$), SS (6.81°, 7.82°, $p = 0.19$), PT (-3.41°, -5.00°, $p = 0.74$), LL (23.81°, 21.94°, $p = 0.97$), PI-LL (-20.91°, -19.12°, $p = 0.72$), and osteotomy angular correction (22.04°, 26.59°, $p = 0.11$). There were no significant differences in rates of re-operation, PJK, neuro-deficit, infection, and ASD.

Conclusion

Despite theoretical advantages of performing an L4 vs. L3 PSO, we did not observe an increased correction of SVA increased advantages of spinopelvic parameter correction with L4 vs. L3 PSO.

Take Home Message

Despite theoretical advantages of performing an L4 vs. L3 PSO, we did not observe an increased correction of SVA increased advantages of spinopelvic parameter correction with L4 vs. L3 PSO.

Table: L3 and L4 PSO comparison

Parameters	L3 PSO (n = 75)	L4 PSO (n = 17)	P-Value
Sex	29 males, 46 females	7 males, 10 females	0.85
Age (years)	65.79 ± 8.30	63.10 ± 13.27	0.43
Body mass index	28.90 ± 6.06	28.05 ± 6.29	0.62
EBL (mL)	2729.17 ± 1704.59	2806.67 ± 1321.51	0.85
Surgical time (minutes)	433.55 ± 99.93	435.20 ± 61.90	0.94
Levels of fusion	6.08 ± 2.92	6.74 ± 1.33	0.56
Anterior lumbar interbody fusion (ALIF)	5 patients	1 patient	0.91
Transforaminal lumbar interbody fusion (TLIF)	13 patients	5 patients	0.26
Smith-Petersen osteotomy (SPO)	22 patients	3 patients	0.32
Pre-op SVA (mm)	112.82 ± 59.90	101.20 ± 48.92	0.42
Pre-op CSVL (mm)	22.40 ± 13.88	20.00 ± 12.85	0.52
Pre-op SS (degrees)	21.09 ± 11.14	28.50 ± 10.55	0.02
Pre-op PI (degrees)	47.98 ± 11.48	54.06 ± 15.78	0.16
Pre-op PT (degrees)	27.23 ± 8.19	25.56 ± 11.14	0.58
Pre-op LL (degrees)	19.55 ± 14.41	26.56 ± 13.18	0.07
Pre-op PI-LL (degrees)	23.60 ± 19.26	25.88 ± 12.20	0.54
Post-op SVA change (degrees)	-46.80 ± 23.43	-53.10 ± 15.82	0.33
Post-op CSVL change (mm)	-15.62 ± 12.98	-16.91 ± 14.00	0.82
Post-op SS change (degrees)	6.81 ± 10.96	7.82 ± 8.26	0.19
Post-op PT change (degrees)	-3.41 ± 13.35	-5.00 ± 14.33	0.74
Post-op LL change (degrees)	23.81 ± 16.31	21.94 ± 12.98	0.97
Post-op PI-LL change (degrees)	-20.91 ± 22.04	-19.12 ± 15.30	0.72
Post-op osteotomy site angle change (degrees)	22.04 ± 9.13	26.59 ± 6.14	0.11
Re-operation rates	19 patients	3 patients	0.50
Proximal junctional kyphosis	7 patients	1 patient	0.61
Neuro deficits	6 patients	3 patients	0.23
Infection	4 patients	1 patient	0.93
Adjacent segment disease	4 patients	1 patient	0.93

L3 and L4 PSO group comparison

26. Delayed Staging during Same Hospitalization Increases Complication Risk following Adult Spinal Deformity Surgery

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Summary

Since circumferential adult spinal deformity (ASD) surgery can result in high surgical burden for the patient, surgeons may elect to stage these procedures during the same hospitalization. We aim to determine the optimal time interval between planned same hospitalization staged surgeries. Early surgical staging (<6 days) of ALIF and subsequent staged posterior fusion was associated with less risk of complications relative to delayed staging (≥6 days). Efforts should be made to shorten the interval between ALIF and staged posterior fusion.

Hypothesis

For staged ASD surgeries consisting of ALIF followed by staged posterior fusion, staging the surgeries beyond a week increases risk of complications.

Design

Retrospective review of a multi-center database

Podium Abstracts

Introduction

There is a trend toward planning same-hospitalization staged ASD surgeries. The aim of this study is to determine optimal timing between ALIF and staged posterior fusion.

Methods

Using a prospective, multi-center database, 158 ASD patients undergoing an anterior surgery followed by a planned, staged posterior spinal fusion ≥ 5 levels during the same hospitalization were evaluated. Stratum-specific likelihood ratio (SSLR) analysis was performed to calculate a cutoff point beyond which 90-day complications were increased. The cutoff generated through SSLR was confirmed with multivariable logistic regression analysis controlling for age, gender, levels fused, preoperative alignment, 3-column osteotomy, and CCI. Our outcome measures were 90-day complication rates, alignment, and 2-year ODI.

Results

From 2008 to 2019, staged ant/post procedures in the same hospitalization increased 4x. The mean staging interval was 3 days (range 1-8). SSLR analysis produced two staging categories based on complication risk: early (< 6 day, range 1-5 day; $N=139$) vs. delayed (≥ 6 day, range 6-8 day; $N=19$). On bivariate analysis, the delayed group had higher 90-day complication rates (68.4% vs. 32.4%) and operative time (739 vs. 638 min) compared to the early group ($p < 0.05$ for both). After adjusting for covariates, delayed staging was associated with greater odds of 90-day complications ($OR=7.57$, $p=0.006$) and longer total operative time ($\beta=119$, $p=0.035$) compared to early staging. In particular, delayed staging increased odds of postoperative infection ($OR=11.8$, $p=0.031$). There were no differences in postoperative alignment or 2-year ODI between groups ($p > 0.05$ for all).

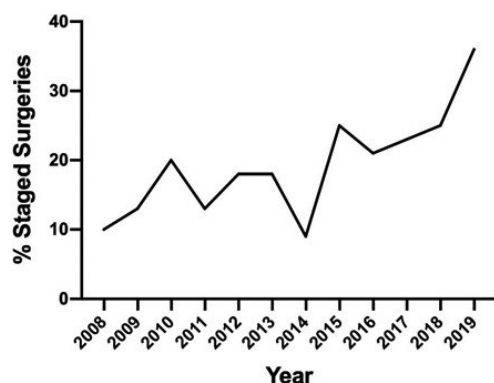
Conclusion

Staging posterior fusion within 5 days of ALIF reduces risk of 90-day complications. When ALIF and subsequent staged posterior fusion are planned during the same hospitalization, efforts should be made to shorten the staging interval.

Take Home Message

Compared to early staging (< 6 days) of ALIF and subsequent staged posterior fusion, delayed staging (≥ 6 days) is associated with greater odds of 90-day complications, particularly infection.

Figure 1. Trends in Utilization of Staged ASD Surgery



27. Pelvic Fixation Using the S2AI Technique in ASD Surgery: Ten-Year Clinical and Radiographic Follow-Up

Varun Puvanesarajah, MD; *Kevin Y. Wang, BS*; Micheal Raad, MD; Floreana N. Kebaish, MD; Paul D. Sponseller, MD; Khaled M. Kebaish, MD

Summary

Pelvic fixation is often necessary in adult spinal deformity (ASD) surgery. In the last decade, increased surgeon experience with the S2-alar-iliac (S2AI) technique has led to reduced rates of instrument-related complications and pseudarthroses at the lumbosacral junction. In this study of 39 patients with 10-year follow-up, we demonstrate that the S2AI technique has long-term durability with low revision and complication rates. Most patients report minimal pain and high satisfaction, with much improved overall health status.

Hypothesis

The S2AI pelvic fixation technique is durable with low revision rates and high patient satisfaction at long-term follow-up.

Design

Retrospective review of an institutional ASD surgical registry.

Introduction

ASD surgery is technically challenging and has high complication rates. In the last decade, use of S2AI technique for pelvic fixation has increased with a relatively low rate of complications at short-term follow-up. There are currently no studies evaluating the long-term durability of this construct at ten years in ASD patients.

Methods

Adult patients who underwent unilateral or bilateral S2AI technique for pelvic fixation as part of a thoracolumbar fusion from 2006-2010 were included. Of the 125 patients initially identified (mean age 60.0 \pm 12.8 years), 22 (18%) died prior to ten-year follow-up of causes unrelated to spine surgery. Our primary outcome was S2AI screw fracture or revision. Secondary outcomes were L5-S1 pseudarthrosis or rod fracture. Satisfaction was determined using the NASS patient satisfaction index, and improvement in health status was assessed using the Patients' Global Impression of Change scale.

Results

Thirty-nine patients (38%) had ten-year radiographic follow-up (median: 11.0, range: 9.5-13.4 years). Of these patients, 4 (10.5%) underwent revision or removal of S2AI screws, 1 had asymptomatic L5-S1 rod fracture and S2AI screw fracture (2.6%), and 1 additional patient had isolated S2AI screw fracture (2.6%). Twenty-one of the patients with ten-year radiographic follow-up (54%) also completed a questionnaire. 57% (12) reported no pain. 90% of patients (19) reported that the surgery met their expectations. 72% reported at least "much improved" overall health state compared to before surgery. Of the 86 patients without ten-year follow-up, 6 (7.0%) patients underwent revision or removal of S2AI screws, and 4 patients had asymptomatic fracture of S2AI screws (4.7%) (median follow-up 65, range: 3-111 months).

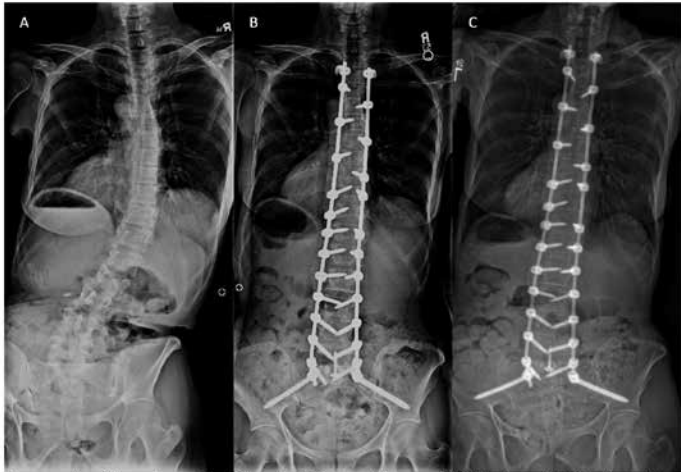
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Conclusion

At ten-year follow-up, the S2AI technique for pelvic fixation was found to be durable with low revision and complication rates. Most patients report minimal pain and high satisfaction, with improved overall health status.

Take Home Message

At 10-year follow-up, patients who underwent the S2AI technique for pelvic fixation have a low incidence of implant-related complications, including revision, and are highly satisfied with their surgery.



Preoperative (A), postoperative (B), and at 10-year follow-up (C) following pelvic fixation with the S2AI technique.

28. The Basic Science Supporting Rib Fixation Rather than Spinal for Early Onset Hyperkyphotic Deformity

Mohammed Alshareef, MD; Daniel Bonthius, BS; Zeke J. Walton, MD; Alison Smith, DVM; Richard H. Gross, MD; Hai Yao, PhD

Summary

Hyperkyphosis is associated with a higher complication/failure rate than scoliosis. We compared the resistance of pedicle screw and rib fixation to kyphotic pullout forces in porcine spines, and studied spinal remodeling in immature pigs with fixed kyphotic deformities following insertion of corrective extraspinal rib fixation.

Hypothesis

1) Proximal rib fixation is more capable of resisting kyphotic pullout forces than proximal pedicle screw fixation 2) The instrumented porcine spine with a fixed kyphotic deformity remodel by developing a compensatory lordosis

Design

1) Twelve pig spines from C5 to L6 with intact rib cages (six for the rib construct group, six for the pedicle screw group) were harvested from 8-week-old Yorkshire domestic male pigs. For rib fixation, two down-going hooks were on ribs 3 and 4 and two up-going hooks on ribs 5 and 6. For spinal fixation, pedicle screws (5.0mm×20mm) were placed in T3 and T4 bilaterally. Spines were potted, and anchored to the testing system, 858 Mini Bionix II, MTS. A pure flexion bending moment was applied to the proximal end, and loaded from 0-90° 2) A thoracic hyperkyphotic animal model was created by thoracotomy in 10Kg pigs with partial vertebrectomy of T10 followed by compression of T9-11

4-6 weeks following creation of the kyphosis, corrective extra-spinal rib fixation was placed from T6-T14 in 3 pigs. Pigs were sacrificed 8 weeks after placement of instrumentation, with CT and anatomic analysis.

Introduction

Clinical studies of early onset spinal deformity (EOSD) have consistently identified hyperkyphosis as a vexing problem. Furthermore, more severe hyperkyphotic deformities are accompanied by reduced pulmonary function

Methods

Described in study design.

Results

1) The pedicle screw group withstood $64.6 \pm 7.3^\circ$ of bending and 118.6 ± 25.7 N of maximal force, at which point all failed. The rib construct group which withstood $97.9 \pm 10.0^\circ$ of bending ($p < 0.001$) and 119.7 ± 13.9 N of maximal force with no failure. 2) CT and anatomic analysis (gross and histologic) documented wedging of the instrumented vertebral bodies, with stunted anterior growth and anterior displacement of the nucleus. The posterior groove of Ranvier was characterized by disordered cellularity with an attenuated, bent bone bark; the anterior groove had an orderly cellular arrangement with a healthy bone bark.

Conclusion

Rib fixation provides secure proximal anchoring

Take Home Message

Consider rib proximal rib fixation for hyperkyphotic EOSD



Kyphotic deformity at time of instrumentation(left); remodeled spine 8 weeks postop(right)

29. The Effect of Apical Vertebra Position on Growing Rod Treatment: A Clinical and Finite Element Study

Gokay Dursun, MD; Riza Mert Cetik, MD; Dilek Guzel, BS; Gokhan H. Demirkiran, MD; Ercan Gurses, BS; Muharrem Yazici, MD

Summary

An ideal GR treatment should preserve growth and control the deformity; but distraction-based systems have a limited capacity of three-planar correction. In this retrospective clinical study and FEA, we evaluated the effect of apical vertebra position on growth and deformity control. The group with the greatest apical translation achieved less growth and had worse control on rotation, and FEA showed higher residual rotation. Bringing the apex to midline with GR application increases longitudinal growth and allows better rotational control.

Hypothesis

Bringing apical vertebral segments to midline with growing rod (GR) application positively affects growth preservation and deformity control.

Design

Retrospective clinical study and finite element analysis (FEA)

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Introduction

The purpose of GR treatment is to preserve spinal growth while effectively controlling deformity. Distraction-based systems anchor the spine from only two points and have a limited capacity of three-planar correction compared to spinal fusion, and the effect of the position of apical vertebra hasn't been studied previously.

Methods

Between 2000-2018, 140 patients treated with GR were evaluated. Exclusion criteria: < 2-year FU, vertebral anomaly at apical segments. Deformity characteristics (coronal/sagittal) and length of T1-12, T1-S1, instrumented segments were measured on pre/post-index and final FU x-rays. Apical rotation (Nash-Moe) was measured. Patients were divided into 3 groups according to the apical rotation on the post-index X-ray: Gr 1(both pedicles are located between 2 rods), Gr 2(concave rod located between 2 pedicles), Gr 3(concave pedicle located lateral to the convex rod) (Fig 1). For FEA, a simple volumetric model was created based on a CT scan, simulating the 3 groups. A Young's modulus of 75 MPa, Poisson ratio of 0.29, and a distraction force of 200 N is used.

Results

58 patients were included (mean age 7 (3.4-9.9)). 43 patients were managed with TGR, 15 with MCGR. According to the rotational position of the apical vertebra; 10 patients (17.2%) were in Gr 1, 34 (58.6%) in Gr 2, and 14 (24.2%) in Gr 3. Radiologic results are in Fig 1. Gr 3 was the least successful in terms of both height gain and rotational control. FEA showed a decrease in rotation for every group, while the residual rotation was highest in Gr 3.

Conclusion

Bringing the apex in line with GR in index surgery increases the capacity of growth preservation. However, as demonstrated by the FEA model, distraction alone is inadequate for controlling rotation, and with increasing apical translation, residual rotation after distraction also increases. In this case, additional control strategies for apical rotation should be considered.

Take Home Message

Bringing apical vertebral segments to midline with growing rod (GR) application increases longitudinal growth and allows better rotational control.

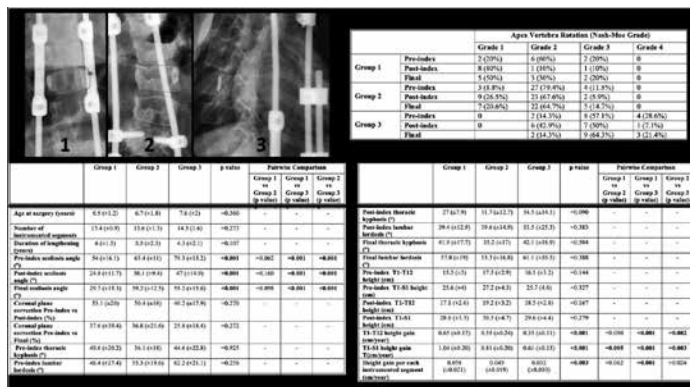


Fig 1. Study groups and results.

30. Sagittal Alignment Changes During Childhood: Results of a National Cohort Analysis of 1078 Healthy Children

Sebastien Pesenti, MD, PhD; Brice Ilharreborde, MD, PhD; Federico Solla, MD; Benjamin Blondel, MD, PhD; Solène Prost, MD; Erik-André Sauleau, MD, PhD; Yann Philippe Charles, MD, PhD

Summary

Sagittal plane is often involved in pediatric spinal deformities and should be restored if surgery is considered. However, normal sagittal alignment in children remains unclear and normative repository for sagittal alignment is needed. Analysis of 1059 healthy children and adolescents revealed PI increase, pelvic retroversion and sagittal curvatures increase (TK, LL) with age. Taking PT into account when evaluating global alignment in children appears crucial. This study provides normative values that should be considered before spinal deformity correction in children

Hypothesis

Sagittal curvatures and global alignment change over growth according to skeletal maturity in children

Design

Multicentric retrospective

Introduction

Spinal sagittal alignment is often altered in pediatric deformity and should therefore be restored if surgery is considered. Changes of spinal curvatures have been reported during growth, but literature is scarce and to date, physiological values remain unknown. Our objective was to describe spinal sagittal contour changes over growth and to provide normative values according to skeletal maturity status.

Methods

Full spine radiographs of 1059 healthy children and adolescents (5-18 yo) were retrospectively analyzed. Patients were classified according to Roussouly types and the main spinopelvic sagittal parameters were measured. Patients were divided in 2 groups according to triradiate cartilage status (open (O) or closed (C)). 224 healthy young adults (21-34 yo) were included as control group.

Results

Pelvic incidence (PI) increased during growth (40° (O) vs. 43° (C) vs. 45°(Controls), p<0.01), as well as pelvic tilt (PT) (4°(O) vs. 7(C) vs. 13°(Controls), p<0.01). Anteverted Roussouly type 3 was significantly more frequent in group O (29% vs. 18% (C) vs. 6% (Controls), p<0.01). Both maxTK and maxLL increased during growth. Segmental analysis revealed that L1L4 Lordosis increased (L1L4 vs. age R=0.14, p<0.01) whereas L4S1 Lordosis remained constant (L4S1 vs. age R=-0.01, NS). ODHA and C7-vertical tilt were not different between groups, whereas Global Tilt and GSA were (4(O) vs. 9(C) vs. 15°(Controls) for GT and 26(O) vs. 19(C) vs. 16°(Controls) for GSA, all p<0.01)

Conclusion

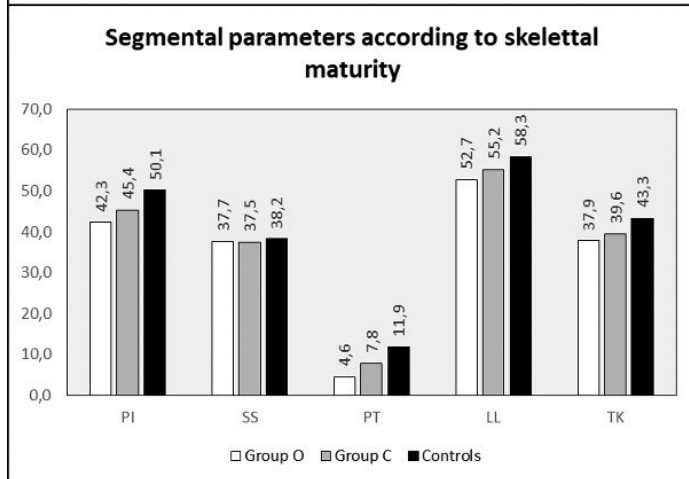
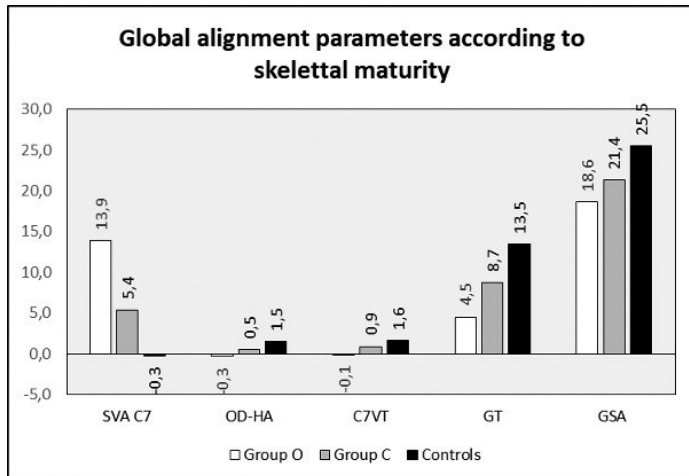
This study is the biggest cohort of healthy children describing changes observed in sagittal alignment according to skeletal maturity. The main significant growth-related changes were PI increase, pelvic retroversion and sagittal curvatures increase.

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Taking PT into account when evaluating global alignment in children appears crucial. This study provides normative values that should be considered before surgery (fusion in group C or growth modulation in group O)

Take Home Message

Several changes in spinal sagittal alignment occur with growth: PI increase and pelvic retroversion, sagittal curvatures increase. Taking PT into account when evaluating global alignment in children appears crucial.



Sagittal parameters according to skeletal maturity groups

31. Salvaging of Magnetically Controlled Growing Rods in Deep Wound Infections Does Not Lead to Increased Rates of Recurrent Infection in Early Onset Scoliosis

Krishna Vangipuram Suresh, BS; Majd Marrache, MD; Paul D. Sponseller, MD; Pediatric Spine Study Group

Summary

Deep surgical site infections (SSI) in patients with magnetically controlled growing rods (MCGR) represent a serious financial and medical burden for patients and families. As a result, surgeons may be tempted to first attempt more conservative management with incision and drainage compared to rod removal and exchange. Here, we demonstrate that rod salvaging has similar rates of recurrent infection following surgery compared to patients with rods removed or exchanged.

Hypothesis

We hypothesize rod salvaging is not associated with similar rates of recurrent wound infection compared to rod removal or exchange.

Design

Retrospective multi-center review

Introduction

SSI following spine surgery is a serious burden. Little is known regarding outcomes following deep SSI in EOS patients with MCGR and whether implants can be safely retained.

Methods

Using a multicenter registry, we identified patients with EOS who underwent surgical correction with MCGR. We defined deep SSI as any infection that required subsequent I&D and antibiotic therapy. Recurrent infection was considered to be any additional deep SSI following treatment of index deep infection. We considered MCGR to be salvaged if implant exchange or removal was not performed for at least 1 year following date of infection. Descriptive statistical analyses were utilized to identify rates of recurrent infection as well scoliosis type in patients who underwent rod removal/exchange vs. those who had implants salvaged.

Results

992 EOS patients were identified, of whom 33 (3.3%) developed deep SSI. The mean time between initial surgery and first deep SSI was 13.1 months (Interquartile range [IQR]: 1 to 25 months). 13/354 patients (3.6%) had neuromuscular scoliosis (NMS), 9/225 (4.0%) syndromic, 6/248 (2.4%) idiopathic, 3/135 congenital (2.2%), and 2/30 (6.6%) unknown etiology. There was no significant difference in age ($p=0.85$) and prior treatment with traditional growing rods ($p=0.74$) performed among patients with salvaged MCGR and those without. MCGR was salvaged in 69% of NMS patients, 77% of syndromic patients, 100% of congenital patients, and 83% of idiopathic patients. (Table 1). There were only four recurrent infections (2/13 NMS, 2/9 syndromic), with three infections (12%) in the salvage group and one infection (12.5%) in the non-salvage group.

Conclusion

MCGR deep wound infection occurred in 3% of patients at a mean of 13.1 months. Recurrent infection rates were similar in salvaged implants and those removed or exchanged.

Take Home Message

Deep SSI following MCGR occurs at a rate of 3.3% in EOS patients. Surgeons may consider more conservative interventions, such as I&D, prior to total implant removal/exchange.

	Salvage (n=25)	Non-Salvaged (n=8)
Age	6.9 +2.6	7.1 + 2.0
Etiology	NMS: 9/13	NMS: 4/13
	Syndromic: 7/9	Syndromic: 2/9
	Idiopathic: 5/6	Idiopathic: 1/6
	Congenital: 3/3	Congenital: 0/3
	Unknown: 1/2	Unknown: 1/2
Recurrent Infection	3 (12%)	1 (12.5%)

Table 1: Salvage vs. Non-Salvage Cohorts

32. Matched Comparison of Growing Rods vs. Primary Posterior Spinal Fusion in “Tweeners” with Early Onset Scoliosis

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Summary

In this matched retrospective comparative study of 25 pairs of “tweeners” age 7-11yo with EOS, GRs followed by revision PSF afforded ~2cm of additional thoracic height over primary PSF at the cost of 25% worse overall deformity correction and an additional 1 complication and 2 operations per patient. There was a trend towards decreasing benefit of GRs over primary PSF as pre-index age and Cobb angle increased. Surgeons and families should weigh these concerns when choosing a treatment plan.

Hypothesis

The thoracic height afforded by growing rods (GRs) would be offset by decreased overall deformity correction, more complications, and more total operations.

Design

Matched retrospective comparative study.

Introduction

In 7 to 11-year-old “tweeners” with early onset scoliosis (EOS) in whom bracing fails, the optimal surgical option remains uncertain. This study compares GRs followed by definitive PSF vs. primary PSF in this population.

Methods

This study included EOS patients aged 7.0-11.9 years at index surgery treated with GR→PSF or primary PSF between 2013 and 2020. Primary outcomes were thoracic height (T1-12H) and coronal deformity (Cobb angle). Secondary outcomes included other measures of spinal length and deformity, complications, and total operations. Primary PSFs were manually matched with replacement 1:n to GR→PSFs by age at index, etiology, and Cobb angle. A linear mixed effects model was used.

Results

Twenty-eight GR→PSFs met criteria, including 19 magnetically controlled GRs (MCGRs) and 9 traditional GRs (TGRs). Three MCGRs were definitively explanted without PSF due to complications. The remaining 25 GR→PSFs were matched to 17 primary PSFs with 100% etiology match, mean Δ Cobb of 1°, and mean Δ age at index of 0.5 years (PSFs older). Median Δ T1-12H pre-GR to post-PSF was 4.7 cm with median deformity correction of 37%. Median Δ T1-12H among primary PSFs was 1.9 cm with median deformity correction of 62%. GR→PSFs had median 2 complications and 2 operations. Primary PSFs had median 0 complications and 1 operation. Matched analysis showed adjusted mean differences of 2.3 cm greater Δ T1-12H among GR→PSFs than their matched primary PSFs, with 25% less overall coronal deformity correction, 1.2 additional complications, and 2.2 additional operations per patient. There was a trend towards decreasing benefit of GRs over primary PSF as pre-index age and Cobb angle increased.

Conclusion

In “tweeners” aged 7 to 11 with EOS, the ~2 cm of thoracic height gained over primary PSF may not warrant the 25% loss of deformity correction and additional 1 complication and 2 operations per patient.

Take Home Message

In “tweeners” 7-11yo with EOS, ~2 cm of thoracic height gained over primary PSF may not warrant the 25% loss of deformity correction and additional 1 complication and 2 operations.



Matched pair with characteristic T1-12H and percent correction

33. Lung Parenchymal Characterization via Thoracic Dynamic MRI (dMRI) in Pediatric Patients with Early Onset Scoliosis (EOS): A Novel Approach

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Summary

We propose a new technique to assess lung parenchymal aeration properties by using a dMRI protocol on both normal children and pediatric patients with EOS. Image processing to standardize (T2-weighted) MRI pixel intensities to bear tissue-specific numeric meaning reveals that lung intensity at end-inspiration is significantly lower than that at end-expiration. Furthermore, lung intensity of post-operative EOS patients is closer to that of normal children and significantly lower than pre-operative lung intensity, indicating improvement in lung aeration.

Hypothesis

Difference in lung parenchymal tissue aeration during breathing can be assessed using a dMRI protocol for patients with EOS.

Design

A basic science study

Introduction

The potential of quantitative thoracic dMRI for evaluating treatment effects on lung dynamics in EOS by extracting volumetric parameters from a 4D image has been previously demonstrated. However, changes in lung tissue characteristics by using signal intensity is yet to be studied. dMRI-based lung parenchymal characterization is non-invasive. The proposed method can be useful in better understanding lung physiology during normal growth and in EOS before and after corrective procedures.

Methods

The proposed approach includes: dMRI acquisition, 4D image construction, image non-uniformity correction, intensity standardization to achieve tissue-specific meaning, and lung

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segmentation in the 4D constructed image. Then, statistics of standardized image intensity properties in the lung region are estimated. The subject cohort includes 22 dMRI scans from 11 EOS patients (each with pre-operative and post-operative scans) and dMRI scans from 23 healthy children. Two-sided paired t-testing is performed to compare lung intensity properties at end-expiration (EE) and end-inspiration (EI) within EOS patients and normal children. Intensity properties at EE and EI among pre-operative EOS, post-operative EOS, and normal children are also compared.

Results

The volume of the lungs at EI was visually larger than that at EE. Mean image intensity of the lung at EI was lower (appears darker) than at EE, with all p values < 0.05 for EE vs. EI comparison for normal children and EOS patients. The mean intensity of the lungs at EI for post-operative EOS patients was closer to that at EI of normal children, and significantly lower than that for pre-operative EOS patients (82 ± 39 vs. 112 ± 52 , $p = 0.003$).

Conclusion

dMRI can detect change in lung parenchymal tissue aeration during breathing for EOS patients and normal children.

Take Home Message

This basic science study provides a practical approach for studying physiological changes in lung parenchymal aeration in pediatric EOS using dynamic MRI.

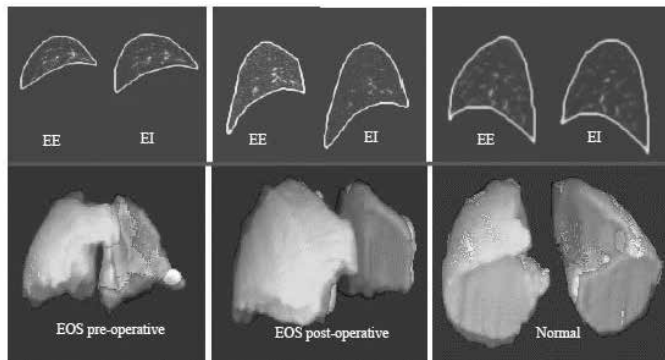


Figure 1. An example of segmented lung with image intensity (top row) and 3D surface renditions (bottom row) for one EOS patient (pre-operative and post-operative) and one normal child. The same display window is set up for the EOS patient and the normal child.

	EOS pre-op	EOS post-op	Normal
Mean lung intensity at EI (unitless)	112 ± 52	82 ± 39	54 ± 12
Mean lung intensity at EE (unitless)	136 ± 64	112 ± 39	58 ± 12
p (EE vs. EI)	0.001	0.003	< 0.001
p (EOS pre-op vs. post-op at EI, paired t-test)		0.003	
p (EOS pre-op vs. post-op at EE, paired t-test)		0.06	
p (EOS pre-op vs. normal at EI, unpaired t-test)		0.004	
p (EOS pre-op vs. normal at EE, unpaired t-test)		0.002	
p (EOS post-op vs. normal at EI, unpaired t-test)		0.04	
p (EOS post-op vs. normal at EE, unpaired t-test)		0.001	

34. Upper Instrumented Vertebra (UIV) Selection Matters: Increased Risk of Proximal Junctional Kyphosis When UIV is Closer to the Apex in Scheuermann's Kyphosis

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Summary

This study investigated the association between upper instrumented vertebra (UIV) location and development of proximal junctional kyphosis (PJK) in Scheuermann's Kyphosis (SK) patients undergoing posterior spinal fusion (PSF). Patients with UIV located closer to the apex (within 4.5 vertebrae) had an increased risk of PJK when compared to those with UIV further (57.1% vs. 21.4%, $p=0.034$). In a regression model, there was a 2.7 times increased risk of PJK in those with UIV located closer to the apex ($p=0.012$).

Hypothesis

In patients with SK treated with PSF, those with UIV located closer to the preop kyphosis apex have an increased risk of PJK at 2 years when compared to those with UIV further.

Design

Retrospective cohort study

Introduction

Studies have reported various risk factors for PJK in SK patients; however, the interplay between UIV, characteristics of kyphosis, and PJK remains unclear. The purpose of this study was to investigate the association between UIV location in relation to kyphosis apex and risk of PJK at 2 years following PSF.

Methods

SK patients who underwent treatment with PSF and reached 2 years postop were identified in a multicenter international registry. Those with anterior release, prior spine surgery, neuromuscular comorbidity, or post-traumatic kyphosis were excluded. Location of UIV as well as the number of levels between UIV and preop kyphosis apex were determined, and the occurrence of PJK (proximal junctional angle $\geq 10^\circ$ that is $\geq 10^\circ$ greater than the preop measurement) was recorded.

Results

91 patients (16.5 ± 1.9 yo, 64.8% male) were included, and all underwent PSF that included the proximal end vertebra of the major kyphosis (MK). Preop and 2-year postop MK was $74.8 \pm 11.7^\circ$ and $45.9 \pm 10.4^\circ$, respectively. 22 (24.2%) patients developed PJK at 2 years. Patients with UIV below T2 (34.1% vs. 16.0%, $p=0.042$) or closer to the apex (≤ 4.5 vertebrae) (57.1% vs. 21.4%, $p=0.034$) had an increased risk of PJK when compared to their counterparts. PJK was not associated with preop MK, % MK correction, pelvic incidence (PI), PI-lumbar lordosis mismatch, or symmetry of the fusion construct surrounding the apex (equal # of vertebrae fused above and below). In a regression model, those with ≤ 4.5 vertebrae between UIV and apex had a 2.7 times increased risk of PJK when compared to those with >4.5 vertebrae ($p=0.012$) (UIV below T2 had collinearity thus excluded).

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Conclusion

Building on previous work, these results demonstrate an association between UIV location in relation to preop kyphosis apex and PJK in SK patients. This association supports consideration of the kyphosis apex when selecting UIV in this setting.

Take Home Message

SK patients with UIV located closer to the preoperative kyphosis apex have an increased risk of developing PJK at 2 years following PSF.

35. To Prevent PJK in Scheuermann's Kyphosis, Restore Kyphosis to Patient's PI Value and Choose Proximal UIV

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Summary

In this study, we investigate PJK and its possible prevention with an examination of SK patients operated with all pedicle screw (PS), hybrid fixation (HF), and anterior/posterior fusions with hybrid fixation (AP) as well as determining a goal correction parameter based upon kyphosis, pelvic incidence, and UIV. We found that while the technique of correction does not have a significant role in the development of PJK postoperatively, the choice of UIV and matching postoperative kyphosis to pelvic incidence does.

Hypothesis

Risk of PJK increases with pedicle screws.

Design

Retrospective Chart Review

Introduction

Incidence of proximal junctional kyphosis (PJK) in Scheuermann's Kyphosis (SK) varies between 24 – 40%. Multiple factors have been implicated, including: overcorrection of kyphosis, failure to include the proximal end vertebra and choice of implants. Recently, studies have attempted to analyze pelvic parameters in SK, including lumbopelvic mismatch. However, the issue remains unresolved.

Methods

X-ray and chart review of all SK patients operated with all pedicle screw (PS), hybrid fixation (HF), and anterior/posterior fusions with hybrid fixation (AP). Kyphosis minus pelvic incidence $>-10^\circ$ was determined to be normal. T1/T2 were grouped together as proximal fusion group compared to T3 and distal group.

Results

96 total patients: PS (n=41), HF (n=24), and AP (n=31). Overall, at early postop 12/96 (12.5%) patients had PJK. At final follow-up 33/96 (34.4%) had PJK. There was no significant difference between groups at early postop ($p = 0.86$) or final follow up ($p = 0.67$). When correcting Kyphosis-PI to $>-10^\circ$ and UIV was chosen to be T1 or T2, PJK developed in 6% of patients. When fusing to T1/T2 and having kyphosis-PI $<-10^\circ$, 38.9% of patients developed

PJK. When having Kyphosis-PI to $>-10^\circ$ but UIV chosen at T3 or below, 77.8% of patients developed PJK. When fusing to T3 or below and failing to correct kyphosis-PI to $>-10^\circ$, 37% of patients developed PJK.

Conclusion

While surgical techniques and implants do not seem to have a substantial role in development of PJK, selecting proximal UIV and avoiding Kyphosis-PI mismatch can significantly decrease this possibility. Surgeons treating Scheuermann's Kyphosis should, therefore, aim to correct kyphosis closer to patient's pelvic incidence.

Take Home Message

While the technique of correction does not have a significant role in the development of PJK postoperatively, the choice of UIV and matching postoperative kyphosis to pelvic incidence does.

36. A Normal PI-LL Relationship is Associated with Pain Improvement Following Posterior Spinal Fusion for Scheuermann's Kyphosis

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Summary

This study investigated the relationship between postoperative pelvic incidence and lumbar lordosis (PI-LL) and its association with pain improvement following posterior spinal fusion (PSF) for Scheuermann's Kyphosis (SK). When PI-LL mismatch was corrected after surgery, SRS-22 pain scores improved in a significant number of patients. Patients with a matched postoperative PI-LL relationship had an increased likelihood of pain improvement by 1.63 times when compared to those with PI-LL mismatch ($p=0.06$).

Hypothesis

In SK patients undergoing PSF, those with a normal PI-LL relationship (corrected or maintained) following PSF have an increased likelihood of pain improvement at 2 years when compared to those with mismatch.

Design

Retrospective cohort study

Introduction

Pain improvement is well documented in SK patients following PSF. However, a complete understanding of factors associated with this improvement remains elusive. Studies have demonstrated an association between correction of sagittal parameter mismatch and improved outcomes. The purpose of this study was to investigate the association between a normal PI-LL relationship and improvement in pain at 2 years following PSF for SK.

Methods

SK patients who underwent PSF and reached 2 years postop were identified in a multicenter international registry. Patients with anterior release, prior spine surgery, neuromuscular comor-

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idity, or post-traumatic kyphosis were excluded. A normal PI-LL relationship ($<10^\circ$ difference; either correction of mismatch OR maintenance of normal) was determined at 2 years. Improvement in pain was defined as a 2-year postop increase in SRS-22 pain score \geq the minimal clinically important difference.

Results

Of 91 patients who met inclusion criteria, 59 (16.5 ± 2.0 yo, 67.8% male) had PI-LL data available for analysis. Preop and 2-year postop major kyphosis was $75.3 \pm 11.1^\circ$ and $49.6 \pm 11.4^\circ$, respectively. The average pain score was 3.9 ± 0.8 at preop and 4.2 ± 0.8 at 2-year postop ($p=0.004$). Only 7 (10.4%) patients had normal PI-LL at preop and 23 (39%) patients had normal PI-LL at 2 years postop. In those with normal postop PI-LL, 68.4% ($N=13$) had improvement in pain, compared to 41.9% ($N=13$) in those with PI-LL mismatch ($p=0.069$). Patients with normal postop PI-LL had an increased likelihood of pain improvement by 1.63 times when compared to those with PI-LL mismatch ($p=0.062$). No patient or preop radiographic measures were associated with pain improvement.

Conclusion

Improvements are seen both in PI-LL relationships and pain scores following PSF for SK at 2 years postop. Patients with normal PI-LL postoperatively had an increased likelihood of pain improvement.

Take Home Message

SK patients with normal postop PI-LL (corrected or maintained) had an increased likelihood of pain improvement at 2 years following PSF.

37. Characterization of the Different Spino-Pelvic Profiles of Walking Diplegic Cerebral Palsy Patients

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Summary

We propose a prognostic classification describing the link between spino-pelvic profile, walking performance and back pain in order to drive therapeutic multidisciplinary management. With PI comparable to the normal population, more than half of our 77-patient cohort maintain an adapted spino pelvic morphology in adulthood. Most of efficient walkers (79,2%) maintain a high sacral slope ($> 38^\circ$) either with a true anteverted pelvis ($PI < 54$) or with a high PI. Retroverted patients are the least efficient (mainly GMFCS 3).

Hypothesis

In cerebral palsy patients, muscle weakness, musculotendinous retractions and spastic hypertonia are responsible for the secondary deformities above and below the pelvis, which condition the processes of adaptation to the maintenance of the spino pelvic balance. Spino-pelvic balance of the adult CP patient is a prognostic factor for chronic back pain and trunk imbalance, which themselves are prognostic factors for walking performance.

Design

We characterize the spino-pelvic profile of adolescent and adult diplegic CP patients with walking ability (GMFCS 1-3) in order to

develop a prognostic classification system of spino-pelvic alignment on walking performance.

Introduction

Cerebral palsy, a frequent affection (2.1/1000 births) is characterized by brain damage during development (before 2 years). Primary neurological lesions lead to muscle weakness and hypertonia and then, during growth, tendon retractions and bone deformities. In the functional diplegic CP (GMFCS 1-3), lesions mainly affect the lower limbs, but the spine can be affected by the pelvic tilt.

Methods

This study is a single-center (multidisciplinary medical and surgical reference center) retrospective series involving 77 walking CP patients for whom we had a functional evaluation and a concomitant whole-body EOS radiographic analysis. We analyzed the link between spino pelvic parameters, gait pattern, severity of neurological impairment (GMFCS) and back pain.

Results

While the average pelvic incidence is within the norm (50.8°), our study shows, in CP diplegic walkers, a high proportion of anteverted pelvis. The Roussouly type 4 represent 45.9% of the cohort and are significantly more painful, more functional, with a larger anterior imbalance (SVA $43,2$ mm). Conversely, retroverted patients are less effective walkers (GMFCS 3 in 56.2%, vs. 23% of anteverted patients, $p = 0.0066$)

Conclusion

Spino pelvic profile is balanced in more than half of CP patients who maintain efficient walking at adulthood. The most efficient predominantly have anteverted pelvis, but experience more back pain.

Take Home Message

We propose a prognostic classification of the spino-pelvic profiles of walking diplegic CP to better drive the therapeutic strategies in childhood, and to reduce the prevalence of pain in adulthood.

38. Concurrent Scoliosis and Hip Dysplasia in Children with Cerebral Palsy: Should We Fix the Spine or Hip First?

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Summary

Restoring pelvic obliquity in patients with severe cerebral palsy and scoliosis are important in restoring sitting balance improving HRQoL. This study demonstrated that there was no further hip deteriorating in patients with hip subluxation and scoliosis who were treated with scoliosis correction surgery first and then followed for 4 years.

Hypothesis

Scoliosis surgery may be protective of hip subluxation in neuromuscular patients.

Design

Retrospective cohort design

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Introduction

Children with cerebral palsy (CP) frequently develop both neuromuscular scoliosis and hip dysplasia; and, occasionally the timing of surgical consideration of these pathologies are concurrent and evidence is lacking. The purpose of this project was to determine the impact of posterior spinal fusion (PSF) on the change in hip displacement for children with CP without previous reconstructive hip surgery.

Methods

This was a retrospective cohort study of 67 patients from 2004-2018. Inclusion criteria were children with CP, 18 years or younger, GMFCS IV and V, undergoing PSF at a single tertiary care children's hospital with 2-year radiographic and clinical follow up of the hip and spine. The primary outcome was the change in hip displacement as quantified by the Migration Percentage (MP); change in MP before and after PSF was measured and compared using Welch's t-tests (significant $p < 0.05$), for a minimum of 3 years post-PSF or until hip reconstruction was performed. The hip with the highest MP (worst hip) at the spine preoperative analysis was included for analysis. Tri-radiate cartilage status and pelvic obliquity correction were analyzed with multivariate analysis.

Results

The mean age of the 67 patients was 12.5 yrs (± 2.3). The magnitude of the major curve was 77° (± 23), and the mean preoperative pelvic obliquity was 20.7° (± 12). There was no statistically significant change in MP following PSF from a mean preoperative value of 41% (± 27), to a mean postoperative value of 41% (± 29), $p = 0.760$. The mean follow-up time was 48.9 months. Multivariate analysis showed that tri-radiate cartilage status ($p = 0.52$) and the severity of pelvic obliquity ($p = 0.10$) did not statistically impact the change of MP following PSF.

Conclusion

There was no deterioration of hip status after scoliosis surgery in children with CP.

Take Home Message

The lack of progression of hip subluxation after PSF could suggest that addressing the spine deformity and pelvic obliquity first is beneficial

39. When is Pelvic Fixation Necessary in Children with Hypotonic Neuromuscular Scoliosis (NMS) Treated with Growing Instrumentation?

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Summary

Lower baseline pelvic obliquity (PO) and L5 tilt may be indications to exclude the pelvis in children with hypotonic NMS treated with growing instrumentation. Distal spine anchors (DSA) provided similar long-term control of the major curve and PO as distal pelvic anchors (DPA) with no difference in complication rates.

Hypothesis

The pelvis can be successfully excluded in properly selected children with hypotonic NMS treated with growing instrumentation.

Design

Multicenter retrospective review.

Introduction

Prior studies have shown that lower preoperative PO and L5 tilt were associated with good radiographic outcomes when the fusion ended short of the pelvis in children with NMS. Our purpose was to identify indications to exclude the pelvis in children with hypotonic NMS treated with growing instrumentation.

Methods

Children with spinal muscular atrophy and muscular dystrophy treated with TGR, MCGR, or rib-based growing constructs with minimum 2-year follow-up after the index surgery were identified.

Results

141 patients were identified. 45 patients had DSA and 96 patients had DPA placed at the index surgery. Pre-index radiographic measures were similar except the DSA patients had a lower PO (12o vs. 19o, $p = 0.003$) and L5 tilt (8o vs. 12o, $p = 0.011$) than the DPA patients (Table). Post-index and most recent radiographic data were comparable between the groups. 11 (24%) of the DSA and 32 (33%) of the DPA patients had a PO ≥ 10 o at most recent follow-up. There was no difference in the complication and unplanned return to the operating room (UPROR) rates. At most recent follow-up, the DSA group had significantly better EOSQ-24 Physical Function, Daily Living, and Satisfaction scores. Only 2 DSA patients have undergone extension of their instrumentation to the pelvis.

Conclusion

Lower PO and L5 tilt may be indications to exclude the pelvis in children with hypotonic NMS treated with growing instrumentation. Revision surgery to include the pelvis was rare and PO remained stable at most recent follow-up in the DSA group. DSA and DPA were equally effective at long-term major curve control, and complication and UPROR rates were similar.

Take Home Message

Lower PO and L5 tilt may be indications to exclude the pelvis in children with hypotonic NMS treated with growing instrumentation.

Table 1. Comparison of patients with distal spine anchors vs distal pelvic anchors placed at the index surgery.

Demographics	Distal spine anchors (N=45)	Distal pelvic anchors (N=96)	p-value
Age at index surgery (years; mean ± SD)	7.3 ± 2.5	7.7 ± 2.2	0.415
BMI at index surgery (kg/m ² ; mean ± SD)	17.3 ± 5.4	16.5 ± 4.6	0.521
Nonambulatory status at index surgery [n (%)]	31 (69)	92 (96)	<0.001
Length of follow-up (years; mean ± SD)	4.3 ± 2.7	5.0 ± 3.0	0.197
Radiographic data			
Major curve (°; mean ± SD)			
Pre-index	71 ± 21	72 ± 24	0.856
Post-index	43 ± 17	43 ± 18	0.803
Most recent	44 ± 18	48 ± 20	0.240
Pelvic obliquity (°; mean ± SD)			
Pre-index	12 ± 10	19 ± 12	0.003
Post-index	8 ± 5	8 ± 6	0.878
Most recent	9 ± 10	9 ± 8	0.879
L5 tilt (°; mean ± SD)			
Pre-index	8 ± 6	12 ± 9	0.011
Post-index	5 ± 4	5 ± 4	0.831
Most recent	7 ± 8	6 ± 5	0.250
Outcomes			
Total complications (n)	43	148	0.005
Number of patients with complications [n (%)]	24 (53)	57 (59)	0.456
Total UPRORs (n)	19	34	0.256
Number of patients with UPRORs [n (%)]	10 (22)	24 (25)	0.910
EOSQ-24 Domains			
Pain/Discomfort [mean (95% CI)]	72 (64-79)	62 (57-68)	0.070
Physical Function [mean (95% CI)]	47 (37-58)	23 (17-29)	<0.001
Daily Living [mean (95% CI)]	41 (31-51)	20 (14-26)	<0.001
Satisfaction [mean (95% CI)]	60 (53-68)	49 (43-54)	0.026

Comparison of patients with distal spine anchors vs. distal pelvic anchors placed at the index surgery.

40. An Algorithm for Using Deep Learning Convolutional Neural Networks with Three-Dimensional Depth Sensor Imaging in Scoliosis Detection

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Summary

We developed a system to accurately predict Cobb angle using the deep learning algorithm with the convolutional neural network for regression analysis. The correlation between the actual and the mean predicted Cobb angles was 0.91, and the mean absolute error and root mean square error were 4.0° and 5.4°, respectively. The three-dimensional depth sensor imaging system with its newly innovated convolutional neural network for regression is objective and has significant ability for predicting the Cobb angle in children and adolescents.

Hypothesis

The deep learning algorithm (DLA) with the convolutional neural network (CNN) can accurately predict Cobb angle using three-dimensional (3D) depth sensor images.

Design

Retrospective analysis of prospectively collected, consecutive, nonrandomized series of patients at five scoliosis centers in Japan.

Introduction

Timely intervention in growing individuals, such as brace treatment, relies on early detection of adolescent idiopathic scoliosis (AIS). To this end, several screening methods have been implemented. However, these methods have limitations in predicting the Cobb angle.

Methods

One hundred and sixty human subjects suspected to have AIS were included. Patient demographics, radiographic measurements, and predicted Cobb angle derived from the DLA were the outcome measures for this study. One hundred and sixty data

files were shuffled into five datasets with 32 data files at random (dataset 1, 2, 3, 4, and 5) and five-fold cross validation was performed. The relationships between the actual and predicted Cobb angles were calculated using Pearson's correlation coefficient analyses. The prediction performances of the network models were evaluated using mean absolute error (MAE) and root mean square error (RMSE) between the actual and predicted Cobb angles. The shuffling into five datasets and five-fold cross validation was conducted ten times.

Results

The correlation between the actual Cobb angle and the mean predicted Cobb angle with 10 repeats was 0.91. The MAE and RMSE between the actual Cobb angle and the mean predicted Cobb angle was 4.0° and 5.4° respectively. The accuracy of the mean predicted Cobb angle was 94% for identifying a Cobb angle of ≥10° and 89% for that of ≥20°.

Conclusion

The 3D depth sensor imaging system with its newly innovated CNN for regression is objective and has significant ability to predict the Cobb angle in children and adolescents. This system is expected to be used for screening scoliosis in clinics or physical examination at schools. In addition, this is also a possible surrogate for radiographs to monitor curve progression, preventing unnecessary x-rays for mild case of scoliosis.

Take Home Message

The three-dimensional depth sensor imaging system with its newly innovated convolutional neural network for regression is objective and has significant ability for predicting the Cobb angle in children and adolescents.

41. Sanders Stage 7b: Using the Ulna Physis Improves Decision-Making for Brace Weaning in Adolescent Idiopathic Scoliosis

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Summary

Sanders staging (SS) has been used frequently for measure of skeletal maturity. Its role for deciding brace weaning is uncertain. This was a prospective analysis for post-brace weaning outcomes in 179 patients with adolescent idiopathic scoliosis (AIS). The appearance of ulnar closure was used to differentiate between SS7a and SS7b. Weaning at SS7b provides best prevention of post-brace weaning curve progression.

Hypothesis

Including the stages of ulnar physeal closure in SS7 aids in more accurate assessment for brace weaning.

Design

Prospective study

Introduction

SS has been used frequently for measure of skeletal maturity. Its prediction for curve progression after brace weaning has been challenged. SS7 represents the early mature stage at which all phalangeal physes are fused and only distal radial physes are

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open. At SS8, complete fusion is observed. There may still be a range of radiological appearances between SS7 and SS8.

Methods

Patients who weaned brace-wear from June 2016 to December 2018 was studied. Skeletal maturity at weaning was assessed using Sanders staging with SS7 subclassified into SS7a (all phalangeal physes are fused and only distal radial physes are open, with narrowing of medial physal plate of the distal ulna) and SS7b (those with >50 % fusion of the medial growth plate of distal ulna). Weaning maturity grading and any curve progression were analyzed using Fisher's exact test, with Cramer's V and Goodman and Kruskal's tau.

Results

A total of 179 AIS patients were studied with mean age of 14.8 ± 1.1 years and Cobb angle of $34.6 \pm 7.7^\circ$ at weaning. Follow-up period was 3.4 ± 1.8 years. Curve progression rates for patients weaning at SS7a vs. SS7b were 11.4% and 0% respectively for $<40^\circ$ curves. The use of SS6, SS7a/b, SS8 for maturity assessment at weaning strongly associated (Cramer's V: 0.326, $p=0.016$) with whether curve progressed at post-weaning 6-months. Weaning with the SS7 subclassification allowed a 10.6% reduction of error in predicting curve progression. The mean difference between weaning at SS7b and SS8 was 9.0 months. For larger curves, the curve progression rate post-weaning was not associated with any of the skeletal maturity indices.

Conclusion

The use of SS7a and SS7b allows accurate maturity assessment for guiding brace weaning. Weaning at SS7b is more appropriate without any curve progression cases immediately post-weaning for curves $<40^\circ$. This makes reaching full fusion of both distal radius and ulna physis at SS8 not necessary and brace weaning can be initiated approximately 9.0 months earlier.

Take Home Message

Weaning at SS7b is appropriate for Cobb angle $<40^\circ$. For large curves of $\geq 40^\circ$, curve progression can occur regardless of the skeletal maturity status at which weaning takes place.



SS7a (left) and SS7b (right)

42. Outcomes of Magnetically Controlled Growing Rods (MCGR) in Severe Early Onset Scoliosis

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Summary

Magnetically controlled growing rods provided similar deformity correction and thoracic height improvement with less compli-

cations and revision surgeries compared to traditional growing rods in children with severe early onset scoliosis. Magnetically controlled growing rods provide a safe and effective method for controlling these deformities.

Hypothesis

The reduced need of surgical interventions in MCGR treatment results in better quality of life and fewer surgery related complications such as deep wound infections.

Design

A retrospective review of an international database of children with severe ($\geq 90^\circ$) early onset scoliosis.

Introduction

Traditional growing rods (TGRs) are the standard in treating severe childhood deformities. Repetitive surgical interventions lead to high incidence of complications and poor quality of life. MCGRs allow noninvasive lengthenings without the need of surgical interventions.

Methods

Children with severe EOS treated with MCGR ($n=44$) were identified from the database. These patients were matched by age, gender, and etiology with patients with TGRs. Different follow-up times between the groups were analyzed using Kaplan-Meier curve.

Results

The mean major curve was 104° in the MCGR and 104° in the TGR group ($p=0.47$) preoperatively, 53° and 57° after the index operation ($p=0.0.16$), and 54° and 60° at the final follow-up ($p=0.07$). The annual thoracic height increase during the first 2 years of distraction was 10 mm in the MCGR and 11 mm in the TGR group ($p=0.07$). Kaplan-Meier curve was used for analyzing the instrumentation survival. Implant related complications and deep surgical infections requiring revision surgery were considered as survival endpoints. There was statistically significantly less complications requiring revision surgery in the MCGR group ($p<0.05$). The 2-year survival rate was 90% in the MCGR and 49% in the TGR group ($p<0.05$). There were no significant differences between the groups in the preoperative quality of life measured with EOSQ-24. In the most recent follow-up, the General Health and Emotion domains were significantly better in the MCGR group ($p=0.02$, $p=0.04$).

Conclusion

Children treated with MCGR had similar deformity correction and thoracic height improvement, and less complications than those treated with TGR. Children with severe EOS can be safely and effectively treated with MCGR.

Take Home Message

MCGRs provided similar deformity correction and thoracic height increase compared to TGRs. There was significantly less complications and revision surgeries in the MCGR group.

	MCGR n=44	TGR n=44	Significance
Age at surgery, years	7.40 (2.4–10)	7.01 (2.5–10)	0.149
Female gender	34	30	
Mean follow-up, years, mean (range)	2.90 (2.0–5.1)	4.56 (2.0–9.1)	<0.0001
Idiopathic	6	6	1.0
Neuromuscular	25	25	1.0
Syndromic	8	8	1.0
Congenital	5	5	1.0
Mean number of lengthenings, n (range)	9.8 (4–28)	5.8 (3–15)	<0.001
Mean number of surgical procedures, n (range)	1.8 (1–7)	9 (3–19)	0.003
Major coronal curve (°) mean, (range)			
Preoperative	103.5 (90–130)	103.7 (90–139)	0.472
After initial surgery	53.1 (21–85)	56.9 (20–104)	0.161
Most recent prior to fusion	54.3 (20–91)	60.3 (10–119)	0.069
Mean thoracic height (T1–T12) mm, (range)			
Preoperative	155 (108–202)	152 (99–210)	0.336
After initial surgery	184 (141–260)	177 (118–233)	0.113
Most recent prior to fusion	205 (149–289)	204 (139–292)	0.416
Total number of complications, n, (range)	31 (0–4)	82 (0–9)	<0.001
Unplanned revisions, n, (range)	11 (0–3)	61 (0–9)	<0.001
Average unplanned revisions per year, n (range)	0.08 (0–0.76)	0.30 (0–4.5)	0.003
Deep surgical site infection, n (per year)	2 (0.01)	18 (0.08)	0.003 (0.003)
Hardware failure n, (per year)	13 (0.11)	34 (0.25)	0.022 (0.048)
Anchor failure n, (per year)	5 (0.04)	7 (0.07)	0.323 (0.221)
Rod fracture n, (per year)	4 (0.03)	21 (0.16)	0.027 (0.026)
Neurological complication n, (per year)	1 (0.01)	4 (0.01)	0.085 (0.464)

Clinical characteristics

43. Spinal Fusion Leads to Quality Adjusted Life Year Gains in Cerebral Palsy Patients Sustained up to 5 Years after Surgery

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Summary

The CP-Child is a validated instrument that is used to assess quality of life in pediatric cerebral palsy (CP) patients. However, it cannot be used directly to calculate quality adjusted life years (QALY), which allow for cross-comparisons between interventions. (1 QALY = 1 year of life in perfect health) Recently, another instrument, CP-6D, has been validated to calculate QALYs in the CP population. Here, we demonstrate that CP patients undergoing spinal fusion experience net QALY gains up to five years postoperatively.

Hypothesis

We hypothesize that by converting CP-Child scores to CP-6D health utilities, QALY gains can be calculated. Further, we hypothesize that spinal fusion surgery in pediatric CP patients results in net QALY gains up to five years after surgery.

Design

Retrospective Multicenter Study

Introduction

Net QALY changes following spinal fusion have never been quantified in the pediatric CP population.

Methods

Using a multicenter prospective registry, we identified operatively treated pediatric CP patients. Responses to the CP-Child questions (by patient or family) at preoperative baseline and one-, two-, and five-year follow-up visits were used to create responses to matching CP-6D questions. Generated CP-6D scores were converted to corresponding health utilities using previously published discrete choice experiment data. The health utilities were used to calculate QALY gains for the operative cohort at each follow-up time point. Paired t-test was utilized, with significance set to <0.05.

Results

288 patients had complete CP-Child surveys at baseline and one-year follow-up. Of these, 188 and 70 had complete surveys at two- and five-year follow-up, respectively. Compared to pre-operative baseline, calculated health utilities were significantly higher at one-, two-, and five-year postoperative timepoints (Table 1). For each cohort, net QALY gains (mean + standard deviation) from pre-operative baseline to one-, two-, and five-year timepoints were +0.65 + 0.28, +1.33 + 0.48, and +3.41 + 1.14 respectively.

Conclusion

Pediatric CP patients undergoing spinal fusion for scoliosis demonstrate sustained gains in QALY for up to five years following surgery. Future work may focus on prospectively collecting CP-6D responses and on estimating cost-utility of spinal fusion for CP.

Take Home Message

Our results indicate that spinal fusion surgery in this complex patient population is impactful on the burden of care and durable in terms of quality-of-life improvement.

Timepoint	N	Pre-operative HU (Mean +/- SD)	HU at Timepoint (Mean +/- SD)	Total QALY at Timepoint (Mean +/- SD)	P-value
1 year	288	0.51 ± 0.31	0.65 ± 0.28	1.16 ± 0.51	<0.0001*
2-year	188	0.54 ± 0.30	0.66 ± 0.28	1.87 ± 0.68	<0.0001*
5-year	70	0.51 ± 0.30	0.65 ± 0.31	3.92 ± 1.31	<0.0001*

Table 1: Health utility comparison between pre-operative baseline and postoperative time points in CP patients undergoing spinal fusion. Abbreviations: N= number of paired analyses, HU=Health utility. *Denotes statistical significance

44. Mid-Term Health-Related Quality of Life and Caregiver Burden following Spinal Fusion in Children with Cerebral Palsy

Rachel L. DiFazio, PhD, RN; Judith A. Vessey, PhD, RN; Patricia E. Miller, MS; Brian D. Snyder, MD, PhD; Benjamin J. Shore, MPH

Summary

This study elucidates the mid-term outcomes in children with GMSCS IV-V CP who underwent a spinal fusion for neuromuscular scoliosis. Sustained improvements in HRQOL at 5-year follow-up were not noted in children who underwent spinal fusion. Children who underwent a spinal fusion experienced gains in CP-CHILD scores 12 months after surgery, but then CPCHILD scores reverted back to baseline 2 years after surgery and essentially remained at baseline 5 years after surgery.

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Hypothesis

In children with Gross Motor Function Classification (GMFCS) IV-V cerebral palsy (CP) a significant increase in health-related quality of life (HRQOL) will be detected ≥5-years following a spinal fusion with no change in caregiver burden.

Design

Prospective longitudinal study

Introduction

Children with GMFCS IV-V CP often develop progressive neuromuscular scoliosis and require a spinal fusion. The purpose of this study was to evaluate the effects of spinal fusion on HRQOL and caregiver burden in children with GMFCS IV-V CP ≥5-years following surgery.

Methods

Serial parent proxy measures of HRQOL and caregiver burden were obtained prior to and at 6 weeks, 3, 6, 9, 12, 24 and 60 months after spinal fusion using the Caregiver Priorities and Child Health Index of Life with Disabilities (CPCHILD) and the Assessment of Caregiver Experience with Neuromuscular Disease (ACEND). Scores ≥5 years after surgery were compared to pre-surgery scores using Paired Student's t-test. Serial outcome trajectories were estimated by linear mixed modeling.

Results

Twenty-six children (average age =14.4 years, 13 males) participated. Four children died before completion of the study. Initial improvement in HRQOL was noted 12 months following surgery with no statistically significant change in HRQOL scores detected at 5-years compared to baseline. In addition, no significant change was noted in the ACEND total score, however there was a significant improvement of 10.6 points in the time subdomain (10.6; 95% CI=0.83-20.5; p=0.04)

Conclusion

Sustained improvements in HRQOL at 5-year follow-up were not detected in children who underwent spinal fusion. Orthopaedic interventions do not change caregiver burden, owing to persistence of medical co-morbidities, spasticity, limited functional mobility, cognitive and communication disabilities.

Take Home Message

Scoliosis correction improves HRQOL at mid-term follow-up. Since children remain dependent, caregiver burden unchanged by spine surgery. Restrictive lung disease is associated with 15% mortality rate, reflecting fragile health status.

45. Adverse Events in Multilevel Surgery in Elderly Patients with Spinal Deformity: Report of the Prospective Evaluation of Elderly Deformity Surgery (PEEDS)

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no, MD; Yukihiro Matsuyama, MD, PhD; Stephen J. Lewis, MD, FRCS(C)

Summary

Adverse events were identified in 124/219(57%) of elderly patients treated with multilevel fusion surgery for spinal deformity. 245 adverse events were reported, including 120 surgical, 86 medical, and 32 neural. The most common serious events were implant failure, junctional pathology, and neural injuries. 39 patients (18%) required revision surgery for AEs within 2 years. Understanding the rates, types and severity of AEs is important to guide informed choice regarding the appropriateness of surgical interventions for elderly patients with spinal deformity.

Hypothesis

The rate of surgical adverse events in elderly patients with spinal deformity is similar to rates reported for surgery in a general population with adult deformity.

Design

Prospective multicenter observational study

Introduction

The appropriateness of surgery for patients with spinal deformity is based upon the expected risks and benefits. Understanding the risks of spinal deformity surgery in elderly patients is important to empower informed choice for patients and physicians. The purpose of this study is to report observed adverse events over a two-year period after surgery in elderly patients undergoing multilevel surgery.

Methods

Prospective multicenter observational longitudinal case series with 12 sites distributed around the world. Patients included were adults over age 60 with spinal deformity, treated with primary spinal fusion of at least 5 levels. The Adverse Events (AEs) were collected prospectively, with data collection overseen by data monitors. AEs were classified into Medical, Neural, and Surgical, and the timing, severity and resolution were recorded.

Results

219 enrolled from 12 international centers. 176 females/43 males, mean age 67.5(range 60-83) years. 124 pts suffered AEs within the 2-year FU period, and 245 distinct adverse events were attributed to the index surgery. AEs were classified as Medical in 89(36%), Neural in 36(15%), and Surgical 120(49%). AEs were rated as severe in 59 pts (27%), moderate in 36 pts (16%) and mild in 28 pts (13%). There were 101 Severe Adverse Events (SAE), with the most common including implant failure (17), junctional pathology requiring revision surgery (12), and neural injuries (36). 39 pts (18%) required a revision surgery.

Conclusion

Adverse events were identified in 124/219 (57%) of elderly pts treated with multilevel fusion surgery for spinal deformity. The rate of adverse events in elderly patients is similar to reports in a general population treated with surgery for spinal deformity. Understanding the types, rates and severity of AEs is important to guide informed choice regarding the appropriateness of surgical interventions in this population.

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Take Home Message

Adverse events occurred in 124/219 (57%) of elderly patients treated with surgery for spinal deformity. Information regarding specific events, severity, and interventions required will empower informed choice of appropriate care.

46. Alterations of Gait Kinematics Depend on the Type of Deformity in ASD

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Summary

It is still unknown which component of spinal deformity is associated with gait alterations. 82 ASD and 43 controls underwent gait analysis. Patients with high SVA and PT, and to a lesser extent those with only hyperkyphosis, had a decreased range of motion at the pelvic, hips, and knee levels, along with a decreased walking speed and cadence. These kinematic alterations correlated with the increased SVA and PT. ASD with only frontal malalignment had a similar gait pattern as controls.

Hypothesis

The alterations of gait kinematics in ASD depend on the type of deformity.

Design

Prospective

Introduction

Adults with spinal deformity (ASD) are known to have spinal malalignment affecting their quality of life and walking behavior and autonomy. Radiological criteria for ASD classification are based on spinal malalignment either in the frontal (Cobb>20°) and/or sagittal plane (TK>60°, SVA>50mm, PT>25°). It is still unknown which spinal deformity component affects the gait pattern.

Methods

82 primary ASD (51±20y, 61F), age and sex-matched to 43 controls, underwent 3D gait analysis with subsequent calculation of the 3D lower limb, trunk and segmental spine kinematics as well as the gait deviation index (GDI). ASD were classified into 3 groups: 36 with sagittal malalignment (ASD-Sag: PT>25° and/or SVA>50mm), 25 with only frontal malalignment (ASD-Front: Cobb>20°) and 21 with only hyperkyphosis (ASD-HyperK: TK>60°). Kinematics were compared between groups.

Results

ASD-Sag and ASD-HyperK had a decreased ROM pelvic obliquity (6 vs. 11°) and rotation (10 vs. 12°) and a decreased ROM of knee flex/extension (54 vs. 61°) when compared to controls. However, only ASD-Sag showed a decreased ROM hip flex/extension (38 vs. 45°) and lack of knee flexion in swing (54 vs. 62°). Furthermore, only ASD-Sag exhibited a decreased walking speed (0.8 vs. 1.2m/s), cadence (98 vs. 117step/min) and GDI (80 vs. 96, all p<0.05). ASD-HyperK showed similar patterns but in a less

pronounced way. ASD-Front had similar patterns to controls. GDI, knee flex/extension and walking speed were determined by SVA and PT (adj-R2:0.28 to 0.55, fig.1).

Conclusion

Sagittal spinal malalignment seems to be the driver of gait alterations in ASD. Patients with higher SVA or PT tended to walk slower, with shorter steps in order to maintain stability with a limited flexibility in the pelvis, hips and knees. These changes were found to a lesser extent in ASD with only hyperkyphosis but not in those with only frontal malalignment, showing the importance of differentiation between ASD patients depending on the type of deformity.

Take Home Message

High SVA and/or PT, and to a lesser extent high TK, are responsible of the abnormal walking kinematics in ASD.

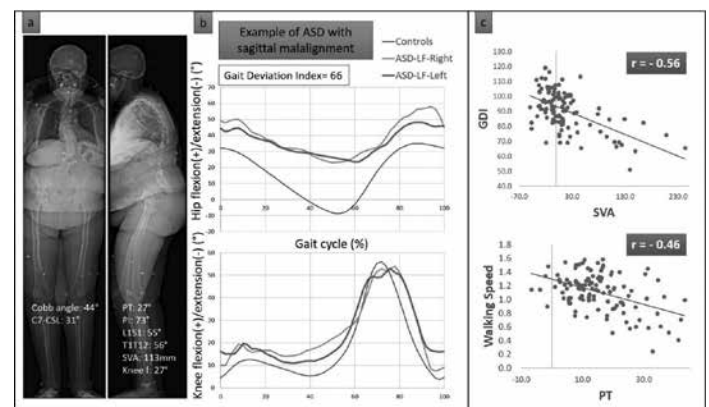


Fig.1- Altered kinematics in ASD with sagittal malalignment during walking and correlations with radiographic parameters.

47. Kyphosis and Early Disc Degeneration Induced by Paraspinal Muscle Impairment in Female TSC1mKO Mice

Hwee Weng Dennis Hey, MD; Wing Moon Raymond Lam, PhD; Kimberly Tan, MBBS; Simon Cool, PhD; Wenhai Zhuo, MD; Elisa Marie Crombie, PhD; Shih-Yin Tsai, PhD

Summary

Progression of degenerative thoracolumbar kyphosis is known to be associated with Intervertebral disc degeneration (IVD) and sarcopenia. Relationship remains unclear as human cohort studies are confounded by various comorbidities. TSC1 muscle knockout (TSC1mKO) mice have muscle specific knockout of the TSC1 inhibitor leading to chronic muscle loss and kyphosis in later stages of life cycle. Current study showed that myopathic changes on paraspinal muscle in TSC1mKO mouse can accelerate degeneration of IVD and kyphosis development in an age dependent manner.

Hypothesis

Paraspinal muscle weakness can reduce tensile force that cancel spinal load by gravity increasing compression force associated IVD degeneration and kyphosis development in TSC1mKO mice.

Design

Twenty-four female mice were divided into four groups: 9 months old (TSC1mKO n=3 & control n=7) and 12 months old

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(TSC1mKO n =7 & control n =7), respectively. Muscle myopathy, disc change and bone architecture of TSC1mKO mouse were studied and compared with age matched control.

Introduction

Progression of degenerative thoracolumbar kyphosis is known to be associated with IVD and sarcopenia. TSC1mKO mice have muscle specific knockout of the TSC1 inhibitor leading to chronic muscle loss and kyphosis in later stages of life cycle.

Methods

High resolution μ CT was used to measure thoracolumbar kyphosis, disc height, and trabecular bone architecture. Myopathic changes in the paraspinal muscle were examined by H&E stain, PGC-1 α and WGA/DAPI stain, and IVD was evaluated via FAST stain and graded for annulus fibrosus, nucleus populeus degeneration.

Results

Development of thoracolumbar kyphosis is more significant in TSC1mKO than control mice at 12 months (Fig. 1A) (TSC1mKO 83.7 ± 17.2 vs. control 52.2 ± 14.4 $p < 0.01$). Both H&E stained paraspinal muscle and WGA/DAPI section of TSC1mKO mice shows signs of myopathic alterations at 12 months, including presence of central nuclei, triangular fibres and vacuole formation (Fig. 1B) greater heterogeneity in muscle fiber size distribution (Fig.1C) and higher central nucleus formation/fiber, PGC 1 α stained muscle fiber (Fig. 1D). Vertebral bone density of lumbar spine increased in TSC1mKO mice suggesting that osteoporosis is unlikely the cause of kyphosis. Early degeneration of disc at 9 months was observed in TSC1mKO mouse lower lumbar IVD before disc height loss is detectable on μ CT(Fig.1D). At 12 months old reduction of disc height is observed at L/3 to L4/5. Deterioration of disc health was detectable in increasing fast staining disc score.

Conclusion

This study demonstrates that paraspinal muscle myopathy can accelerate the development of thoracolumbar kyphosis and cause early degeneration of the intervertebral disc.

Take Home Message

From TSC1mKO study, muscle weakness can accelerate IVD degeneration. Further study on the paraspinal muscle weakness may help us to reduce susceptibility associated with degenerative kyphosis and disc disease.

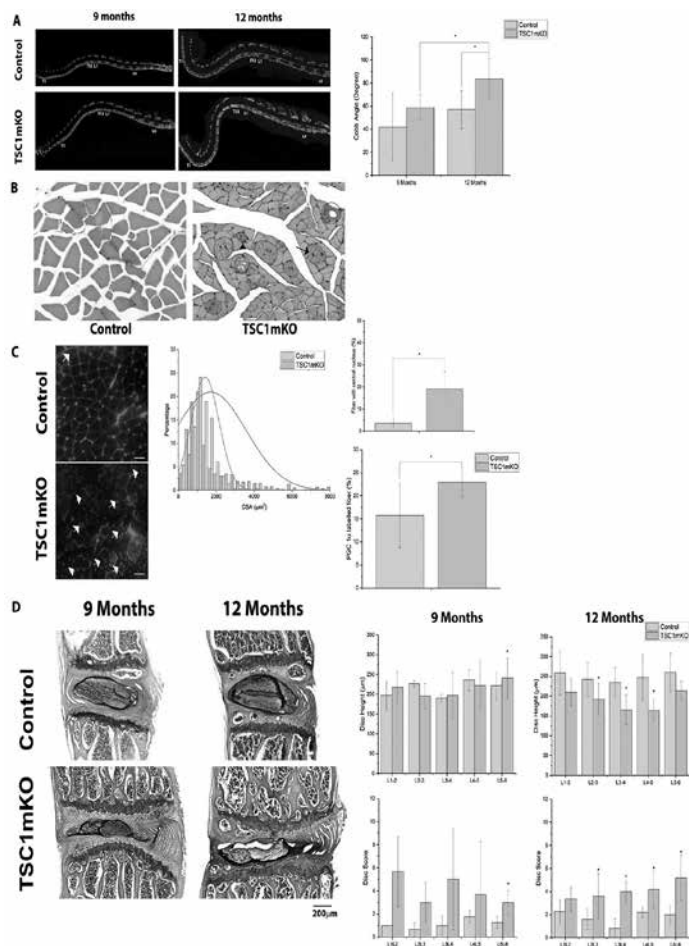


Figure 1

48. Comparison of Patient Factors (Frailty) vs. Surgical Factors (Invasiveness) for Optimization of 2-Year Cost-Utility: We Should Focus on the Patient Factors

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Summary

To optimize cost-utility in ASD surgery it is important to identify targets for improvement. We sought to compare the influence of patient factors, measured by frailty, vs. surgical factors, measured by surgical invasiveness (SI), on cost-utility. Frailty appears to be a more important determinant of 2-year cost-utility. In this analysis of 505 ASD surgeries with 2-year follow-up although increased SI leads to a higher index cost, surgeons should focus on improving modifiable patient factors to improve 2-year cost-utility.

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Hypothesis

Patient factors and surgical factors equally influence cost-utility in surgical treated ASD patients

Design

Retrospective analysis of a prospective, multicenter study

Introduction

Patient frailty is an approximation of baseline patient health status, whereas SI represents extensiveness of the intervention. There is limited data comparing the relative importance of these aggregate measures on cost-utility. The aim of this study was to assess if frailty or SI is a more important determinant of 2-year cost-utility in ASD surgery.

Methods

ASD patients with >4 level fusion and eligible for 2-year follow-up were included. Index and total episode of care (EOC) cost was calculated using Medicare's inpatient prospective payment system (IPPS) for MS-DRGs 453-460 and adjusted for inflation to 2020 real dollars. QALYs gained were calculated using baseline, 1-year, and 2-year SF-6D score with a discount rate of 3%. Cost/QALY was determined by calculating total EOC per cumulative QALY at 2 years. Patients were categorized as not-frail (NF, <0.3), frail (F, 0.3<= to <0.5), and severely frail (SF, >0.5). SI was categorized as low-SI (SI<90) and high-SI (SI>90). A generalized liner model controlling for covariates was used to estimate the association between frailty and SI on cost/QALY.

Results

DRG data for index and revision surgery was available for 505/889 patients. Mean age was 62.5+12.4 years, 76% women. 72% of patients demonstrated positive 2-year QALY gain (0.12+0.09, p<0.0001) compared to baseline. The mean cost/QALY was \$52,358. On adjusted analysis, F and SF patients compared to NF patients had significantly and incrementally higher cost/QALY compared to NF patients (p<0.001 for all) regardless of SI. However, SI was not significantly associated with cost/QALY regardless of patient's frailty.

Conclusion

Increasing levels of frailty was associated with significantly and incrementally higher values of 2-year cost/QALY in both low and high SI groups. However, within each frailty group, the high and low SI groups had equivalent cost/QALY. Frailty appears to be a better predictor of cost/QALY compared to SI.

Take Home Message

Surgeons should place more importance on modifiable patient factors compared to surgical factors to improve or optimize 2-year cost-utility in ASD surgery.

Table: Distribution of Cost-per-QALY by Frailty and Surgical Invasiveness

Surgical Factors	Patient Factors			P-value ^a	
	NF (n=142)	F (n=260)	SF (n=103)	F vs NF	SF vs NF
Low – SI (n = 255)					
n (%)	84 (32.9)	126 (49.4)	45 (17.6)	<0.0001	<0.0001
Mean Cost-per-QALY	35598.82	51446.21	67541.83		
High – SI (n = 250)					
n (%)	58 (23.2)	134 (53.6)	58 (23.2)	<0.0001	<0.0001
Mean Cost-per-QALY	36750.20	57094.64	71494.44		
P-value ^b	0.42	0.11	0.67		

a: p-value indicates pair-wise comparisons between F and NF and F and SF within the low-SI group

b: p-value indicates pair-wise comparisons between F and NF and F and SF within the high-SI group

All models are adjusted for gender and estimated blood loss.

49. Genetic Age Determined by Telomere Length is Significantly Associated with Risk of Complications in Adult Deformity Surgery Despite No Significant Difference in Chronological Age: Pilot Study of 43 Patients

Michael Safaee, MD; Jue Lin, PhD; Christopher P. Ames, MD

Summary

Risk stratification is increasingly critical in adult deformity surgery. Discrepancies between chronological and biological age may guide surgical planning and treatment algorithms. We performed a prospective study to assess the potential associations between telomere length and perioperative complications in adult spinal deformity surgery. A pilot study of 43 patients found that telomere length was significantly associated with the rate of any 90-day perioperative complications despite only mild differences in chronological age.

Hypothesis

Genetic age is associated with risk of perioperative complications in adults undergoing surgery for spinal deformity.

Design

Prospective, single-center cohort

Introduction

Telomeres are DNA-protein complexes found on the ends of chromosomes and serve an important role in protecting genomic DNA. Their shortening is an inevitable consequence of aging with telomere length demonstrating associations with common diseases of aging and mortality. There is also compelling data to suggest telomere length can provide insight towards overall health. We sought to determine potential associations between telomere length and perioperative complications in a cohort of adult patients undergoing surgery for spinal deformity.

Methods

Adult patients undergoing elective surgery for spinal deformity (scoliosis, flat back, sagittal imbalance) were prospectively enrolled. Preoperative whole blood was acquired to quantify average telomere length using quantitative PCR (qPCR), expressed as TSR (T/S ratio, i.e. ratio of telomere vs. single copy gene). Patient demographics, surgical variables, and perioperative complications (<90 days) were collected.

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Results

Forty-three patients were included. Mean age was 66 years with 31 women (53%) and mean BMI of 28.5. Mean number of levels fused was 11.3 with average length of stay of 10.4 days. Twenty-two patients (51.2%) had any medical or surgical perioperative complication. Patients with a perioperative complication had significantly lower TSR (0.712 vs. 0.813, $p=0.008$) despite mild difference in age (68 vs. 63 years, $p=0.069$). Mean difference in telomere length was 242 bp, which correlates to an estimated difference of 6-8 years of additional telomere shortening in the complication group.

Conclusion

Genetic age was significantly associated with risk of complications despite no statistically significant difference in chronological age. Larger studies are needed; however this pilot study presents compelling data to suggest a role for biological age as a risk stratification tool in adult spinal deformity surgery.

Take Home Message

Telomere length may be associated with the presence of perioperative complications in adult deformity surgery. Consideration of biological age may play a role in risk stratification.

50. Cellular Immunophenotyping in Adult Spinal Deformity Surgery: Next Step in Personalized Medicine

Annie Hess, MD; Isaiah Turnbull, MD, PhD; Ayu Frazier, PhD; *Michael P. Kelly, MD*

Summary

Current prediction models focus on readily available patient and radiographic parameters, though their significance is small and results remain variable. Patient biology, specifically the immunologic response to surgery, is associated with recovery from sepsis, surgery, and unintentional trauma. This is an unexplored area of adult spinal deformity (ASD) care. We used a systems immunology approach to measure the cellular immunophenotype of ASD surgery, finding an overall immunocompromised state. This is an area for further exploration as we develop personalized protocols.

Hypothesis

An immune signature from ASD surgery is detectable using immunophenotyping

Design

Observational Cohort

Introduction

Outcomes of ASD surgeries remain variable despite extensive work using readily available clinical and radiographic data. ASD reconstructions are a major, sterile traumatic insult and likely cause perturbations of the innate and adaptive immune systems. The variability in immune response to sterile trauma has been associated with recovery from smaller orthopedic surgeries.

Methods

Consecutive patients were approached and enrolled in this pilot study. All patients underwent ASD reconstructions of at least 7 levels and older than 18 years. Peripheral blood was drawn

before incision, 4 hours after incision and 24 hours after incision. Blood was stabilized and comprehensive flow cytometric immunophenotyping performed. Leukocyte population frequency, absolute number and activation marker expression were defined based on canonical markers. 76 immunologic features were defined and were analyzed by Hierarchical clustering and principle component analyses were used to define data structure. Changes over time were evaluated by Repeated measures ANOVA (RMANOVA) and were corrected for a 1% False Discovery Rate. Post hoc testing was by Dunn's test. P values of ≤ 0.05 were considered significant.

Results

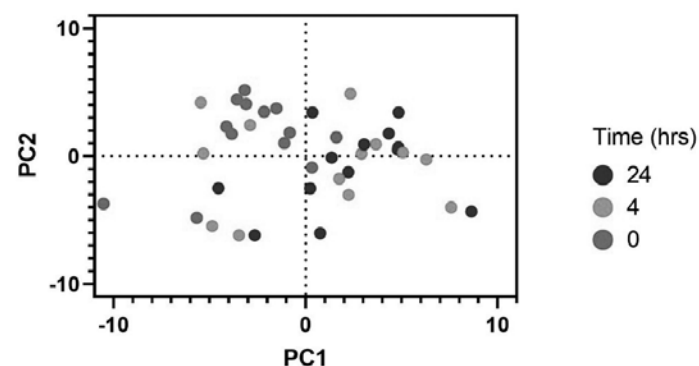
13 Patients were enrolled; 11(85%) F, 65.4yrs (+/-7.5), surgical duration 418+/-83 minutes, EBL 1928+/-1253mL. Hierarchical clustering found time from incision dependent changes in immunologic features, confirmed by principle component analyses (Figure). HLA-DR and activating co-stimulatory molecule CD86 were significantly decreased on monocyte surface, depressed at 4 hours and furthermore at 24 hours. CD4+ HLA-DR+ T cells, but not CD8+, increased over time with increased expression of PD-1 at 4 and 24 hours.

Conclusion

Despite heterogeneity of surgery and patient characteristics, we identified an immune signature associated with the sterile trauma of ASD surgery. Circulating leukocyte populations change in composition and signaling protein expression after incision and persisting to 24hr after incision. In total, these changes suggest an immunocompromised state.

Take Home Message

We have defined a common immunologic signature for ASD surgery. These results will guide future work to risk-stratify patients for complicated outcomes based upon preoperative immune status and perioperative changes.



51. Complications? Reoperations? Let's Do It Again: Decision Regret after Adult Spinal Deformity Surgery

Daniel Rubio, MD; Christopher F. Dibble, MD, PhD; Ayu Frazier, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD

Summary

MCID is a common currency in patient-reported outcomes research. Not infrequently, however, ASD surgeries do not achieve MCID in some domain. The decision regret scale (DRS) is a

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validated questionnaire assessing the appropriateness of a treatment decision. Despite high rates of complication (59%) and lack of MCID change across domains, few patients (15%) expressed DR after surgery.

Hypothesis

Rates of decision regret (DR) will not be different between patients with and without complications/reoperation/MCID.

Design

Observational cohort

Introduction

Complications and reoperation after adult spinal deformity (ASD) surgery are not uncommon. The minimum clinically important difference (MCID) is used as a threshold for success in outcomes research. The Decision Regret Scale (DRS, range 0-100) is a validated instrument that aims the "correctness" of a treatment decision from the patient perspective. The relationships between DR and complications/reoperation/poor outcomes are not known.

Methods

ASD patients with minimum 2-year follow-up completed DRS and SRS-22r. Records were reviewed for complications and revision surgeries. Responder analysis identified patients achieving MCID. Change in SRS-22 was assessed at 2 years and dichotomized according to MCID. Patients with DRS of 0-20 were defined as having "no decision regret". Rates of decision regret were compared between yes/no MCID and complication/reoperation groups. Significance was defined as $p < 0.05$.

Results

46 patients met inclusion criteria for enrollment. Mean age was 64 years with 4.3 yr fu (2.0-15.5 years). The mean DRS was 7.6 with a median score of 0; 15% (7/46) expressed DR. MCID was achieved for SRS-22 pain, activity, self-image, and sub-score in 80%, 44%, 35%, and 72%, respectively. Rates of DR were not different between those achieving MCID and those not (Pain $p=0.1$, Activity $p=0.1$, Self-Image $p=0.4$, SS $p=0.09$) There was no difference in the number of patients with DR in patients with post-operative complication (59%) or patients requiring revision surgery (54%) and those not.

Conclusion

Decision regret after ASD surgeries was uncommon despite complications, reoperations, and PRO improvement below MCID. Appropriate indicators of success are needed as well as control for cognitive dissonance.

Take Home Message

Despite a lack of MCID improvement with frequent complications, ASD patients rarely express decision regret. This fact has implications for patient selection and judging outcomes for patients, surgeons, and payors.

52. Would You Do It Again? Discrepancies between Patient and Surgeon Willingness for Adult Spine Deformity Surgery

Shay Bess, MD; Breton G. Line, BS; Renaud Lafage, MS; Christopher P. Ames, MD; Robert K. Eastlack, MD; Gregory M. Mundis, MD; Virginie Lafage, PhD; Eric O. Klineberg, MD; Alan H. Daniels, MD; Munish C. Gupta, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group

Summary

Analysis of 580 surgically treated ASD patients asked, at minimum 2 years postoperative, if they would undergo the ASD surgery again, 18.6% (n=108) indicated NO. NO had worse postoperative improvements in ODI, SF-36 and SRS-22r scores, had fewer percentages of patients reaching MCID for ODI and SRS-22r, and had more complications requiring surgery than patients willing to undergo surgery again (YES; $p < 0.05$). Surgeons were accurately able to identify YES patients (91%) but poorly identified NO patients (22%).

Hypothesis

Patients and surgeons will agree upon willingness to receive/perform the same ASD surgery again.

Design

Prospective analysis of ASD patients and surgeons participating in a multicenter study.

Introduction

ASD surgery can improve quality of life but is associated with complications and long recovery. Accordingly, if given a choice, patients may indicate they would not undergo surgery again.

Methods

Surgically treated ASD patients, prospectively enrolled into a multicenter study from 2009-2018, were asked at minimum 2 years postop, using SRS-22r question 22 if, based upon their surgical and recovery experience, they would undergo the same surgery. Surgeons were matched to corresponding patients and the surgeons asked if 1) surgeon would perform the same surgery on the patient and why/why not, 2) surgeon believed the patient would undergo the same surgery and why/why not. Patients were divided into those that indicated they would (YES) or not (NO) have same surgery. Agreement between patient and surgeon willingness for same surgery was assessed and correlations between willingness for same surgery and postop complications, deformity improvement, and PROMs evaluated.

Results

580 of 961 patients eligible for study were evaluated. NO (n=108, 18.6%) had similar levels fused, osteotomies, duration of hospital and SICU stay, and major complications as YES (n=472; 81.4%; $p > 0.05$; table). NO were younger, more frail, had more revision surgery, and worse postop PROM improvements than YES ($p < 0.05$). MCID was reached in 62- 81% of YES vs. 28-56% of NO. Patient willingness to receive surgery again varied by

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surgical institution (70% to 89%; $p < 0.05$). Surgeons accurately identified YES (91%) but poorly identified NO (22%; $p < 0.05$).

Conclusion

ASD patient willingness to undergo same surgery is important for patient counseling. Unwillingness for same surgery was associated with poor PROMs, low MCID, and complications requiring surgery. Surgeons poorly identified patients unwilling to undergo same surgery. Research is needed to understand patient experiences recovering from ASD surgeries.

Take Home Message

Approximately 20% of 580 ASD patients indicated they would not undergo surgery again, if given a choice. Unwillingness for surgery was associated with poor 2-year PROM improvements and complications.

N=580	YES N=472	NO N=108	P Value
Age (yrs)	61.6 (12.7)	58.5 (13.6)	<0.05
ASD Frailty Index	3.3 (1.5)	3.9 (1.5)	<0.05
Preop Max Cobb (deg)	41.3 (20.4)	39.5 (21.3)	>0.05
Last Max Cobb (deg)	19.6 (13.9)	19.0 (16.0)	>0.05
Preop SVA (mm)	75.0 (73.3)	71.5 (70.2)	>0.05
Last SVA (mm)	30.6 (53.6)	38.0 (55.2)	>0.05
Levels	13.3 (3.5)	13.4 (3.6)	>0.05
LOS (days)	8.1 (4.3)	8.4 (4.0)	>0.05
Major Complications (%)	34.3	32.0	>0.05
Reoperations (%)	19.5	38.0	<0.05
Preop ODI	43.9 (17.2)	48.0 (16.6)	<0.05
Last ODI	25.0 (20.5)	44.2 (16.5)	<0.05
ODI MCID (%)	66.5	32.4	<0.05
Preop SRS22 Pain	2.4 (0.8)	2.2 (0.8)	>0.05
Last SRS22 Pain	3.6 (1.0)	2.7 (1.0)	<0.05
SRS22 Pain MCID (%)	75.3	48.2	<0.05
Preop SRS22 Activity	2.9 (0.9)	2.6 (0.8)	<0.05
Last SRS22 Activity	3.6 (0.9)	2.8 (0.7)	<0.05
SRS22 Activity MCID (%)	62.6	27.8	<0.05
Preop SRS22 Self Image	2.4 (0.7)	2.2 (0.6)	<0.05
Last SRS22 Self Image	3.7 (0.9)	2.8 (0.8)	<0.05
SRS22 Self Image MCID (%)	81.3	56.5	<0.05
Preop SRS22 SSD	2.8 (0.7)	2.5 (0.6)	<0.05
Last SRS22 SSD	3.7 (0.8)	2.9 (0.6)	<0.05
SRS22 SSD MCID (%)	76.4	45.4	<0.05

53. The Impact of Unplanned Reinterventions Following ASD Surgery

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Summary

A large prospective multicentre cohort of surgical patients with adult spinal deformity (ASD) showed that unplanned reinterventions (UR) were associated with lower gains in HRQL at 5YFU. The effect did not diminish over time and was related to the number and the resolution of the associated adverse events (AE) but not invasiveness of the UR. Prevention of mechanical complications and surgical-site-infection (causing 64.9% and 15.7% of UR, respectively) may improve the effectiveness of ASD surgery.

Hypothesis

UR following surgical treatment of ASD are associated with lower gains in long-term HRQL after index surgery.

Design

Retrospective analysis of prospectively collected data.

Introduction

Despite the high incidence (17-36%) of UR following ASD surgery, their association with the long-term outcome is still poorly understood.

Methods

All patients enrolled in a prospective international multicentre ASD database, operated before March 2015, were included in the study. Adverse events (AEs) leading to UR, time of UR occurrence, UR invasiveness (blood loss, surgical time, hospital stay) and resolution of AEs were assessed. Linear models, controlling for baseline data (demographic, HRQL and radiological) and index surgery characteristics, assessed the relationship between number of UR and their invasiveness on the gain in HRQL (ODI, SRS22 and SF36) at 2YFU and 5YFU. The association between time of occurrence of UR and AE resolution vs. 5YFU HRQL gain were also investigated.

Results

361 patients [77.8% women; mean (SD) age 52.1 (19.17) y], mean 8.9 fused levels, 16.6% 3CO, 36.3% pelvic fixation, 94.6% posterior only] met the inclusion criteria. 316 (87.5%) completed 2YFU and 258 (71.5%), 5YFU. 96 (30.4%) patients with 2YFU and 73 (28.3%) with 5YFU data had respectively 165 (1.71/patient) and 117 (1.60/patient) URs (Table). Mechanical complications (64.9%) were the most common cause of UR, followed by SS-infection (15.7%). At 5YFU the AE leading to UR was solved in 67 (91.8%) patients. UR blood-loss, surgical-time and hospital stay were not associated with 5YFU HRQL. The number of UR was negatively associated with all HRQL measures, and this was constant over the years, independent of the time elapsed since UR. Mean associated reduction of HRQL gain per UR was 40.9% (range 19.1% to 66.1%). UR resulting in no resolution of the AE or resolution with sequelae had a greater impact on 5YFU HRQL scores than UR resulting in resolution of the AE. (Table)

Conclusion

UR following ASD surgery were associated with significantly lesser gains in HRQL. The association did not diminish over time, and was affected by the number, but not magnitude, of the UR. Resolution of the associated AE reduced the impact of UR.

Take Home Message

Postoperative unplanned reinterventions (UR) are negatively associated with 5YFU outcomes of ASD surgery, regardless of the time elapsed since UR. Their prevention may improve the effectiveness of ASD surgery.

Descriptives				
	2YFU data	5YFU data		
N of patients analyzed	316	258		
N of patients without reinterventions	220 (69.6%)	185 (71.7%)		
N of patients with reinterventions	96 (30.4%)	73 (28.4%)		
N of reinterventions	165, mean 1.71/patient (range 1-6)	117, mean 1.60/patient (range 1-6)		
Causes of reinterventions (proportion)				
Mechanical complications		64.9%		
Surgical site infections		15.7%		
Other complications		12.9%		
Neurologic complications		6.5%		
Index surgery vs revision surgery characteristics				
	Index	Revision	p value	
Blood Loss (ml)	1555.9	475.2	<0.001	
Surgical time (min)	312.3	173.7	<0.001	
Hospital stay (days)	13.2	14.1	0.48	
HRQL loss associated to each reintervention by follow-up year				
HRQL measure and FU time-point	(Average) HRQL gain per Index Surgery	HRQoL loss per Reintervention	Relative Impact*	p value
ODI 2Y	-10.109	4.879	48.3	0.001
ODI 5Y	-9.428	4.695	49.8	0.001
SRS22 2Y	0.659	-0.158	24.0	0.007
SRS22 5Y	0.615	-0.186	30.2	0.002
SF36-PCS 2Y	5.778	-1.104	19.1	0.16
SF36-PCS 5Y	5.349	-1.666	31.0	0.022
SF36-MCS 2Y	3.786	-2.226	58.8	0.016
SF36-MCS 5Y	3.504	-2.315	66.1	0.801
5Y HRQL loss associated with reinterventions (73 patients)				
67 (91.8%) with final status = solved		HRQoL loss per Reintervention	p value	
6 (8.2%) with final status = not solved/with sequelae				
ODI	Complication solved	+4.1	0.005	
	Complication not solved/with sequelae	+9.1	0.07	
SRS22-subtotal	Complication solved	-0.1	0.02	
	Complication not solved/with sequelae	-0.5	0.007	
SF36-PCS	Complication solved	-1.3	0.111	
	Complication not solved/with sequelae	-4.1	0.08	
SF36-MCS	Complication solved	-2.2	0.017	
	Complication not solved/with sequelae	-3.9	0.14	

54. Racial Disparities in Presenting Physical Functionality and Mental Distress Characteristics of Patients Undergoing Spine Surgery

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Summary

Patient-reported outcomes (PROs) have become increasingly emphasized in orthopedic surgery as surrogates for quality of care. The literature suggests that Black and other minority patients undergoing spine surgery are more likely to present with lower baseline PROs (bodily pain, physical functioning), worse symptom severity, lower functioning, and greater pain compared to white patients. This study showed that black patients reported worse Visual Analog Scale pain, PROMIS Mental, and PROMIS Physical scores upon presentation for spinal surgery compared to white patients.

Hypothesis

Black patients would show worse PROMIS scores for mental health and physical impairment upon indication for spine surgery.

Design

Retrospective Chart Review

Introduction

Patient-reported outcomes (PROs) have become increasingly

emphasized in orthopedic surgery as surrogates for quality of care. The literature suggests that Black patients undergoing spine surgery are more likely to present with lower baseline PROs (bodily pain, physical functioning), worse symptom severity, and greater pain compared to white patients.

Methods

Univariate and multivariate analysis of patients' demographic data along with self-reported Patient-Reported Outcome Measurement Information System (PROMIS) Global Physical Health (GPH) score, a PROMIS Global Mental Health (GMH) score, and a Visual Analog Scale (VAS) pain score at the time of presentation was performed. Surgeries examined included 1-2 segment cervical decompression and fusion, 1-2 segment cervical or thoracic laminotomy, 1-2 segment lumbar laminotomy, 1-2 level lumbar interbody fusion, and arthrodesis to correct long, spinal deformity but limited to 8 segments or fewer.

Results

Black patients had median VAS pain scores that were 16.7% higher, indicating greater pain, for cervical decompression and fusion (P= 0.047) as well as lumbar interbody fusion (P=0.0167). Black patients had median VAS pain scores that were 60% higher, for cervical/thoracic laminotomy (P=0.0005), lumbar laminotomy (P<0.0001), and arthrodesis for spinal deformity (P=0.0012) when compared to White patients undergoing the same procedure. Additionally, Black patients had lower median PROMIS GMH for cervical/thoracic laminotomy (P=0.0012), lumbar laminotomy (P=0.0195), and lumbar interbody fusion (P=0.0208). Black patients had lower median GPH scores for cervical decompression and fusion (P=0.0028), cervical or thoracic laminotomy (P=0.0024), lumbar laminotomy (P<0.0001), lumbar interbody fusion (P=0.0100), and arthrodesis to correct long, spinal deformity (P=0.0261).

Conclusion

Black patients had significantly worse PROs at time of spinal surgery referral when compared to white patients.

Take Home Message

Black patients reported worse Visual Analog Scale pain, PROMIS Mental, and PROMIS Physical scores upon presentation for spinal surgery.

Demographic Characteristics	White		Black/African American		P Value	
	n	%	n	%	P Value	P Value
Age in Years	55.02	55.02	55.27	55.27	0.928	0.928
Gender	200 (63.3%)	63.3%	158 (63.3%)	63.3%	0.928	0.928
Insurance	100 (31.0%)	31.0%	100 (31.0%)	31.0%	0.928	0.928
Operational Complication Score	0.00	0.00	0.00	0.00	0.928	0.928
HRQL	0.00	0.00	0.00	0.00	0.928	0.928
Visual Analog Scale Pain	0	0	0	0	0.928	0.928
Intervention Change	0	0	0	0	0.928	0.928
Mean PROMIS Score	10	10	10	10	0.928	0.928
Operational Change	0	0	0	0	0.928	0.928
Mean PROMIS Score	10	10	10	10	0.928	0.928
Operational Change	0	0	0	0	0.928	0.928
Mean PROMIS Score	10	10	10	10	0.928	0.928

Patient Reported Scores Stratified by Race

55. Preoperative Opioid Use Poorly Correlates with Mental Health in Adult Spinal Deformity: Time to Rethink Foregone Conclusions

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Summary

Preoperative opioid consumption, poor mental health, and lower socioeconomic status (SES) are associated with worse surgical outcomes. We hypothesized that preop MME consumption correlates with preoperative depression, anxiety, poor mental health and low SES. Prospective evaluation of 207 ASD patients demonstrated minimal to no correlations between preop MME and preop anxiety, depression and low SES. Preop MME demonstrated moderate correlations with pain, and function. The negative impacts of opioid consumption on physical measures are independent of psychosocial variables in ASD.

Hypothesis

Greater morphine milligram equivalent (MME) consumption prior to ASD surgery is associated with greater preop depression, anxiety, and lower socioeconomic status (SES).

Design

Prospective analysis of ASD patients enrolled into a multi-center, ASD study.

Introduction

Preoperative opioid consumption, poor mental health, and lower socioeconomic status are associated with worse surgical outcomes for ASD. Little data exists evaluating preop MME and preop mental health, social function, and SES in ASD.

Methods

From 2018-2020, ASD patients were enrolled into a prospective, multi-center study. Preop daily MME consumption was calculated. Preop PROMIS-Depression (DEP), PROMIS-Anxiety (ANX), Satisfaction with Social Roles (SR) and Satisfaction with Discretionary Social Activities (SSA) computer adaptive tests (CATs), SRS-22r Mental Health (MH), and VR-12 mental component summary (MCS) were calculated. Area Deprivation Index (ADI) scores were collected. MME data were log transformed and two-tailed Pearson correlation coefficients calculated. Correlation strengths were interpreted according to Cohen. Confidence intervals were created with 1,000 sample bootstrapping.

Results

207/207 patients enrolled were evaluated; mean age 61 years (18-81). 38% patients reported preop opioid consumption (n=78; mean MME 22.5mg, 1-420 mg). Preop MME did not correlate with PROMIS-ANX (p=0.07) or ADI (p=0.37). MME had small correlations with PROMIS-DEP (r=0.2, p=0.01), VR-12 MCS (r=-.2, p=0.002), and SRS-MH (r=-0.2, p=0.005). Preop MME had moderate correlations with PROMIS-PI (r=0.4, p<0.0001), PROMIS-PF (r=-0.4, p<0.0001), SRS-22r pain (r=-0.5, p<0.0001), SRS-22r function (r=-0.4, p<0.0001), PROMIS-SR (r=-0.3, p<0.0001) and PROMIS-SSA (r=-0.4, p<0.0001).

Conclusion

Preop MME showed little to no correlations with preop anxiety, depression, poor mental health or lower SES. Preop MME demonstrated moderate correlations with pain, physical and

social function. The negative impacts of opioid consumption on physical measures are likely independent of a negative impact on mental health or low SES.

Take Home Message

Analysis of preop opioid consumption in ASD demonstrated minimal correlations between MME and psychosocial factors but moderate correlations with pain/function. Opioid consumption impacts physical measures independent of mental health.

56. Using Patient Reported Outcomes to Counsel Adult Symptomatic Lumbar Scoliosis Patients (ASLS)

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Summary

PROM are an essential “vital sign” when counseling adult symptomatic lumbar scoliosis patients. Score clustering below PROM ceilings suggests a limitation to improvement possible. Patients with mild to moderate baseline disability tend to achieve similar 2yr PROM, while the most disabled patients tend to remain moderately to severely disabled. Counseling of these patients for expected outcomes is necessary to optimize treatments.

Hypothesis

PROM change after surgery is independent of baseline PROM for ASLS

Design

Observational cohort

Introduction

PROM change after ASLS surgery is often reported as mean change rather than considering baseline PROM. There may be limits to the improvement surgery can provide across pain, function, and self-image domains. The outcomes of surgical treatment are likely related to both the possibilities of surgery and baseline disability.

Methods

Operative results from the combined ASLS cohorts were examined. Score clustering after surgery investigated limits of surgical improvement. Patients were categorized according to baseline SRS-22 and ODI disability categories (mild/moderate/moderate-severe/severe) and responder analysis for static and dynamic (MCID=30% of remaining scale, SCB=50%) MCID, SCB values were performed. Best (top 5%), worst (bottom 5%), and most likely (median) scores were calculated across disability categories.

Results

171/187 (91%) Patients achieved 2yr follow-up. Patients rarely achieved the ceiling of PROM for any measure, with 33-43% of patients clustering near 4.0 for SRS domains. Patients with “severe” (<2.0) SRS-Pain and -Function scores were most likely left with moderate to severe disability (2.1-2.9), unlike patients with higher (>3.0) starting PROM values. Patients with mild SRS-Function are unlikely to improve and may worsen. Crippling (>60) ODI disability left patients most commonly left patients with mod-

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erate disability (median ODI=32). Dynamic threshold values for MCID and SCB were more sensitive to change for patients with minimal ODI disability vs. those with severe disability across all PROMs, with more patients deemed clinically improved.

Conclusion

These findings suggest that ASLS surgery on those with mild disability may worsen rather than improve across domains such as Pain and Function. The most disabled patients often had Moderate to Severe Disability at 2yrs suggesting surgery earlier in the disease process may have been warranted.

Take Home Message

Surgical treatment has limitations in terms of absolute PROM improvement and the most disabled patients frequently remain moderately to severely disabled at 2yrs after surgery for ASLS.

57. AO Adult Spine Deformity Patient Profile: A Paradigm Shift in Comprehensive Patient Evaluation in Order to Improve Patient Care

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Summary

Adult Spine Deformity (ASD) patients seek medical attention for pain, disability, spine deformity and neurological symptoms. The available classifications for ASD are purely radiological in nature which fail to address the full spectrum of the disease. The proposed ASD Patient Profile offers a systematic approach in collecting those factors influencing the outcome of ASD management in a uniform comprehensive manner.

Hypothesis

Each patient of ASD presents with unique combination of pain, disability and risk factors along with a radiological deformity and classification system should be able to capture all the components.

Design

International Modified Delphi study.

Introduction

The available classifications of ASD are predominantly radiological in nature. A comprehensive patient profile that captures full picture of ASD patients in uniform and organised manner is lacking. Purpose of this study was to propose a multimodal comprehensive ASD patient profile.

Methods

Part 1: Development of prototype of patient profile: Data from the Core Outcome Study on Scoliosis (COSSCO) by Scoliosis Research Society (SRS) was categorised into a conceptual framework. Part 2: Modified Delphi study: 51 panellists participated in a four round iterative process including a face-to-face round. Part 3: Pre-test validation: Content validity and usability were evaluated quantitatively. and usability survey with Likert scale for agreement was conducted.

Results

The developed profile consisted of four domains i.e. 1. General health with demographics and comorbidities, 2. Spine-specific health with spine related health and neurological status, 3. Imaging with radiographic and MRI parameters and 4. Deformity type. Each domain consisted of one or two components with various factors and their respective measuring instruments. All the domains were designed as individual drivers of decision making without any hierarchy. The developed Patient Profile was found to have an excellent content validity (I-CVIR 0.78-1.00; Ave-CVI 0.92), appropriateness, relevance and usefulness.

Conclusion

The profile offers a systematic approach in collecting those factors influencing the outcome of ASD management. Different combination of these factors could indicate the severity of the disease, help in patient counselling, facilitate shared decision making and post-operative risk stratification. Identifying groups of ASD patients with similar profiles can potentially help in designing decision making pathways.

Take Home Message

Patient Profile is the first attempt towards comprehensive evaluation of ASD patients and offers a uniform systematic approach in collecting factors influencing the outcome of ASD management

AO
SPINE
AO Spine Adult Spinal Deformity Patient Profile

Demographics	Comorbidities	Health Status	Neurologic Status	Radiograph	MRI	Type of Deformity	Etiology
Age (in 10's) Gender Gender Social Support	Chronic respiratory disease Diabetes Rheumatoid Arthritis Hypertension Atrial fibrillation Chronic kidney disease Chronic liver disease Chronic heart failure Chronic obstructive pulmonary disease Chronic pain Chronic alcohol use Chronic tobacco use Chronic substance use Chronic illicit drug use	Functional Ability Back Pain Lip Pain HRQoL Physical Status Frailty	Neurological Impairment Lag Pain	Cervical Curve Thoracic Curve Lumbar Curve Global Spine Balance (Global Tilt) Largest Cobb Angle (Degree) Distraction (degrees) Alar point (C5-C6, C7-T1) Sagittal Plane Coronal Plane Transverse Plane Sagittal Plane	Neural Compression Distraction Largest Cobb Angle (Degree) Distraction (degrees) Alar point (C5-C6, C7-T1)	Distraction Global Spine Balance (Global Tilt) Largest Cobb Angle (Degree) Distraction (degrees) Alar point (C5-C6, C7-T1)	Chronic respiratory disease Diabetes Rheumatoid Arthritis Hypertension Atrial fibrillation Chronic kidney disease Chronic liver disease Chronic heart failure Chronic obstructive pulmonary disease Chronic pain Chronic alcohol use Chronic tobacco use Chronic substance use Chronic illicit drug use

LEGEND
 - indicates space for free response text number
 * indicates multiple-choice question. Please only tick one from the column.
 # indicates multiple-choice question. Please tick all that apply. Circle only.
 ~ These items are not yet fully validated measurement instruments in the literature.
 Please do not base on your own clinical opinion.

AOSpine Adult Spine Deformity Patient Profile

58. FDA IDE Study of Decompression and Paraspineous Tension Band Stabilization vs. TLIF for Degenerative Spondylolisthesis: 24-month Outcomes in 98 Patients

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Summary

Interim results in 98 subjects with 24m follow-up, from an FDA study comparing decompression and paraspineous tension band stabilization vs. TLIF show significant clinical improvement in both groups.

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Hypothesis

Decompression and paraspinous tension band (D+PTB) have similar outcomes compared to decompression and fusion (D+F) for symptomatic degenerative spondylolisthesis (DS), with lower perioperative morbidity.

Design

Interim analysis of 24m outcomes from FDA IDE trial of D+PTB vs. D+F

Introduction

DS is commonly treated with D+F. The PTB is an investigational device designed to provide sagittal plane stability without fusion for patients with DS undergoing decompression.

Methods

Patients with Grade 1 DS were enrolled in the FDA IDE study comparing D+PTB and D+F (NCT03115983). Operative and patient-reported outcomes were recorded at baseline and 6w, 3m, 6m, 12m and 24m follow-up. All prospectively enrolled patients in the IDE study who reached 24m follow-up were included in this analysis.

Results

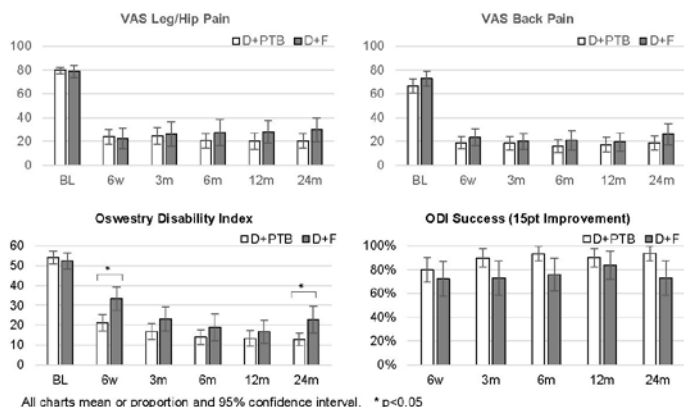
98 patients (61 D+PTB/37 D+F) reached 24m follow-up and were included in this analysis. Mean characteristics of D+PTB/D+F groups were: age 64.5/63.9yrs; BMI 28.3/29.3. Mean operative outcomes for D+PTB/D+F were: OR time 110/171 min; EBL 41/245 mL; LOS 0.7/3.3 nights (all $p < 0.01$). There were no significant differences between groups in VAS or ODI scores at baseline. Both groups demonstrated improvement in VAS and ODI scores at 24m (all $p < 0.01$). The D+PTB group had significantly lower ODI outcomes at 6w and 24m follow-up. During the 24m follow-up, 3 D+PTB patients (4.9%) and 5 D+F patients (13.5%) had reoperations at index or adjacent segments.

Conclusion

Patients receiving D+PTB and D+F both demonstrated significant clinical improvement through 24m follow-up. The D+PTB group had shorter procedure time, less blood loss and shorter length of stay vs. the D+F group, and lower ODI during initial recovery and at 24m follow-up. If these results are durable and generalizable, the D+PTB may offer an alternative to fusion for patients with symptomatic DS. Further study will include longer-term follow-up with propensity score-selected and matched subgroups

Take Home Message

Decompression and paraspinous tension band may represent a promising alternative to lumbar fusion for symptomatic degenerative spondylolisthesis, with shorter procedure time lower blood loss and shorter hospital stay.



Patient reported outcomes for D+PTB and D+F

59. The Longitudinal Impact of Intervertebral Disc Distraction on Disc Health: A Preliminary, In Vivo Study Using Magnetic Resonance Imaging in a Rabbit Model

Hwee Weng Dennis Hey, MD; Wing Moon Raymond Lam, PhD; Kimberly TAN, MBBS; Wenhai Zhuo, MD; Kim Cheng Tan, MS; XiaFei Ren, MD, PhD; Hee Kit Wong, MBBS, FRCS

Summary

Intervertebral disc (IVD) degeneration is one of the commonest causes of low back pain. Pharmaceutical and physical treatment modalities provide only symptomatic relief, while surgical options often predispose to accelerated IVD degeneration at the index or adjacent levels. Potentially therapeutic effects of IVD distraction have yet to be demonstrated over a prolonged period. MRI-compatible rabbit IVD distraction model showed that IVD distraction can attenuate IVD dehydration, improve nutrient diffusion and vascularity, as well as maintain NP integrity in degenerated IVD.

Hypothesis

We hypothesize distraction on degenerated IVD can promote disc health by increase vascularity in a time dependent manner.

Design

Seven adult male rabbits were divided into control (n=2), short (n=2) and long-term (n=3) distraction treatment groups.

Introduction

IVD degeneration is one of the commonest causes of low back pain. Pharmaceutical and physical treatment modalities provide only symptomatic relief, while surgical options often predispose to accelerated IVD degeneration at the index or adjacent levels. Potentially therapeutic effects of IVD distraction have yet to be demonstrated over a prolonged period.

Methods

Six weeks following IVD degeneration induced by stabbing, treatment group rabbits were implanted with titanium-PEEK IVD distraction devices. IVD hydration, height and nutrient diffusion were evaluated by MRI at 7 and 15-weeks post-distraction treatment. After last MRI scan, the animals were euthanized, treated and adjacent spine segments were assessed via high-resolution μ CT and histology. Control group rabbits underwent the same protocol without IVD distraction treatment.

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Results

The distraction device was MRI-compatible and generated negligible artefacts. T2-STIR imaging showed that IVD hydration declined faster in the control group than in the distraction treatment groups. All stabbed IVDs sustained loss of height, which did not improve despite short- or long-term distraction treatment. Nutrient diffusion was improved in the long-term distraction group as compared to the control. Porosity data on μ CT showed that IVD distraction increased its vascularity. Histological examination showed that nucleus pulposus (NP) integrity was maintained in both short and long-term treatment groups.

Conclusion

The novel MRI-compatible IVD distractor enabled the longitudinal study of IVD health in vivo over a 15-week period. IVD distraction can attenuate IVD dehydration, improve nutrient diffusion and vascularity, as well as maintain NP integrity in degenerated IVD. IVD distraction therapy may have a significant role to play in improving the IVD microenvironment to make it conducive for regeneration.

Take Home Message

Long term IVD distraction can attenuate IVD dehydration, improve nutrient diffusion and vascularity and maintain NP integrity in degenerated IVD probably via improving the IVD microenvironment for regeneration.

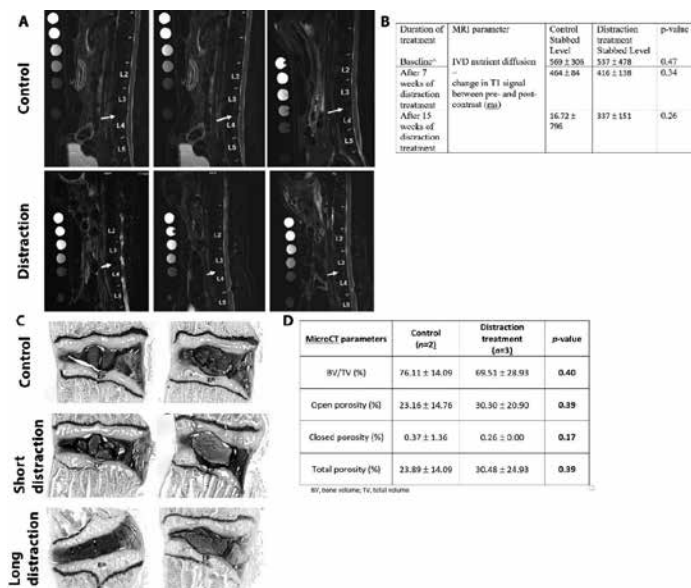


Fig 1

60. Impact of the Flexibility of Coronal Deformities on Low Back Pain and Disc Degeneration in Adult Patients Nonoperatively Treated for Adolescent Idiopathic Scoliosis with Thoracolumbar/Lumbar Curves

Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD

Summary

In adults who were nonoperatively treated for adolescent idiopathic scoliosis (AIS) with thoracolumbar/lumbar (TL/L) curves,

reduced flexibility of L4/5 disc wedging was significantly associated with increased low back pain (LBP) and disc degeneration, independent of the magnitudes of TL/L curves and disc wedging. Our findings indicate that maintaining or improving flexibility of L4/5 disc wedging might be a target for preventing or treating LBP related to AIS with TL/L curves.

Hypothesis

The flexibility of TL/L curves and related deformities has positive effects on LBP and disc degeneration in adulthood.

Design

Subanalysis of a longitudinal follow-up study.

Introduction

Although several radiographic predictors of LBP in adult scoliosis have been reported, the impacts of the flexibility of TL/L curves and related deformities remain unclear.

Methods

We included 47 adult patients (1 man and 46 women; mean age, 40.5 years) who were nonoperatively treated for AIS with TL/L curves. The mean duration of follow-up after skeletal maturity was 26.6 years (16–40 years). The magnitude and flexibility of deformities, including TL/L curves and lumbar disc wedging, were measured in standing and supine side-bending radiographs, respectively. Lumbar disc degeneration on MRI was calculated as the average Pfirrmann grade from L1/2 to L5/S1. LBP was evaluated using the VAS, the Oswestry Disability Index (ODI), SRS-22, and SF-36. Measurements obtained from radiographs were correlated with scores for LBP and disc degeneration using Pearson's correlation (unadjusted, r) and Pearson's partial correlation (adjusted, r') coefficients.

Results

The average magnitude and flexibility of TL/L curves was 49.0° and 56%, respectively. The magnitudes of the TL/L curves and disc wedging significantly correlated with LBP ($|r|=0.29-0.42$, $p<0.05$). The flexibility of TL/L curves and disc wedging significantly correlated with LBP and disc degeneration ($|r|=0.30-0.50$, $p<0.05$). After controlling for the magnitudes of TL/L curves and disc wedging, the flexibility of the L4/5 disc wedging remained significantly correlated with the SRS-22 pain score ($r'=0.46$), ODI (-0.31), and lumbar disc degeneration (-0.44 ; $p<0.05$).

Conclusion

Reduced flexibility of L4/5 disc wedging was associated with increased LBP and disc degeneration, independent of the magnitudes of coronal deformities. Maintaining or improving the flexibility of L4/5 disc wedging might be beneficial for preventing or treating LBP related to AIS with TL/L curves.

Take Home Message

In patients who were nonoperatively treated for AIS with TL/L curves, maintaining or improving the flexibility of L4/5 disc wedging might reduce LBP and disc degeneration.

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	SRS-pain		LBP-VAS		ODI		Disc degeneration	
	r	r'	r	r'	r	r'	r	r'
TL/L curve								
Cobb angle	-0.33*	-	0.42*	-	0.31*	-	0.20	-
Flexibility	0.30*	0.10	-0.18	0.21	-0.25	-0.06	-0.22	-0.20
Disc wedging								
L3/L4 disc								
Wedging angle	-0.11	-	0.19	-	0.03	-	-0.09	-
Flexibility	-0.13	-0.28	0.07	0.25	0.13	0.24	0.20	0.26
L4/5 disc								
Wedging angle	-0.22	-	0.34*	-	0.22	-	0.03	-
Flexibility	0.53 [†]	0.46 [†]	-0.38 [†]	-0.27	-0.38 [†]	-0.31 [†]	-0.35 [†]	-0.44 [†]
Max wedged disc								
Wedging angle	-0.15	-	0.29*	-	0.15	-	0.33*	-
Flexibility	0.06	-0.09	-0.07	0.15	0.01	0.14	-0.13	-0.09

[†]p<0.05. *p<0.01. †p<0.001.
r: Pearson's correlation (unadjusted) coefficient.
r': Pearson's partial correlation (adjusted) coefficient (r'), adjusted for magnitude of deformities.

61. Autograft Viability and Cellular Contribution to Fusion

Gregory M. Mundis, MD; Jeremy Lombardo, PhD; Nick Russell, PhD; Jiawei He, PhD; Frank Vizesi, PhD

Summary

Autograft has been considered the gold standard graft material for spinal fusion, purportedly due to its osteogenic properties. The bone forming potential of autograft may derive from contributions of adherent cells and/or the non-adherent cellular milieu (i.e. bone marrow cells) of the graft. This study tested viable autograft, partially devitalized autograft (non-adherent cells removed), and devitalized autograft (non-adherent cells removed, adherent cells lysed) in a rabbit model. Cell viability changes were also evaluated in harvested bone left out to dry.

Hypothesis

Both viable and partially devitalized autograft outperform devitalized autograft in a rabbit spinal fusion model. Autograft cell viability is adversely affected in ambient conditions.

Design

Controlled study

Introduction

Autograft consists of adherent and non-adherent cellular components in a cancellous bone scaffold. The contribution of each component to bone healing in spinal fusion is not well understood. During surgery, autograft may be left out on the back table for prolonged periods of time, which may adversely affect osteogenic potential. Furthermore, there has been recent controversy over the role of cells in allogeneic cell bone matrices, which begs additional questions about the role of cells in autograft.

Methods

In vivo: posterolateral spinal fusion was performed using the Boden model in 24 NZ white rabbits. N=8 were assigned each to viable, partially devitalized, or devitalized iliac crest. Partially devitalized and devitalized grafts were rinsed with saline to remove non-adherent cells. Devitalized graft was additionally freeze/thawed to lyse adherent cells. Fusion was assessed at 8 wks via manual palpation and microCT. In vitro: cancellous bone was harvested in 1-4mm pieces from fresh sheep or cow femurs,

rinsed with saline, then left out to dry to mimic intraoperative conditions. Cell viability was assayed using Alamar Blue at baseline, 1, 2, and 4 hrs.

Results

Spinal fusion by manual palpation was 7/12 (58%) for viable vs. 12/14 (86%) for partially devitalized autograft, which was not statistically different. Both fusion rates were significantly higher than 0/16 (0%) for the devitalized group (p < .001). 3 animals (6 fusion masses) died after surgery and were not replaced. In vitro bone cell viability reduced by 37% at 1 hr, 54% at 2 hr, and 63% at 4 hr when bone was left out dry (p < .001).

Conclusion

Autograft with viable cells had significantly higher fusion rates vs. devitalized autograft. Thus, the cell component of autograft is important for spinal fusion. Similar results for viable and partially devitalized autograft suggest that adherent graft cells are the more important cellular component for fusion in the rabbit model. In vitro bone cell viability rapidly declines when left out dry.

Take Home Message

Adherent autograft cells are important for fusion performance, and their viability rapidly decays when left out on the back table.

62. Perioperative Complications of Total En Bloc Spondylectomy (TES) for Spinal Tumors

Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noriaki Yokogawa, MD; Takaki Shimizu, MD; Makoto Handa, MD; Ryohei Annen, MD; Yohei Yamada, MD; Motoya Kobayashi, MD; Hiroyuki Tsuchiya, PhD

Summary

Major and minor perioperative complications after TES were observed in 39.7% and 27.4% of the patients respectively. The amount of bleeding in the lumbar lesion and respiratory complication in the thoracic lesion were statistically higher after TES.

Hypothesis

The characteristics of perioperative complications after TES were different depending on the extent and level of the tumor resection.

Design

Retrospective single-center study

Introduction

Major and minor perioperative complications after TES were observed in 39.7% and 27.4% of the patients respectively. The amount of bleeding in the lumbar lesion and respiratory complication in the thoracic lesion were statistically higher after TES.

Methods

We retrospectively reviewed 307 patients who underwent TES. The subjects comprised 164 men and 143 women with a mean age of 52.9 years at the time of surgery. The main lesion was located in the thoracic spine in 213, and lumbar spine in 94 patients. There were 97 patients who underwent TES for more than 2 consecutive vertebrae.

Results

Major and minor perioperative complications were observed in 122 (39.7%) and 84 (27.4%) patients respectively. The breakdown of complications was as follows: bleeding more than 2000cc in 60 (19.5%) patients, hardware failure 82 (26.7%), neurologic 46 (15.0%), SSI 23 (7.5%), wound dehiscence 16 (5.2%), CSF leakage 45 (14.7%), respiratory 52 (16.9%), cardiovascular 11 (3.6%), digestive 19 (6.2%), and mortality within 2 months 4 (1.3%). The total number of complications per surgery were 1.01 ± 1.0 in single group and 1.56 ± 1.2 in more than 2 resection group. Cardiovascular, respiratory complication and hardware failure were statistically higher in more than 2 resection group. The amount of bleeding in lumbar lesion and respiratory complication in the thoracic lesion were statistically higher. Multivariate analysis showed combined approach and more than 2 vertebral resections were significant independent factors.

Conclusion

The characteristics of perioperative complications after TES were different depending on the extent and level of the tumor resection. In addition to preoperative clinical and pathological factors, it is also important to consider these factors in cases of en bloc resection for spinal tumors.

Take Home Message

The characteristics of perioperative complications after TES were different depending on the extent and level of the tumour resection.

64. Incidence of Post-Spinal Surgery Pulmonary Emboli Over a 12-Year Period in a Specialist Tertiary Referral Centre

Puneet Tailor, MBBS; Hannah Norman, Medical Student; Egidio Da Silva, MD; Jwalant S. Mehta, FRCS (Orth), MCh (Orth), MS (Orth), D Orth

Summary

This study sought to measure the rate of post-op pulmonary emboli in post-op spinal patients treated with mechanical prophylaxis. Our sample of 25,063 patients shows very low incidence of PE of 0.028% in post-operative patients diagnosed with CTPA and intra-operative mortality from PE of 0.012%.

Hypothesis

PE risk in post-op spinal patients is less than 1:1000 on CTPA

Design

Retrospective observational study

Introduction

Spinal surgery is believed to have a high risk of VTE. CT pulmonary angiogram (CTPA) provides definitive diagnosis of PE prior to therapeutic anticoagulation. The Royal College of Radiologists (RCR) guidelines state judicious CTPA use should diagnose PE in >15%. Our aim was to identify the incidence of PE based on CTPA in post-op spinal patients.

Methods

We reviewed 25,063 patient records between 2007-2018. 43 patients underwent CTPA for suspected PE. Length of post-op immobility and documented symptomatic indications for CTPA

were examined.

Results

7/43 patients had confirmed PE on CTPA (16.7%). A further 3 patients had post-mortem diagnosis of intra-operative PE. All patients had compression stockings and sequential pneumatic calf pumps post-operatively. The incidence of confirmed PE on CTPA was 0.028% (figure 1A). We found prolonged post-operative immobility (median 5.5-days) in patients with PE vs. 3-days in negative scans. The commonest symptoms prompting CTPA were dyspnoea, immobility >3 days post-op, and chest pain. Dyspnoea had the highest sensitivity of 86%, specificity of 46%, and negative predictive value (NPV) 94%. Dyspnoea in combination with chest pain and immobility raised specificity to 88% with PPV 50% and NPV 91%.

Conclusion

The incidence of PE in post-op spinal patients treated with mechanical prophylaxis and early mobilisation is 40:100,000 and mortality from PE is 12:100,000. Dyspnoea and post-op immobility are sensitive symptoms for suspicion of PE.

Take Home Message

The incidence of PE in post-op spinal patients treated with mechanical prophylaxis is 40:100,000 and mortality is 12:100,000. Dyspnoea and post-op immobility are sensitive symptoms for suspicion of PE.

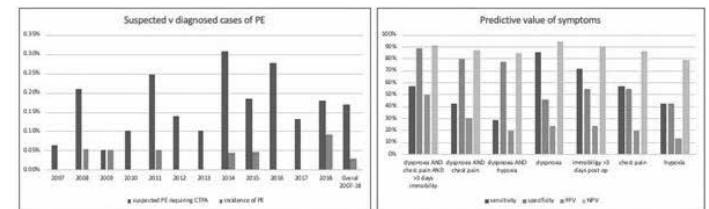


Figure: A – Incidence PE based on CTPA. B – predictive value of common symptoms.

65. Early Postoperative Anticoagulation after Spinal Fracture Surgery Decreases Venous Thromboembolism Rates

Khaled Taqhlabi, MBBS; Douglas C. Burton, MD; Brandon B. Carlson, MD; Robert Sean Jackson, MD; Joshua Bunch, MD; Robert Winfield, FACS

Summary

Anticoagulation within 72 hours of spinal fracture fixation surgery decreased VTE rates with no increase in bleeding complications compared to initiation 10 days or longer after surgery.

Hypothesis

Initiating VTE anticoagulation within 72 hours of spinal fracture surgery may decrease VTE rates without increasing complications.

Design

Retrospective cohort study

Introduction

Prophylactic anticoagulation effectively lowers venous thromboembolism (VTE) after operative treatment of spinal fractures. Optimal initiation has not been fully described. Early anticoagu-

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lation has been presumed to increase bleeding and wound complications. In 2017, our institutional protocol began initiating VTE chemoprophylaxis 72 hours after operative spinal fixation. The purpose of the study was to compare VTE rates and bleeding complications for EARLY (within 72h) vs. LATE (no prophylaxis or after 10-14 days) chemoprophylaxis timing after spinal fracture operative intervention.

Methods

A review of patients treated for spinal fractures that received anticoagulation chemoprophylaxis administration between May 2015 and June 2019 were studied. Chemoprophylaxis initiation timing (EARLY vs. LATE) was the primary grouping variable. Patients with GCS<13 or evidence of intracranial or intraspinal bleed were excluded. Demographics, injury mechanisms, operative procedures, timing of administration of VTE prophylaxis, Injury Severity Score (ISS) and Spine Abbreviated Injury Scale (AIS), and complications including VTE and bleeding complications were collected. Predictors of VTE and bleeding complications were identified using a bivariate analysis.

Results

One-hundred patients (74M, 26F) met inclusion criteria. Median age was 54 yrs, and median ISS was 13. EARLY had 68 patients and LATE had 32. Ten patients developed VTE (7 LATE, 3 EARLY, $P=0.007$). Three patients developed bleeding complications, and all occurred in the LATE group ($P=0.010$). ISS ($P=0.024$) and AIS ($P=0.017$) also correlated with increased VTE rate.

Conclusion

Chemoprophylactic anticoagulation within 72 hours in surgically treated spinal fracture patients reduces VTE rates without increasing complications. VTE prophylaxis can be initiated at 72 hours following spine fixation to decrease postinjury morbidity and mortality in this high-risk patient population.

Take Home Message

Large, multicenter prospective studies are required to further define the efficacy and safety of an early pharmacological VTE prophylaxis strategy in this high-risk patient population.

66. Biomechanical Characterization of Common Thoracolumbar Adult Spinal Deformity Correction Constructs: An Implication for Proximal Junctional Kyphosis Risk Assessment

Robert Koffie, MD, PhD; Bernardo de Andrada, MD; Jennifer N. Lehrman, MS; Brian P. Kelly, PhD; Juan S. Uribe, MD; Jay D. Turner, MD

Summary

We perform a biomechanical study in human cadaveric specimens looking at the range of motion (ROM) on flexion, extension, lateral bending, and axial rotation aimed at determining which correction constructs are associated with increased ROM at the proximal adjacent free level (PAFL). We find that constructs involving anterior column realignment (ACR) have lower ROM at the PAFL when compared to constructs with three column osteotomies. Use of 4 rods and large interbody support mitigate this effect in 3-column osteotomy constructs.

Hypothesis

Different adult spinal deformity correction constructs affect the ROM at the PAFL differently. Constructs with increased ROM at the PAFL may increase the risk of proximal junctional kyphosis (PJK)

Design

Biomechanical study on human cadaveric specimen

Introduction

PJK is a common complication after complex adult spinal deformity correction. The biomechanical basis for PJK is not completely understood, but pathologic motion at the PAFL of constructs likely plays a role. We studied the biomechanical profiles of different deformity correction constructs looking at ROM of the PAFL in flexion, extension, axial rotation and lateral bending.

Methods

Standard nondestructive flexibility tests (7.5 Nm) were performed on 21 cadaveric specimens: 14 had PSO and 7 had ACR as the prime approach for correction. ROM at the PAFL was analyzed using repeated-measures analysis of variance and 2-tailed paired Student t-test ($P<0.05$ was considered significant).

Results

ACR constructs have a lower ROM on flexion at the PAFL compared to constructs with PSO (1.0 vs. 1.3 degrees, $P<0.01$). Use of lateral lumbar interbody fusion (LLIF) adjacent to PSO and 4 rods were more effective at limiting ROM at the PAFL when compared to using transforaminal interbody fusion (TLIF) and 2 rods in correction constructs with PSO (1.1 vs. 1.3 degrees, $P<0.01$). Use of 2 screws to anchor ACR interbody further decreases ROM at the PAFL on flexion, but when the ACR 2-screw construct with 4 rods was compared to the 2-rod construct with the same ACR condition there was no significant difference. There was also no statistical difference in ROM at the PAFL on extension, lateral bedning, and axial rotation in all constructs evaluated.

Conclusion

ACR constructs limit ROM on flexion at the PAFL compared to PSO constructs, but if 3-column osteotomy is necessary, use of 4 rods and LLIF adjacent to osteotomy site mitigates excessive motion at the PAFL and may decrease risk for PJK.

Take Home Message

ACR constructs limit motion at the PAFL when compared to PSO constructs. Use of 4 rods and large interbody support (LLIF instead of TLIF) mitigate this effect in PSO constructs.

67. Biomechanical Investigation of Long Spinal Fusion Model Using the Three-Dimensional Finite Element Analysis

Norihiro Oku, MD; Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noriaki Yokogawa, MD; Hiroyuki Tsuchiya, PhD

Summary

We examined the mechanical stress (MS) changes generated according to the different fusion segments, type of implants, and sagittal alignment in the long spinal fusion model using three-dimensional finite element analysis (3D-FEA). In all models, the MS

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to the lower lumbar body, sacrum, and L4-S2AI (S2 alar iliac) implants was high. Focusing on the difference in sagittal alignment, the MS of sagittal vertical axis (SVA) 100 mm was 4–6 times that of 0 mm.

Hypothesis

We hypothesized that MS in the long spinal fusion model using 3D-FEA differs depending on the different fusion segments, type of implants, and sagittal alignment.

Design

Finite element analysis

Introduction

Long instrumentation for adult spinal deformity (ASD) with osteoporosis has increased. However, the ideal fusion segments and the appropriate implant type for long spinal instruments remain unclear in the biomechanical model. This study aimed to examine MS changes generated by different fusion segments, type of implants, and sagittal alignment in long spinal instrumentation using 3D-FEA.

Methods

We obtained a finite element (FE) model from the first thoracic vertebra to the pelvis based on the CT images of an osteoporotic patient. FE models of the two types of fusion segments (T2-S2AI and T10-S2AI) was constructed. Furthermore, we analyzed the two types of implants (pedicle screw or transverse hook) in the upper instrumented vertebra (UIV). We restrained the acetabulum and loaded 1,200 N according to each upper surface of the vertebral body. The load direction assuming the SVA 0 mm, 50 mm, and 100 mm was investigated.

Results

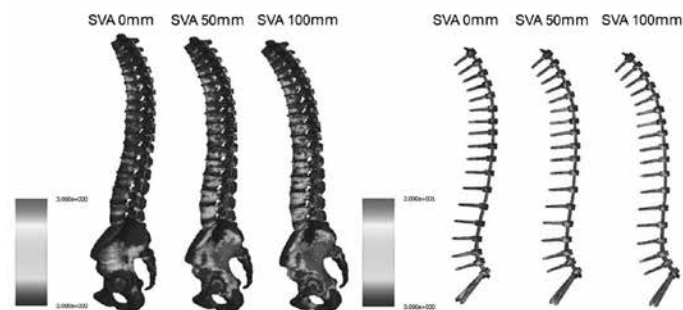
In all models, the MS to the lower lumbar body, sacrum, and L4-S2AI implants was high. The MS in the UIV did not differ among the two types of implants. In the T2-S2AI models, the MS of the SVA 100 mm model was four times that of 0 mm. In the T10-S2AI models, the MS of the SVA 100 mm model was six times that of 0 mm.

Conclusion

The MS to the lower lumbar body, sacrum, and L4-S2AI implants was high in all models. Focusing on the difference in sagittal alignment, the MS of the SVA 100 mm model was higher than that of 0 or 50 mm.

Take Home Message

In long spinal instrumentation for ASD using the 3D-FEA, the MS to the lower lumbar body, sacrum, and L4-S2AI implants was high in all models.



68. Telehealth: Comparison of Physical Exam between Telehealth Visits and In-Person Visit for Patients with Spine Pathology

Hershil Patel, BS; Zoe Norris, BFA; Kimberly Ashayeri, MD; Nicole Mottole, BS; Eaman Balouch, MD, PhD; Ethan Sissman, MD; Constance Maglaras, PhD; Charla R. Fischer, MD; Themistocles S. Protopsaltis, MD; Aaron J. Buckland, MBBS, FRCSA; *Kola Jegede, MD*

Summary

There is limited data on differences in telehealth physical exam findings when compared to in person physical examinations in the same patient. A retrospective study of 296 patients demonstrates TV found higher rates of false positives (FP) and negatives (FN) in tibialis anterior (TA) strength, Straight leg raise test (SLR) test and tandem gait testing. Hand intrinsic and grip strength were found to have deficits in 15.6 % and 12.7% of patients in OV but not documented in TV.

Hypothesis

TV examinations will underestimate subtle weakness and reflex abnormality.

Design

Single-center retrospective cohort study

Introduction

History, physical exams (PE) and imaging are used to diagnose spine pathology. Further analysis is required to determine differences in TV and OV examinations and the clinical significance of these differences.

Methods

Included: Patients, with spine pathologies, who received an initial TV and a subsequent OV Post-March 2020. Excluded: Patients who received telehealth and office visit by two separate providers, providers outside of the spine service, or patients with an initial office visit in the timeframe. The cohort was further analyzed by pathologies. Motor exam results were categorized dichotomously as “full-strength: antigravity” or deficit and other physical exam findings were classified as abnormal and normal. FP were classified as abnormalities detected only in TV and FN were categorized as abnormalities detected only in OV. Relationships between the TV and OV exam findings were established using chi-squared analyses($\alpha=0.05$).

Results

296 patients (247 surgical and 49 non-surgical) met these criteria. The total cohort’s average age is 56.5, BMI=28.6, and 50% female. 8.9% of lumbar radiculopathy (LR) patients’ TV (w/ 5.1% being FP) had a recorded a TA deficit, but 16.5% reported deficit in OV($p=0.048$). Thus, TV either missed or falsely recorded 17.7% TA deficits. 0% deficits were recorded in both handgrip (HG) and hand intrinsic (HI) in myelopathy (MY) TV, but 12.5% and 15.6% had reported HG and HI deficits in OV, respectively. 21.9% MY (w/ 6.3% FP) patients’ TV reported an abnormal tandem gait (TG), but in and 31.3%($p=0.009$) reported abnormalities. 16.5% LR (w/ 5.1% FP) reported abnormal straight-legged raise in TV but 13.9% had abnormalities in OV ($p<0.001$). 8.9% LR TVs.

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reported abnormalities in extremity sensations and 8.9% LR OV reported abnormalities; however, there were 6.3% FP and 6.3% FN (p=0.046).

Conclusion

TA, TG, SLR, and motor sensation have the highest rates of FP and FN in the spine telehealth examination. There should be a low threshold for an OV in the setting of equivocal testing.

Take Home Message

During a pandemic, surgeons rely on TV history/examination and imaging to make a diagnosis. OV is appropriate in cases in which an accurate TA, TG, SLR, and ES is required.

Table 1. Comparison of Motor/Physical Exam Results in Telehealth and In-Person Visits for Myelopathy and Radiculopathy Patients

	Lumbar Radiculopathy: Telehealth Motor Exams vs. In-Person Motor Exams						Myelopathy: Telehealth Motor Exams vs. In-Person Motor Exams					
	Telehealth (%)		In-Person (%)		Agreement (%)	p-value	Telehealth (%)		In-Person (%)		Agreement (%)	p-value
	Radiology (N=78)	Physical (N=78)	Radiology (N=78)	Physical (N=78)			Radiology (N=11)	Physical (N=11)	Radiology (N=11)	Physical (N=11)		
	Deficit Present	Deficit Present	Deficit Absent	Deficit Absent			Deficit Present	Deficit Present	Deficit Absent	Deficit Absent		
Diagnosis	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Clonus/Spasms	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Weakness	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Spasticity	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Extremity Motor	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Extremity Sensation	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%
Extremity Reflexes	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%

69. Cervical Sagittal Alignment Parameters Across Ages

Yann Philippe Charles, MD, PhD; Sebastien Pesenti, MD, PhD; Benjamin Blondel, MD, PhD; Jean-Charles Le Huec, MD; Vincent Fiere, MD; Louis Boissiere, MD; Vincent Challier, MD; Aymeric Faure, MD; Erik-André Sauleau, MD, PhD; Brice Ilharreborde, MD, PhD

Summary

An observational study on cervical sagittal alignment parameters on 2599 individuals without spinal pathology was carried out to describe their distribution and normal variation according to age (5 to 80+), gender and spinopelvic morphology (Roussouly and PI).

Hypothesis

Cervical sagittal parameters may vary according to age and thoracic and spinopelvic alignment.

Design

[Prospective observational study.](#)

Introduction

The purpose was to describe cervical alignment parameters from childhood to elderly without spinal pathology with respect to gender and Roussouly types.

Methods

EOS radiographs of 2599 individuals (1488 females, 1111 males) were analyzed. Cranial cervical parameters were: McGregor-C2, C1-C2, posterior occipito-C2 angles. Caudal cervical parameters were: C2-C7, C2-apex (upper arch) and apex-cervicothoracic inflexion point (lower arch) lordosis, C7 and T1 slope. Cervical morphology and the number of vertebrae in lordosis were assessed. The distribution of parameters was analyzed using a Bayesian inference (significance Pr>0.95). Correlations with global alignment, TK, LL and spinopelvic parameters were investigated.

Results

Among cranial parameters, McGregor and C1-C2 lordosis was larger in females, and increased significantly during growth, whereas the posterior occipito-C2 angle decreased (Pr>0.95). Among caudal cervical parameters, C2-C7 lordosis, C7 and T1 slope was larger in males and increased after 50 years (Pr>0.95). Roussouly 1-2 (small PI) had larger values (Pr>0.95). Lordosis changes were non-significant in the upper arch, whereas values increased in the lower arch after 35 years, were large in males and Roussouly 1-2 (Pr>0.95). The average number of vertebrae in lordosis was 7 in all age groups. Cervical morphology was lordotic in 50.9%, kyphotic in 1.3%, sigmoid in 47.9%. Strong correlations existed between C2-C7, caudal arch lordosis and C7, T1 slope, TK and the level of cervicothoracic inflexion point (rho>0.5; Pr>0.95). There was no significant correlation with global and spinopelvic parameters.

Conclusion

This observational study demonstrates that values for cervical alignment parameters vary with age, gender and spinopelvic alignment type. In the cranial cervical spine, changes occur mainly during the growth period. In the caudal cervical spine, lordosis increases mainly in the lower arch. This is strongly related to thoracic kyphosis which increases with age and where the caudal cervical arch might act as a compensatory segment.

Take Home Message

Reference values for cervical alignment parameters vary with age and mainly depend on changes in the thoracic spine.

70. Posterior Cervical Spinal Fusion in the Pediatric Population Using Modern Adult Instrumentation: Clinical Outcome and Safety

Alexander Spiessberger, MD; Peter O. Newton, MD; William G. Mackenzie, MD; Amer F. Samdani, MD; Firoz Miyajani, MD; Joshua M. Pahys, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Mark Abel, MD; Jonathan H. H. Phillips, MD; Burt Yaszay, MD

Summary

In this retrospective multicenter outcome study on 79 pediatric patients undergoing posterior cervical fusion using adult instrumentation with 3.5mm titanium rods, the most common indications for surgery were basilar invagination and congenital deformities and the mean number of fused segments was 4. Overall, the operative complication rate was 4/79 (5%), revision rate 4/79 (5%) and fusion rate 72/72 (100%). Minimal to no differences were found in outcomes when stratified by length of fusion, approach type and indication for surgery.

Hypothesis

Posterior cervical fusion in the pediatric population using adult instrumentation is safe.

Design

Retrospective

Introduction

Posterior cervical fusion in the pediatric population is not well studied. The aim of this study is to define the clinical outcome

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and safety of posterior instrumented fusion in the pediatric population using adult posterior instrumentation.

Methods

A multicenter review of pediatric patients who underwent posterior cervical fusion using a 3.5mm posterior cervical system for any indication was performed. Outcome parameters studied included complications, revision and fusion rates, operative time (OR), blood loss and postoperative neurologic status. Outcomes were compared between patient groups (posterior only vs. anterior/posterior approach, short vs. long fusion, and between different etiologies) using Mann-Whitney and Chi-square test.

Results

A total of 79 patients with a mean age of 9.9 years and mean follow-up of 2.8 years were included. At baseline 44 (56%) had an abnormal neurologic exam. Congenital deformities and basilar invagination were the most common indications for surgery (Table). Posterior-only surgery was performed in 66 (84%) cases; the mean number of levels fused was 4 (range 1-15). Overall, 4 (5%) operative complications and 4 (5%) revisions were reported at an avg postoperative time of 2.6 yrs. Fusion at final follow-up was verified in 72 of 72 patients (100%). Neurologic status remained unchanged in 73%, improved in 19% and worsened in 8%. When comparing outcome measures between anterior/posterior vs. posterior approach group, short vs. long fusions and between different etiologies only two significant differences were found: OR was longer in the anterior/posterior approach group and deterioration of neuro status was more frequent in the long fusion group.

Conclusion

Posterior cervical fusion with an adult 3.5mm posterior cervical system was safe in this cohort of 79 pediatric patients irrespective of surgical technique, fusion length and etiology of spinal disorder, resulting in a high fusion and low complication/revision rate.

Take Home Message

Posterior spinal fusion in the pediatric population using adult instrumentation can be performed safely.

Table. Indications for Surgery and Outcome Variables

Indications for Surgery	N (%)
Vertebral segmentation/ formation anomaly	23 (29%)
Basilar invagination	10 (13%)
Congenital kyphosis	7 (9%)
Spinal stenosis of other causes	7 (9%)
Trauma	7 (9%)
Atlantoaxial instability	4 (5%)
Larson syndrome	4 (5%)
Infection	1 (1%)
Tumor	1 (1%)
Other	15 (19%)
Outcome Variables	N (%) or mean (SD, range)
Fusion rate	72 (100%)
Neuro status postop	unchanged in 49 (74%), improved in 15 (23%), worse in 2 (3%)
Neuro status at last f/u	unchanged in 54 (73%), improved in 14 (19%), worse in 6 (8%)
Hospital stay (days)	22.9 (36.1, 3-166)
ICU stay (days)	5 (15.6, 0-130)
OR time (min)	305 (106.1, 65-614)
Blood loss (ml)	318.8 (375.4, 25-1800)
Administration of blood products	30 (38%) PRBCS, 2 (3%) FFP, 1 (1%) platelet
Revision surgery	4 (5%) (3 deformity, 1 not further specified)
Time to revision	2.6 (1.2, 1.1-4.5)
Operative complications at index surgery	4 (5%) (1 CSF leak, 2 face/tongue swelling, 1 neck extensor weakness)

71. Interval for Repeat Pediatric Trisomy 21 Atlanto-Axial Instability Surveillance

Jennifer M. Bauer, MD; Virkamal Dhaliwal, BS; Walter F. Kregel III, MD

Summary

Single institution retrospective review of 12yrs of interval repeat pediatric Trisomy 21 cervical xrays. Of 160 included patients, 7 had atlanto-axial instability: 4 initially, 3 on interval repeat radiograph. 71% of those unstable had os odontoidium, including 2 of the 3 with interval development, vs. 2% of the stable patients. This low rate of instability development over an average of 4.3yrs suggests repeat surveillance may not be needed in the absence of os odontoidium.

Hypothesis

We hypothesize regular interval radiographic surveillance is necessary to monitor pediatric Trisomy 21 cervical spine instability.

Design

Retrospective review

Introduction

Atlanto-axial instability (AAI) is common in pediatric patients with Trisomy 21 and can lead to spinal cord injury during sports, trauma, or anesthetized neck manipulation. Children with Trisomy 21 therefore commonly undergo radiographic cervical spine screening, but recommendations on age and timing varies. The purpose of this study was to determine what intervals to repeat the surveillance radiographs, and whether there is an ideal age to begin or halt AAI screening.

Methods

We performed a retrospective review for all pediatric Trisomy 21 patients receiving at least two cervical spine radiographic series between 2008-2020 at our institution. Atlanto-dens interval (ADI) and space available for the cord at C1 (SAC) were measured on each; bony abnormalities such as os odontoidium were noted. Instability was determined by ADI>6mm or SAC<14mm based on our groups' prior study. Age and time between radiographs were noted, and those who developed instability were

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compared to those who did not.

Results

A total of 437 cervical spine radiographic series from 192 patients were evaluated, with 160 included. The mean age at first radiograph was 7.4yr +/-4.4, average ADI was 3.1mm (+/-1.2), and SAC was 18.1mm (+/-2.6). The average time between first and last radiographs was 4.3yr (+/-1.8), with average final ADI 3.2mm (+/-1.4) and SAC 18.9mm (+/-2.9). Seven patients (4%) had instability: four were unstable on their initial studies and three (1.6%) on subsequent imaging. Os odontoideum was found in five (71%) unstable spines and 3 (2%) stable spines (p<0.0001); only one patient that became unstable on subsequent radiograph did not have an os. There was no specific age cut-off or surveillance time period after which one could be determined no longer at risk.

Conclusion

Repeat pediatric Trisomy 21 radiographic surveillance screening identified instability in 1.6%. Those with os odontoideum had a high rate of instability and should continue to be surveilled at regular intervals.

Take Home Message

Pediatric Trisomy 21 patients with os odontoidium should have regular cervical spine surveillance radiographs for instability; others may not need regular repeat films.

UNSTABLE Patient	Age at Initial Xray (yr)	Initial ADI (mm)	Initial SAC (mm)	Os?	Time to unstable Xray (yr)	Subsequent ADI (mm)	Subsequent SAC (mm)
1	6.4	7.6	10.6	os	Initial		
2	16.7	7.2	15.4	-	Initial		
3	12.9	8.6	14	-	Initial		
4	20.8	8.7	8.3	os	Initial		
5	12.6	4.2	15.2	os	0.8	9.6	5.8
6	5.7	2.6	13.4	os	3.6	9.7	10.6
7	14.5	5.6	17.5	-	1.5	7.1	13.1

Individual unstable patients

72. Pediatric Cervical Spine Fusions: Opportunity for Improvement

Edward Compton, BS; Stephen Stephan, MD; Kenneth D. Illingworth, MD; David L. Skaggs, MD; *Lindsay M. Andras, MD*

Summary

Use of halo immobilization and autograft did not appear sufficient to protect against development of a nonunion, which occurred in 1 out of 4 patients with uninstrumented occipitocervical fusions.

Hypothesis

In cases of pediatric cervical spine fusions, those including the occiput have a higher rate of nonunion.

Design

Retrospective, Comparative

Introduction

Our purpose was to examine the rate and risk factors for nonunion in the pediatric cervical spine.

Methods

Retrospective review of patients with cervical spinal fusion and ≥1-year follow-up between January 2004-December 2019 at a

tertiary pediatric hospital. Charts and radiographs were reviewed. Nonunion was defined as absence of radiographic union as assessed by the attending surgeon that required additional surgical management.

Results

74 patients (mean age: 9.0 ± 5.4 years) were included with mean follow-up 51.5 ± 40.2 months (range: 12-170 months). 32 fusions (43%) included the occiput. 48 patients (65%) had instrumentation, while 26 patients (35%) were uninstrumented. 62 patients (84%) had autograft, while 12 patients (16%) had allograft alone. The incidence of nonunion was as follows: overall=8/74 (10.8%); posterior fusion=12.7% (8/63); anterior fusions= 0% (0/6); and anteroposterior fusions= 0% (0/5). Although not significant, the rate of nonunion was nearly 4 times higher in fusions involving the occiput (occipitocervical fusions: 18.8%; 6/32 vs. cervical alone: 4.8%; 2/42; p=0.07) and the rate of nonunion was 3 times higher in uninstrumented fusions (19.2%; 5/26) than instrumented fusions (6.3%; 3/48) (p=0.12). In patients with an uninstrumented fusion to the occiput, the rate of nonunion was 27.8% (5/18) compared to 5.4% (3/56) in those who did not (p=0.02). There was a similar incidence of nonunion in the patients who received autograft (11.3%; 7/62) to those who received allograft alone (8.3%; 1/12)(p>0.999).

Conclusion

The nonunion rate in pediatric cervical spine fusions remained high despite frequent use of halo immobilization and autograft. Patients with uninstrumented occipitocervical fusions are at particularly high risk with more than 1 in 4 developing a nonunion.

Take Home Message

The rate of nonunion was high in pediatric cervical spine fusions, particularly for those with uninstrumented occipitocervical fusions, despite frequent use of autograft and halo immobilization.

Procedure (n)	Nonunion Rate
Anterior (6)	0%
Anterior + Posterior (5)	0%
Posterior (63)	12.7%
Cervical only w/out instrumentation (8)	0%
Cervical only w/ Instrumentation (34)	4.8%
Occipitocervical w/ Instrumentation (56)	5.4%
Occipitocervical w/out Instrumentation (18)	27.8%

Table 1

73. Can Lateral Mass Screw Fixation be Improved with Supplemental Screws?

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Summary

Posterior cervical fusion patients undergoing deformity correction or patients with compromised bone quality have increased

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risk of fixation failure. Adding supplemental fixation to traditional lateral mass screws (LMS) can increase the construct pullout strength.

Hypothesis

Pullout strength of C3-C6 LMS fixation supplemented with two unicortical screws or one tricortical transfacet screw will be superior to traditional LMS fixation.

Design

Biomechanical cadaveric study

Introduction

Fixation failure of LMS occurs in up to 5.4% of posterior cervical fusions and suboptimal bone quality may increase failure risk. An increasing number of elderly patients with suboptimal bone quality meet the indications for spinal fusion. In addition, deformity correction requires longer constructs and places greater force demands on screws at the construct end points. This work addresses the question; can supplemental fixation of LMS improve pullout strength?

Methods

Fifteen C3-C6 vertebral bodies and 15 motion segments (C3-C4/ C5-C6) were used (age: 49-67). Bone mineral density (BMD) was obtained from quantitative CT. Vertebral bodies and motion segments were implanted with bilateral LMS. Supplemental fixation was added on one side of vertebral bodies using two unicortical 2.4mm screws (Fig. Left) and on motion segments with a single transfacet tricortical 2.4mm screw (Fig. Right). Screw constructs were subjected to posterior pullout coincident with the axis of the LMS at 5mm/min until failure.

Results

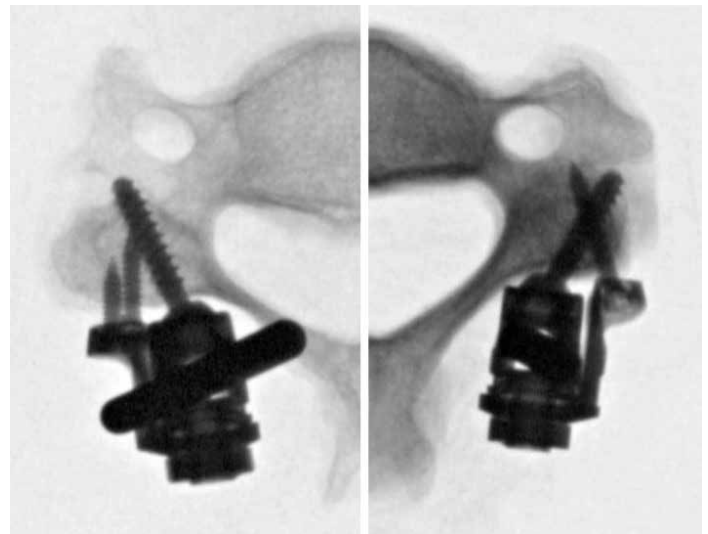
A paired comparison was made of the peak pullout force of LMS alone and LMS with supplemental 2-screw or 1-screw fixation. Correlation analysis was made of BMD and pullout force. Peak pullout force was significantly higher in the supplemented screw side. The average pullout force was 48.2% higher with 2 supplemental screws ($865 \pm 213\text{N}$ vs. $637 \pm 206\text{N}$; $P=0.038$) and 25.9% higher with 1 transfacet supplemental screw ($1055.8 \pm 520.8\text{N}$ vs. $912.7 \pm 507.7\text{N}$; $P=0.047$). Correlation was low between pullout force and BMD in vertebral bodies with LMS supplemented with 2 screws (0.34) and LMS alone (0.45). Correlation for the motion segments was moderate for LMS (0.64) and high for transfacet fixation (0.71).

Conclusion

Data confirms the hypothesis that the pullout strength of C3-C6 LMS with supplemental fixation was superior to LMS alone.

Take Home Message

Adding supplemental screws to LMS can increase pullout strength.



Left) LMS supplemented with two unicortical screws. Right) LMS supplemented with one tricortical transfacet screw.

74. Medium and Long-Term Sagittal Cervical Spine Alignment and Quality of Life in Adult Patients Receiving Primary Surgery for Recent Cervical Subaxial Injury

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Summary

Sagittal cervical alignment has not been studied adequately after subaxial injuries. Fifty-six (56) consecutive adult patients, who underwent an early primary surgery for recent subaxial unstable cervical injury were studied. Lower C2-C7 curvature, CSVA, Spino-Cranial Angle (SCA), T1-slope, Neck Tilt (NT), Thorax Inlet Angle (TIA), Cervical Tilt (CT), Cranial Tilt (CrT) and C0-C2 angle were measured. The “key parameters” for a successful outcome following an instrumented fusion were: T1-slope, CSVA, CT and SCA.

Hypothesis

To analyze the sagittal cervical alignment and its relationship to Health-Related Quality of Life (HRQOL) after instrumented fusion, for recent subaxial cervical injuries and to define a reference for “normative” sagittal cervical roentgenographic parameters in order to analyze sagittal balance and to plan cervical spine surgery.

Design

This is a retrospective cohort study of fifty-six (56) consecutive adult patients, who underwent an early primary surgery for recent subaxial unstable cervical injury and of one hundred (100) age-matched asymptomatic controls.

Introduction

Sagittal cervical alignment has been studied in degenerative disease but little attention has been paid after subaxial injuries. In addition, the relationship between cervical alignment and HRQOL has not been adequately studied.

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Methods

On admission, 17 (30%) patients suffered from Spinal Cord Injury (SCI). Twenty-five patients underwent anterior, 25 posterior & 6 circumferential surgery for single cervical injury. Lower C2-C7 curvature, CSVA, SCA, T1-slope, NT, TIA, CT, CrT and C0-C2 angle were measured. In the last evaluation, HRQOL was estimated using the NDI and SF-36 questionnaires.

Results

Fusion included 2-4 vertebrae. All 56 patients were followed at an average of 5.5 years, with a range of 3-7 years postoperatively. SF-36 scores correlated with SCA, T1-Slope, CSVA and CT. In the last observation, there was no difference in the roentgenographic parameters between patients with and without SCI; between the different numbers of fused vertebrae; between upper and lower fused region.

Conclusion

Cervical fusion increased cervical lordosis while it maintained CSVA within physiological limits. The “key parameters” for a successful outcome following an instrumented fusion were: T1-slope, CSVA, CT and SCA, since they were correlated with SF-36 scores. Although patients with SCI presented poorer NDI & SF-36 scores than their neurologically intact counterparts, no differences in the sagittal roentgenographic parameters were observed postoperatively. The “normative” parameters could be used in spinal reconstructive & trauma surgery.

Take Home Message

The “key parameters” for a successful outcome following an instrumented fusion were: T1-slope, CSVA, CT and SCA.

75. Outcomes Following Occipitocervical Fusion for Complex Spine Trauma: Optimal Fusion Angle and Construct Design Critical to Prevent Dysphagia and Revision Surgery

Daniel C. Kim, MD, MS; Richard P. Menger, MD; Anthony Martino, MD; George Rusyniak, MD

Summary

Complex suboccipital spine instability secondary to trauma is a challenging operative dilemma with serious implications. Trauma is a rising indication for occipitocervical fusion (OCF). Patients undergoing OCF show maintenance or improvements of neurologic function; however, careful attention to optimal fusion position and limitation of construct length are crucial to avoid debilitating complications including dysphagia and revision surgery.

Hypothesis

Good neurologic outcomes associated with OCF, and fusion positioning is an independent risk factors for postoperative dysphagia and revision surgery in this setting.

Design

Retrospective cohort study

Introduction

Instability of the occipitocervical joint in the setting of complex spine trauma is associated with high rates of morbidity and mortality. This study investigates short term outcomes of OCF, including risk factors and postoperative complications.

Methods

A total of 43 consecutive patients were identified with complex suboccipital spine trauma treated with OCF. Retrospective review was performed for etiology, comorbidities, injury severity, and complications. Risk stratification was performed to identify independent variables for poor outcomes. Preoperative, postoperative, and final neurologic function was assessed using ASIA and Nurick grading systems. Radiographic analysis was performed with assessment of fusion positioning via previously established occipitocervical measurements.

Results

Spinal cord injury at presentation was present in 12 patients. At final follow-up, 65.1% of patients were without neurologic symptoms. Within the myelopathy group at final follow-up, the mean Nurick score was 2.2 ± 2.0 . Surgical complications occurred in 27.6% of patients, including five (10.6%) deep infections, four (8.5%) instrumentation failures, and six (12.8%) instances of dysphagia. Mean fusion posterior occipitocervical angle (POCA) was 108.9 ± 8.4 degrees, with higher fusion angles resulting in increased dysphagia (109.1 ± 9.2 vs. 117.6 ± 9.3 , $p=0.03$). POCA fusion position above 120 degrees resulted in 8 times likelihood of dysphagia (OR = 8.0, RR = 5.0, CI (1.19, 53.93), $p = 0.04$). The most common lowest instrumented vertebra (LIV) was C4 with longer constructs leading to an increased rate of revision surgery (4.5 ± 1.2 vs. 6.0 ± 1.4 , $p=0.02$).

Conclusion

Complex suboccipital spine instability has serious potential complications. Patients undergoing OCF show maintenance or improvement of neurologic function; however, correct fusion position and limited construct length are crucial to good outcomes.

Take Home Message

Occipitocervical fusion for suboccipital trauma results in preservation or improvement of neurologic function; however, correct fusion position and limited construct length are crucial to avoid dysphagia and revision surgery.



OCF

76. Surgical and Radiographic Outcomes in Patients with High T1 and C2 Slopes

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Summary

Patients with cervical deformity (CD) can be classified into distinct spinal deformity categories based on their T1 slope (T1S) and C2 slope (C2S). Patients with low T1S-high C2S (LTHC) have CD only, while patients with high T1S-high C2S (HTHC) have global deformity without cervical compensation. HTHC patients undergoing cervical spine surgery had worse pre- and postoperative global spine alignment, more invasive surgeries, and less HRQL improvement than LTHC.

Hypothesis

HTHC have worse global deformity and require more complex surgery than LTHC

Design

Retrospective review of prospective multicenter database

Introduction

T1S and C2S are important radiographic parameters for CD patients. Higher T1S and C2S both correspond to worse cervical alignment and higher T1S to poor global alignment. Patients can be grouped into distinct spinal deformities by T1S and C2S with LTHC having CD only and HTHC having global deformity without cervical compensation.

Methods

A prospective database of operative CD patients was analyzed. Inclusion criteria was high preoperative C2S ($>30^\circ$), defined by 1 SD above a previously published mean for asymptomatic subjects with cervical kyphosis. Patients were categorized as LTHC if $T1S \leq 30^\circ$ and HTHC if $T1S > 30^\circ$. Outcome measures were surgical characteristics, HRQLs, postoperative complications and radiographic parameters. Severe Distal Junctional Kyphosis (DJK) was defined as DJK angle change $>20^\circ$. Statistical analysis included independent samples t-test and chi-square analysis with significance set to $p < 0.05$.

Results

92 patients were evaluated (61 HTHC, 31 LTHC). HTHC had greater preoperative thoracic kyphosis (TK) (-72.9 vs -46.6°), T1 Pelvic Angle (TPA) (18.0 vs 10.6°), and cSVA (58.0 vs 38.8 mm), all $p < .010$. 1y postop, HTHC had higher TK (-69.4 vs -59.7°) and cSVA (49.0 vs 39.4 mm), both $p < .05$; though there were greater improvements in TK and cSVA for HTHC, while TK worsened for LTHC. HTHC had more posterior levels fused (10.3 vs 6.7), fewer anterior levels fused (1.2 vs 2.2), and more circumferential fusions (66.7% vs 38.7%), all $p < .05$. Lower instrumented vertebrae (LIV) was more caudal in HTHC (13.7 vs 9.6 , $p < .001$). Both groups had similar baseline Neck Disability Index (NDI) scores (49.55 vs 49.10), but HTHC had less 1y NDI improvement (-6.8 vs -15.5 , $p = .023$). There were no differences in rates of postop minor or major complications, severe DJK, or reoperation.

Conclusion

HTHC had worse pre- and postop global alignment, requiring more complex procedures (more levels fused, lower LIV, and more circumferential fusions). HTHC had smaller 1y HRQL improvements, likely due to their continued worse global alignment postoperatively.

Take Home Message

Patients with both high T1S and C2S have worse global deformity and require more aggressive surgeries. They have smaller improvements in postoperative HRQLs, but do not have higher complication rates.

	Low T15- High C25 (n=23)	High T15- High C25 (n=52)	p value
Surgical Characteristics			
Op Time (min)	392.67±306.73	497.82±294.43	0.491
EBL (ml)	1231.00±1045.69	741.67±433.84	0.151
Circumferential Fusion	38.7%	66.7%	0.038
Anterior levels fused	2.2±2.11	1.10±1.79	0.013
Posterior levels fused	6.65±3.78	10.28±5.43	0.001
Lower Instrumented Level	9.55±2.83	13.65±4.97	<0.001
Mean # Osteotomies	2.87±3.20	3.26±3.87	0.629
3 Column Osteotomies	16.1%	24.6%	0.552
Postop Complications			
Reoperation Required	3.2%	4.9%	0.707
Severe DJK Incidence	6.5%	3.0%	0.219
Minor Complications	12.9%	18.0%	0.529
Major Complications	9.7%	11.5%	0.793
HRQL Scores			
Baseline NDI	49.10±17.58	49.55±16.77	0.906
1 Y NDI	32.06±18.14	40.49±19.67	0.111
NDI Change (Baseline to 1Y)	-15.47±15.62	-6.79±13.15	0.023
Radiographic Characteristics			
Baseline T15	18.55±10.34	50.48±14.10	<0.001
1Y T15	34.81±12.40	45.28±14.01	0.004
Baseline C25	44.63±12.35	57.00±18.83	0.001
1Y C25	30.92±14.49	33.20±11.62	0.491
Baseline TPA	10.56±10.95	18.01±12.48	0.007
1Y TPA	15.06±10.48	18.05±13.59	0.285
Baseline TK	-46.59±9.81	-72.86±18.26	<0.001
1Y TK	-59.67±15.69	-69.40±14.64	0.017
Baseline PT	18.61±10.92	22.64±10.92	0.120
1Y PT	20.08±12.11	20.92±12.79	0.801
Baseline cSVA	38.77±16.22	57.96±10.54	<0.001
1Y cSVA	39.36±19.98	48.95±12.05	0.024



Figure 1: Lateral cervical radiographs of a LTHC patient pre- (A) and postoperatively (B), and a HTHC patient pre- (C) and postoperatively (D), demonstrating different radiographic parameters and surgical invasiveness between groups

Results

119 cervical deformity patients met inclusion criteria (61.3yrs, 67%F, BMI: 29kg/m², CCI: 0.96±1.3). Demographics, surgical details, and BL radiographs listed in Table 1. Group I consisted of 72 patients, and Group II consisted of 47. Group II had a higher CCI (1.3 vs. .72), more cerebrovascular disease (6% vs. 0%) lower surgical invasiveness (9 vs. 11, all p<0.05) and trended towards a lower EBL (677 vs. 921, p=.124) and LOS (5.1 vs. 7.9, p=.065), with no significant differences in frailty, levels fused, approach, reoperations, DJK development, or HRQL metrics (p>0.05). Controlling for baseline deformity, and age, patients in Group II underwent less three-column osteotomies(3CO) .17[.04-.8], (p<0.05). Patients undergoing a 3CO had a deformity primarily in CT region (48%), followed by C (23%) and T (19%) with similar distribution between Groups (p>0.05). Additionally controlling for levels fused, and three-column osteotomies, Group II experienced less complications .29[.09-.96], (p<0.05).

Conclusion

Despite operating on a higher risk cohort with more co-morbidity, outcomes have remained consistent, indicating improvements in care. Surgically, there has been a reduction in the amount of three-column osteotomies performed, suboptimal realignments, and less complications and adverse events seen. This suggests a better understanding of minimizing the risk of cervical deformity surgery with less invasive techniques.

Take Home Message

Improvements in corrective surgery over the years have led to less invasive treatment strategies with lower complication rates, while operating on a higher risk cohort.

Demographics	
Age (years)	61.3 years
Female (%)	67%
BMI (kg/m ²)	29 kg/m ²
CCI	0.96
Baseline Radiographics	
PT (°)	18.8± 11.3°
PI (°)	53.0±11.1°
PI-LL (°)	-0.45±17.7°
SVA (mm)	4.34±66.8mm
TS-CL (°)	38.1 ±21.4°
cSVA (mm)	45.2±25.6mm
MGS (°)	4.1°
C2S (°)	37.3°
Surgical Details	
Levels Fused	7.6± 3.8
EBL (mL)	824 mL
Approach (%)	
Anterior	18.5%
Posterior	47.1%
Combined	34.5%

77. Evolution of Adult Cervical Deformity (ACD) Surgery Clinical and Radiographic Outcomes Based on a Multicenter Prospective Study: Are Behaviors and Outcomes Changing with Experience?

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Summary

With an aging population and increased prevalence of cervical deformity, corrective surgery is increasingly utilized as a treatment option. Over the course of the past seven years, deformity profile has remained consistent but there has been a reduction in the amount of three-column osteotomies performed. Despite operating on a patient population with a greater degree of comorbidities, there are less complications and adverse events seen, suggesting a better understanding of risk minimization with less invasive techniques.

Hypothesis

To investigate if outcomes, surgical approach, and patient specific factors have changed over time.

Design

Retrospective cohort study of a prospective ACD database.

Introduction

With consistent advancements in cervical deformity surgery, the role of invasive techniques is better understood.

Methods

ACD patients (≥18 yrs) with complete BL and up to 2Y HRQL and radiographic data were included. Patients were grouped into Group I (2013-2014) and Group II (2015-2017) by DOS. Univariate/multivariate analysis determined differences in surgical, radiographic, and clinical outcomes between groups.

78. A Randomized Control Trial of Schroth-Based Therapy Fails to Demonstrate a Positive Influence on Curve Progression in Skeletally Immature AIS

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Summary

53 months after starting a grant-funded multi-site RCT in small

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AIS skeletally immature curves, 55 of 94 enrolled patients have achieved 1-yr follow-up with higher attrition to date (31%) than anticipated. Young patients with mild curves have had difficulty adhering to the intensive demands of supervised PT and a HEP. There is no impact on curve progression or brace outcomes in the exercise group compared to the observation group.

Hypothesis

Physiotherapeutic scoliosis-specific exercises (PSSE) are more effective in Risser 0 patients with mild AIS curves, compared to standard-of-care observation only (control).

Design

SRS Grant-Funded, IRB-Approved Prospective Multi-Site, Dual-Arm RCT

Introduction

The Schroth-based method is a PSSE treatment option for AIS. However, little is known about PSSE outcomes. The purpose of this study is to report on the efficacy of the Schroth-based therapy program in Risser 0 patients with mild AIS curves.

Methods

Six sites enrolled 94 Risser 0 patients with a single AIS curve between 12-24°. Patients were randomized to exercise (E) or control (C) groups in a 2E:1C ratio. Patients in the E group were instructed on the Schroth technique and requested to complete ≥8 hrs supervised PSSE over 6 months and a home exercise program (HEP) (75 min/wk) for 1 yr.

Results

Patient attrition was 31% (29 of 94: 21E, 8C), most commonly due to patients' inability to adhere to the exercise regimen resulting in 55 patients (34E, 21 C) for study. Patients in the E group were significantly younger (11.6 vs. 12.5 years) without differences in the baseline Cobb angle (16.3° vs. 17.0°). In the E group, 27 of 34 (79%) completed ≥8 hrs of supervised PSSE over 6 months. Self-reported exercise adherence averaged 82% (ranging from 27% to 141%) at 1 yr and 19 of 34 patients (56%) achieved ≥80% exercise adherence. There was no difference between the E and C groups in curve progression at 1 year (-0.3° vs. 1.2°, p=0.40) regardless of bracing status (overall p=0.40, unbraced p=0.36). In total, 19 of 54 (35%) patients were braced with a lower frequency seen in the E group (26% vs. 48%, p=0.08). Six unbraced patients (21% E, 10% C) improved ≥10° at 1 yr.

Conclusion

Young patients with AIS have difficulty adhering to the intensive demands of a supervised Schroth therapy and home exercise program. Early results demonstrate no significant benefit of Schroth-based therapy for small, immature AIS curves. There is a trend toward a lower likelihood of bracing in the exercise group.

Take Home Message

Young patients with mild curves may not benefit from PSSE, although 1-year outcomes demonstrate large variability. Early results demonstrate no significant benefit of Schroth-based therapy for small, immature AIS curves.

All Patients	Overall [N=55]	Control [N=21]	Exercise [N=34]	p-Value
Age	11.9±1.3 years	12.5±1.4 years	11.6±1.1 years	0.011
Baseline Max Cobb Angle	16.6±2.7°	17.0±2.9°	16.3±2.5°	0.329
1 Year Max Cobb Angle	16.8±6.6°	18.1±5.5°	16.1±7.2°	0.282
Change in Max Cobb Angle	0.3±6.2°	1.2±5.5°	-0.3±6.6°	0.397
Braced	19 (35%)	10 (48%)	9 (26%)	0.080
All Unbraced Patients	Overall [N=36]	Control [N=11]	Exercise [N=25]	p-Value
Age	11.8±1.1	12.4±0.7	11.6±1.2	0.033
Baseline Max Cobb Angle	16.3±2.9°	16.6±3.6°	16.2±2.6°	0.678
1 Year Max Cobb Angle	14.3±6.2°	15.7±5.5°	13.8±6.5°	0.412
Change in Max Cobb Angle	-2.0±5.5°	-0.7±4.4°	-2.6±5.8°	0.366
All Braced Patients	Overall [N=19]	Control [N=10]	Exercise [N=9]	p-Value
Age	12.2±1.6	12.6±1.9	11.7±1.0	0.244
Baseline Max Cobb Angle	17.0±2.4°	17.4±2.1°	16.4±2.7°	0.395
1 Year Max Cobb Angle	21.3±4.9°	20.5±4.6°	22.2±5.2°	0.543
Change in Max Cobb Angle	4.4±5.3°	3.1±6.1°	5.8±4.2°	0.287
SRS Criteria (Risser 0-2)	17 (90%)	9 (90%)	8 (89%)	---
SRS Criteria (≥25° curve)	7 (37%)	4 (40%)	3 (33%)	---
SRS Criteria (Progress >5°)	16 (84%)	8 (80%)	8 (89%)	---

79. Cost-Utility Analysis of Bracing vs. Observation for Adolescent Idiopathic Scoliosis

Ijezie A. Ikwuezunma, BS; Kevin Y. Wang, BS; Paul D. Sponseller, MD; Amit Jain, MD

Summary

In a cost-utility analysis, bracing for AIS is associated with an incremental net monetary benefit of \$32,854 and is the dominant treatment compared to observation.

Hypothesis

Bracing in AIS is more cost-effective than observation.

Design

Cost-utility analysis

Introduction

There is high quality evidence that bracing can prevent radiographic progression of spinal curvature in skeletally immature adolescent idiopathic scoliosis (AIS) patients with curves between 25-45°. Despite popular use, the cost-utility of bracing has not been established. This study aimed to determine the cost-utility of bracing in AIS.

Methods

A decision-analysis model was developed for a hypothetical, 10-year-old girl, Risser 1, Sanders 3, with a 35° main thoracic curve who could be treated with 2-years of bracing vs. observation. We estimated the probability, cost, and quality-adjusted life years (QALY) for each life event based on comprehensive review of the AIS literature. Costs were reported in terms of 2020 real dollars. QALYs were discounted at 3%. Incremental net monetary benefit (INMB) was calculated based on a probabilistic sensitivity analysis using Monte Carlo simulations of 1,000 hypothetical patients. One-way sensitivity analyses were performed by varying model inputs.

Results

Our decision-analysis model revealed that bracing was the dominant treatment choice over observation at \$50,000/QALY willingness to pay threshold. The net lifetime costs (assuming mean life expectancy 79 years) were \$57,908 ± \$5,443 with bracing and \$79,079 ± \$4,281 with observation. The net lifetime QALYs were 24.1 ± 1.9 with bracing and 23.8 ± 1.8 with observation. Bracing was favored in 99.6% of the simulations with a median INMB of \$32,854 (95% CI, \$13,695 to \$45,689). The model was most sen-

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sitive to the impact of bracing vs. observation on the probability of requiring surgical treatment as an adolescent or adult spinal deformity treatment later in life.

Conclusion

Cost-utility analysis demonstrates that bracing for AIS is dominant over observation, with a positive INMB.

Take Home Message

Bracing is effective for preventing curve progression in skeletally immature AIS patients, and is the dominant choice in cost-utility analysis.

Figure 1A. Decision Node

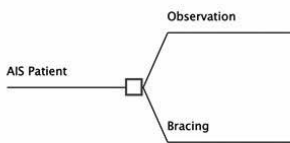
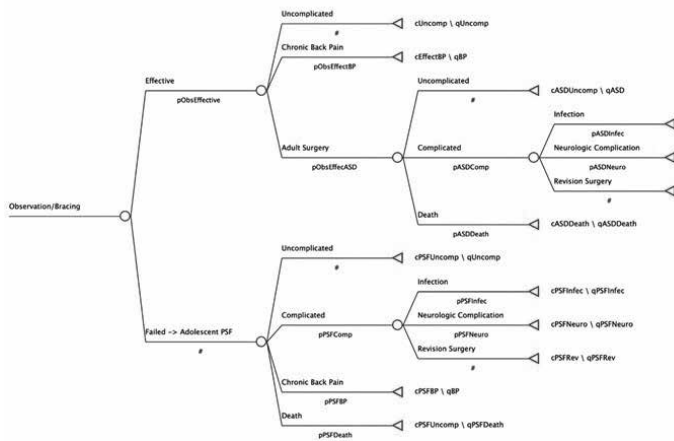


Figure 1B. Event Pathways from Either Management Strategy



Decision analysis model for comparison of bracing treatment vs. observation of AIS. Prefix “c” denotes a cost variable, “q” denotes a quality-adjusted life year (QALY) variable, and “p” denotes a probability variable. AIS indicates adolescent idiopathic scoliosis; PSF, posterior spinal fusion; ASD, adult spinal deformity.

80. Brace Treatment for Scoliosis Associated with Chiari Malformation Type 1 or Syringomyelia without Neurosurgical Intervention: A Matched Comparison with Idiopathic Scoliosis

Hongda Bao, MD; Shibin Shu, PhD; Benlong Shi, PhD; Xu Sun, MD; Bin Wang, MD; Bangping Qian, MD; Yong Qiu, MD; Zezhang Zhu, MD

Summary

Brace treatment is effective for CMS-associated scoliosis without the necessity of neurosurgical intervention. Compared to idiopathic scoliosis, brace can provide similar prevention for scoliosis surgery in CMS patients, but slight or moderate curve progression more often occurs. Specifically, patients with combined CM-1 and syringomyelia should be followed closely with a higher expectation of curve progression.

Hypothesis

Brace treatment is effective for CMS-associated scoliosis without the necessity of neurosurgical intervention.

Design

Retrospective

Introduction

Brace treatment was reported to be effective in preventing curve progression for patients with Chiari malformation type 1 (CM-1) or syringomyelia following posterior fossa decompression. However, its effectiveness had seldom been discussed when neurosurgical intervention was not performed. This study aims to evaluate the effectiveness of brace in patients with CM-1 or syringomyelia (CMS) associated scoliosis without neurosurgical intervention.

Methods

A cohort of 34 CMS patients who received brace treatment without neurosurgical intervention were reviewed. Another 68 matched idiopathic scoliosis patients who received bracing served as the control group. The rate of curve progression and scoliosis surgery was compared between different groups.

Results

Until the last visit, there were 16 (47%) patients with curve progression more than 5° and 9 (26%) patients undergoing scoliosis surgery in CMS group. In IS group, 18 (26%) patients occurred curve progression and 15 (22%) patients underwent scoliosis surgery. Compared to idiopathic scoliosis, patients with CMS-associated scoliosis had a significantly higher rate of curve progression (P=0.038). However, no significant difference was observed between two groups regarding to the rate of surgery (P=0.867). Patients with combined CM-1 and syringomyelia had a higher rate of surgery than patients with isolated CM-1 or syringomyelia (P=0.049). The double major curve pattern was identified as the risk factor for curve progression.

Conclusion

Brace treatment is effective for CMS-associated scoliosis without the necessity of neurosurgical intervention. Compared to idiopathic scoliosis, brace can provide similar prevention for scoliosis surgery in CMS patients, but slight or moderate curve progression more often occurs. Specifically, patients with combined CM-1 and syringomyelia should be followed closely with a higher expectation of curve progression.

Take Home Message

Brace is effective for CMS-associated scoliosis without neurosurgical intervention. Compared to idiopathic scoliosis, brace can provide similar prevention for scoliosis surgeries, but slight or moderate curve progression more often occurs.

81. A Modified Enhanced Recovery after Surgery (ERAS) Protocol Reduces Length of Stay and Opioid Consumption in Adolescents after Idiopathic Scoliosis Surgery

David E. Lebel, MD, PhD; Masayoshi Machida, MD; Fiona Campbell, MD; Natasha Bath, RN; Lisa Isaac, FRCP(C); Martin Koyle, MD, FRCS(C); Danielle Ruskin, CPsych; David Levin, MD, FRCS(C); Jennifer Stinson, PhD, RN

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Summary

We introduced a modified early recovery after surgery (ERAS) approach for surgically treated patients with AIS based on: preoperative management of patients' expectations, multimodal analgesia, early mobilization, early removal of urinary catheters and goals-based discharge checklist. Compared to Non-ERAS patients treated at the same time period, ERAS patients had reduced length of stay, pain scores and opioid consumption. Early removal of urinary catheters and lower opioid consumption were found to be independently and strongly associated with reduced LOS.

Hypothesis

We hypothesized that ERAS treated patients will have reduced LOS, lower post-operative opioid consumption, and reduced pain scores.

Design

Retrospective comparative study.

Introduction

Surgeries for adolescent idiopathic scoliosis (AIS) are among the most prevalent elective surgeries in pediatric orthopedic units. The optimization of post-operative patient care may reduce pain and opioid use; and therefore decrease post-operative length of stay (LOS). We introduced a modified enhanced recovery after surgery protocol (ERAS) based on preoperative management of patients' expectations, multimodal analgesia, early mobilization, early removal of urinary catheters, and a goals-based discharge checklist.

Methods

Retrospective chart review was completed for a consecutive group of patients who were treated between August 2018 and October 2019. All patients with a diagnosis of AIS were evaluated. 100 patients were operated in total; 31 patients from ERAS group and 52 patients from Non-ERAS (N-ERAS) group. 17 patients did not match either of those groups, and therefore their data was excluded.

Results

Patients were comparable in their baseline characteristics with regards to age at surgery, weight, height and number of levels fused, but differed in their initial coronal Cobb angle, $67.7^{\circ} \pm 12$ for the ERAS and $76.3^{\circ} \pm 19$ for the N-ERAS ($P < 0.05$). LOS was 3.8 days (95% CI 3.5-4.2) in the ERAS group compared to 4.76 days (95% CI 4.5-5.1) among the N-ERAS group ($p < 0.005$). The total opioids consumption was reduced by 50% on the day of surgery and by 35% the day after for the ERAS patients. Their mean and maximal pain scores were significantly reduced compared to the N-ERAS group. Furthermore, a multiple regression analysis uncovered that early removal of urinary catheters and lower opioid consumption were found to be independently and strongly associated with reduced LOS. No correlation was found between LOS and the initial Cobb angle.

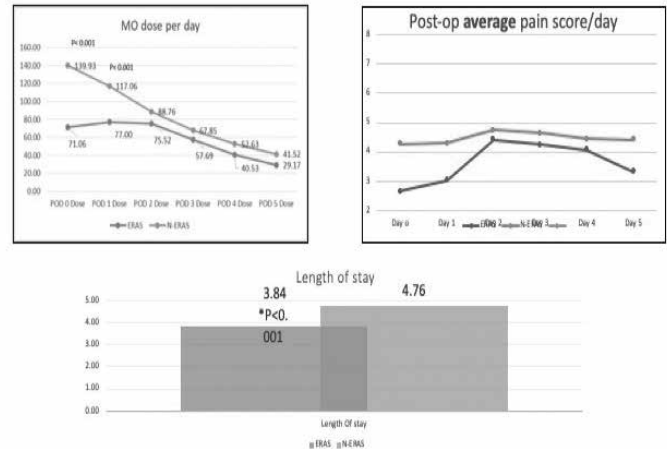
Conclusion

Adoption of ERAS based protocol for patients undergoing posterior spinal fusion to treat their AIS led to significant reduction in LOS, pain scores, and opioid consumption.

Take Home Message

ERAS based protocols should be adopted across surgical units for better predicted post-operative outcomes, especially reduction in pain scores, opioid consumption and post-operative length of stay.

Morphine Equivalents, pain scores and length of stay:



82. AIS Post-Operative Rapid Recovery Program: Liposomal Bupivacaine vs. Epidural

Amy L. McIntosh, MD; Christopher B. McLeod, MD

Summary

Post-operative multi-modal pain management for Adolescent Idiopathic Scoliosis (AIS) patients after Posterior Spinal Fusion (PSF) often involves the combination of both narcotic and non-narcotic medications. This cohort-controlled case series highlights local infiltration anesthesia (LIA) using liposomal bupivacaine (LB) to improve an AIS Post-Operative Rapid Recovery Program. The (LB) cohort consumed statistically significant less morphine equivalents, and demonstrated earlier mobilization and ambulation compared to the epidural (EPI) cohort.

Hypothesis

We hypothesized the LB cohort would have higher post-operative consumption of morphine equivalents, but demonstrate earlier ambulation/mobilization compared to the EPI control cohort.

Design

Retrospective review of prospectively collected data, cohort comparison.

Introduction

The goal of post-operative care pathways is to minimize narcotic usage, which, in turn, allows for earlier mobilization and ambulation. Liposomal encapsulated is a local anesthetic that has a duration of action, up to 72 hours. We compared two cohorts of AIS patients that underwent PSF.

Methods

Two cohorts of AIS patients that underwent PSF were compared. Prior to wound closure, the (2020) LB cohort had local infiltra-

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tion anesthesia (LIA) with a mixture of liposomal bupivacaine, bupivacaine HCL and normal saline injected into the fascial and subcutaneous layers of the incision. The (2019) control cohort had an epidural (EPI) catheter placed by the surgeon prior to fascial closure. The continuous epidural infusion consisted of ropivacaine 0.1% at a range of 0.1-0.2 ml/kg/hr. Otherwise, the cohorts received the same multi-modal post-operative pain protocol (intravenous opioid with transition to oral opioid, as well as dexmedetomidine, acetaminophen, ketorolac, and diazepam).

Results

159 AIS patients underwent PSF. There were no preoperative statistically significant differences between the 2020 LB cohort (n =101) and the 2019 EPI cohort (n = 58) when comparing age (14.3 vs.15.0 years), average BMI (21.7 vs.20.8 kg/m²), preoperative major Cobb (60.7° vs.60.3°), or average preoperative kyphosis (25.7° vs. 27.1°). The LB cohort consumed similar morphine equivalents during the initial 24 hrs. (37.8mg vs.37.3mg), but less at 24-48 hrs. (37.2mg vs. 41.0mg) (p=0.031), and 48-72hrs (23.3mg vs. 29.6mg) (p=0.015). The LB cohort ambulated 6.8 hrs sooner (17.1 vs. 23.9 hrs.) (p=.0001), and the LB cohort's length of stay (LOS) was 5 hrs. less (65.2 vs. 70.4 hrs.) (p = 0.158).

Conclusion

LIA of LB in AIS patients that underwent PSF was associated with less consumption of post-operative morphine equivalents, earlier ambulation, and decreased LOS when compared to the EPI cohort.

Take Home Message

Our institution's AIS Post-Operative Rapid Recovery Program demonstrated decreased narcotic consumption, earlier ambulation, and shorter LOS when LIA of Liposomal bupivacaine was compared to ropivacaine epidurals.

83. Short Term Outcomes of 23-Hour Observation Discharge Pathway after Posterior Spine Fusion in Adolescent Patients

Timothy Oswald, MD; Gilbert Chan, MD; Tonia Dry, PA-C

Summary

Rapid discharge pathways for adolescent spine deformity surgery have been reported to decrease length of stay and provide significant healthcare savings. The purpose of this study was to review safety and short-term outcomes on patients discharged within 23 hours of adolescent spinal deformity surgery at one institution.

Hypothesis

23-hour discharge pathways after adolescent spinal deformity surgery can be implemented with comparable results to traditional discharge outcomes for safety and complications.

Design

Retrospective Chart Review

Introduction

With increased success of implementation of early discharge pathways for adolescent spinal deformity surgery being reported, there have been no studies to date reporting if patients can be safely discharged within 23 hours of surgery. We have ob-

served an increasing number of patients being discharged with 23 hours at one institution with a rapid discharge pathway. For early discharge to be successful, safety and patient satisfaction are critical.

Methods

A retrospective review was performed and patients were identified by length of stay (23 hours) and diagnosis code from 2019-2020. Data on length of stay, average levels fused, hospital readmission, postoperative complications and infections, length of surgery, blood loss and NRC patient experience scores were collected from the electronic medical records from one institution.

Results

40 nonconsecutive patients were identified with diagnoses of Adolescent Idiopathic Scoliosis (39) and Scheuermanns Kyphosis (1) between 2019-2020 from one institution. All patients were discharged postoperatively with in 23 hours of completion of surgery. There were no postoperative readmissions, emergency room visits or infections reported within 60 days of discharge on all patients. Length of surgery was less than 3 hours and EBL less than 200 on all patients. Average levels fused was 9.7. NCR hospital patient experience score averaged 95.2%. There were no reported patient complications.

Conclusion

Patients participating in a 23-hour observation discharge pathway showed no increase in postoperative complications and readmissions and had excellent patients experience scores. While this pathway may not be advisable for all patients, it can be safely implemented with good outcomes. Nursing, physical therapy and postoperative family education are critical to success of the pathway.

Take Home Message

23-hour observation discharge pathways can safely be implemented for adolescent spinal deformity patients with attention to pain management and early postoperative mobilization.

84. Complications after Major Pediatric Surgeries: Comparison with Our Peers

Shalin Patel, MD; Lawrence G. Lenke, MD; Munish C. Gupta, MD; Peter O. Newton, MD; Daniel J. Sucato, MD, MS; Oheneba Boachie-Adjei, MD; Suken A. Shah, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Patrick J. Cahill, MD; Paul D. Sponseller, MD; Richard E. McCarthy, MD; Fox Pediatric Spinal Deformity Study; Michael P. Kelly, MD

Summary

Nearly half (45%) of children treated with complex spine reconstructions sustained an intraoperative complication and nearly one-third (30%) sustained a postoperative complication. When classified according to the scheme of Clavien-Dindo 32% of patients sustained some major complication, more than other pediatric surgeries such as renal transplant and duodenal obstruction. Neurological deficits and major pulmonary complications predominated and these may serve as targets for improvement in these surgeries.

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Hypothesis

Complications after complex pediatric spine surgery are similar to other complex pediatric surgeries.

Design

Prospective, observational cohort

Introduction

Complex pediatric spine reconstructions are associated with substantial morbidity when compared to other pediatric orthopaedic surgeries. The purpose of this study was to describe complications in major spine surgeries according to Clavien-Dindo (CD) for comparison with other major pediatric surgeries (e.g. renal transplant, esophageal atresia).

Methods

Patients ages 10-21yrs treated with vertebral column resection or with any Cobb > 100 degrees were enrolled at 18 centers across two continents. Standard case report forms collected intraoperative and postoperative complication data. These complications were then classified according to the Harms Study Group scheme. Complications were then independently reviewed by two surgeons and classified according to the Clavien-Dindo (CD) scheme. Spinal cord injury (SCI) was deemed single-organ failure. CD 3, 4, 5 were deemed major complications. Rates of CD 3,4,5 were compared with other surgeries using Chi-square and $p < 0.05$ defined significant.

Results

311 total patients were enrolled. 139 patients (44.7%) experienced an intraoperative complication, with 167 total. The majority, 140 (83.8%), were minor (CD 1, 2) and 27 (16.2%) were major. The most common major complications were new neurological deficits (6%, 20). 95 patients (30.5%) experienced a postoperative complication with 119 total. 79 (66.4%) were major. The most common major postoperative complications affected the pulmonary system (9%, 28). Only 13 (10.9%) of the postoperative complications resulted in single- or multi-organ system dysfunction (CD IV). There were no intraoperative or postoperative mortalities (CD V). 32% sustained some major complication, more than other major pediatric surgery reports ($p < 0.001$).

Conclusion

32% of pediatric patients undergoing complex reconstruction experienced major complications. This is higher than reported rates for other complex pediatric procedures emphasizing the difficulty of these surgeries and patients. Intraoperative neurological changes and postoperative pulmonary complications predominate.

Take Home Message

Complex pediatric spine surgeries have major complication rates higher than other serious pediatric interventions. Neurological and pulmonary complications are most common and are targets for improvement.

85. Complications and Additional Procedures after Anterior Vertebral Tethering (AVT) for AIS: A Ten-Year Experience

John T. Braun, MD; Brian E. Grottkau, MD; David F. Lawlor, MD

Summary

Complications and additional procedures were analyzed in our first 62 patients after AVT for AIS. Short-term complications included pleural effusion (3%) and early tether rupture (1.5%) while long-term complications included late tether rupture (17.5%), overcorrection (7.5%), and inadequate correction (2.5%). Despite an overall complication rate of 32%, the revision surgery rate was only 18%, with tether revision required in 1/1 early tether rupture, 1/7 late tether ruptures, and 2/3 overcorrections and fusion required in 2/3 overcorrections and 1/1 inadequate correction.

Hypothesis

The overall complication rate after AVT would be moderate but some additional procedures would be necessary.

Design

Retrospective review of consecutive patients 2010-18.

Introduction

Although AVT has been proposed as an alternative to fusion for AIS, the rate of complications and additional procedures is not well established. This study analyzed complications in our first 62 patients treated with AVT.

Methods

Sixty-two consecutive AIS patients were treated with AVT for T and TL/L curves in the 33-70° range. Charts and X-rays were reviewed to allow analysis of complications and additional procedures.

Results

Sixty-two AIS patients with 82 curves were treated with AVT without intra-operative complication. Short-term post-op complications included 2/62 pleural effusions (both drained) and 1/62 early tether rupture (revised). Long-term complications in 40 patients with 2-10 year F/U included 7/40 late tether ruptures, 3/40 overcorrections, and 1/40 inadequate correction. All tether ruptures occurred T12-L3 at 1-5 years with an average 14° loss of correction. Tether revision was required in 1/7 late tether ruptures (replaced) and 2/3 overcorrections (removed). Fusion was required in 2/3 overcorrections and 1/1 inadequate correction. Thirty-seven of these 40 patients with 50 curves (26T, 24TL/L) at 14+5 years and R=2.8 were definitively treated with AVT demonstrating correction from 47° pre-op to 23° post-op to 21° final at 3.2 years (2-10 years) with skeletal maturity in all but 1 patient ($p < 0.001$).

Conclusion

This analysis of our first 62 AIS patients treated with AVT demonstrated an overall complication rate of 32% but with a revision surgery rate of only 18%. Revision surgery was not commonly required for tether rupture, but was universally required for overcorrection/inadequate correction, often necessitating fusion. While the most common complication, tether rupture, only occurred in R=1 or greater, overcorrection only occurred in R=1 or less. Importantly, overcorrections were avoided after our first 10 patients. Despite a 10% tether revision rate (5% replacement, 5% removal) and an 8% fusion rate, 92% of patients were treated definitively with AVT.

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Take Home Message

Though complications after AVT for AIS occurred at a moderate rate (32%), tether revision surgery, for removal or replacement, was not common (10%) and conversion to fusion uncommon (8%).

86. Improved Surgical Preparedness with Preoperative Psychology Evaluation Prior to AIS Surgery

Heather M. Richard, PsyD; Shelby P. Cerza, MA; Kiley F. Poppino, BS; Daniel J. Sucato, MD, MS

Summary

A series of AIS patients completed preoperative and 2-yr SRS scores. 18.1% (n=29) of patients were referred to and evaluated by psychology preoperatively. There were no significant differences in SRS scores between the two groups. When comparing referred patients who were seen by psychology prior to completing the SRS to non-referred patients, referred patients endorsed significantly higher quality of life.

Hypothesis

AIS surgery is physically and mentally challenging and outcomes vary among patients. Few have analyzed the effect of psychological readiness for AIS surgery. We hypothesized that psychological evaluation/treatment would improve outcomes for patients by improving readiness/expectations.

Design

Prospective

Introduction

There is minimal literature on the impact of interdisciplinary care on surgical treatment and planning of patients undergoing surgery for AIS. In other pediatric orthopedic populations, interdisciplinary care and psychological preoperative preparation has been shown to contribute to postoperative outcomes.

Methods

From 2015-2017, preoperative and 2-yr postoperative SRS data were prospectively collected on patients who underwent PSF for AIS. Patient demographics and SRS scores were compared between patients who received a psychology referral preoperatively to those who did not.

Results

160 AIS patients (128F:32M) completed preoperative and 2-yr SRS scores. 18.1% of patients (20F:9M) were referred to psychology by the surgical team for preoperative psychology evaluation and preparation. Preoperatively, there were no differences in age (13.6 v 13.9; $p=0.39$); BMI (52.8 v 62.9 kg/m²; $p=0.08$); major Cobb angle (62.7 v 62; $p=0.75$), or SRS scores. For referred patients (n=21), the mean number of psychology appointments prior to surgery was 2.1 visits (range 1-9) over an average of 3 months (1 day-23 months). Within the referral group, 21 patients were seen by psychology before completing the SRS. Preoperatively, all domains were higher in the referral group with statistically higher scores (3.89 v 2.67; $p=0.005$). The referred patients reported similar 2-yr postoperative SRS scores to their non-referred counterparts.

Conclusion

Adolescents who were referred for psychological evaluation and preparation had higher baseline SRS scores than those who were not referred. Referring patients for psychological evaluation prior to AIS surgery should be incorporated as standard practice to optimize preparedness and functioning prior to surgical intervention.

Take Home Message

Preoperative psychological intervention may improve postoperative outcomes. The findings of this study highlight the importance of interdisciplinary care and establishing referral protocols for the AIS patient population.

87. Changing Hand Position on EOS Spinal X-rays Does Not Impact Sagittal and Coronal Parameters

Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Jesse Galina, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary

New protocols for spinal x-rays including new hand positioning does not affect coronal or sagittal parameters in non-operative patients. Without compromising radiographic parameters, additional prognostic data can be obtained without increasing radiation.

Hypothesis

Using a new a new spinal x-ray protocol with modified hand position does not affect pelvic parameters in non-operative patients.

Design

Retrospective review

Introduction

Our institution has implemented a new spinal x-ray protocol utilizing a change in hand position to examine bone age films concurrently. This is to decrease the amount of radiation used on this sensitive group of patients. The purpose of this study was to determine if the new spinal x-ray protocol affects pelvic measurements in non-operative patients.

Methods

96 non-operative patients who received spinal x-rays with the old and the new protocol from 2015-2018 were included in the study. Radiographic measurements such as Cobb angle, kyphosis, lordosis, sagittal and coronal balance, Pelvic obliquity, Risser stage, sacral slope, pelvic incidence measured with both protocols. Median (IQR) and kruskal-wallis test was used.

Results

There was no significant difference between any radiographic parameter comparing the two protocols. The average time between new and old protocol x-rays was 1.2 years. The median age for old protocol was 13.3 and 14.6 years for new ($p<0.001$). Risser signs were similar ($p=0.182$). Pelvic parameters were similar between protocols. Kyphosis and lordosis were 26° vs. 24° and 54 vs. 55 for the old and new protocol, respectively. Pelvic incidence – lumbar lordosis (PI:LL) was similar ($p=0.51$). Pelvic obliquity ($p=0.36$), pelvic tilt ($p=0.51$), and sacral slope ($p=0.18$).

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Median Cobb angle was 18° with the old protocol and 17° with the new protocol ($p=0.90$). Coronal balance ($p=0.21$) and sagittal balance ($p=0.35$) were similar.

Conclusion

Modifying the hand positioning on patients undergoing low-dose spinal x-rays does not significantly impact the radiographic parameters of non-operative patients. Given these findings, it only further argues for the implementation of these protocols to reduce unnecessary x-rays. Further studies will be needed to see the effect of these positioning changes in surgical patients.

Take Home Message

Spinal x-rays with new hand positioning do not significantly affect radiographic parameters in non-AIS patients and can be used effectively in a clinical setting.

88. Ultra Low Dose Intra-Operative CT Protocol: Significant Radiation Reduction Without Sacrificing Image Quality in Pediatric Spine Patients

Derrick A. Henry, Richard E. McCarthy, David B. Bumpass

Summary

“Ultra” low-dose image acquisition with intra-operative cone beam tomography does not diminish navigation imaging clarity, and can further reduce radiation exposure in pediatric spine deformity cases from what has previously been published.

Hypothesis

Lowering intra-operative tomography dose settings below a previously reported protocol of 80 kV/20 mA/80 mAs will still generate functional image and navigation quality in pediatric spine surgery.

Study design

Retrospective single-center.

Intro

Intraoperative CT for spinal navigation is increasingly used in pediatric deformity centers. The published Mayo low-dose pediatric protocol of 80 kV/20 mA/80 mAs notably lowered the manufacturer radiation settings, with an effective dose of 0.65 mSv. But, can we go lower, and in which patients?

Methods

21 consecutive patients underwent posterior spinal fusion with ultra low-dose intra-operative navigation. We trialed two settings: 1) 70 kV/10 mA/40 mAs and 2) 80 kVp/10 mA/40 mAs. Dose Length Product (DLP) remained consistent within the protocols. A DLP-to-effective dose coefficient was generated to calculate effective dose. We recorded any need for repeat spins due to poor image quality, or any navigation errors stemming from poor imaging.

Results

27 tomography spins in 21 patients were included in the study, 12 with a 70kVp/10mA/40mA setting (Protocol 1) and 15 under a 80 kV/10 mA/40 mAs setting (Protocol 2). Under Protocol 1, mean age, weight and BMI were 11.6 yrs, 38.5 kg, and 18.6 respectively; 79 vertebra were instrumented. There were no repeated spins due to image quality; only 1 screw required

intraoperative redirection due to medial breach and this was unrelated to image quality. DLP was 13.01 mGy/cm, and effective dose was 0.22 mSv.

Under Protocol 2, mean age, weight and BMI were 13.8 yrs, 49.6 kg, and 21.4 respectively; 94 vertebra were instrumented under navigation. There were no repeated spins due to image quality, with 2 screws redirected intraoperatively due to medial breach. DLP was 19.26 mGy/cm, and effective dose was 0.37mSv.

Patient weight between the protocols differed significantly ($p=0.04$).

Conclusion:

Both of the protocols we trialed for ultra low-dose intra-operative cone beam tomography dosing produced clear and usable navigation images. Protocol 1 generated an effective dose 66% lower than the published predicate, and Protocol 2 a 43% lower effective dose.

Take home message

The currently-accepted low-dose protocol can be further reduced to minimize radiation exposure to pediatric spinal deformity patients, particularly in EOS.

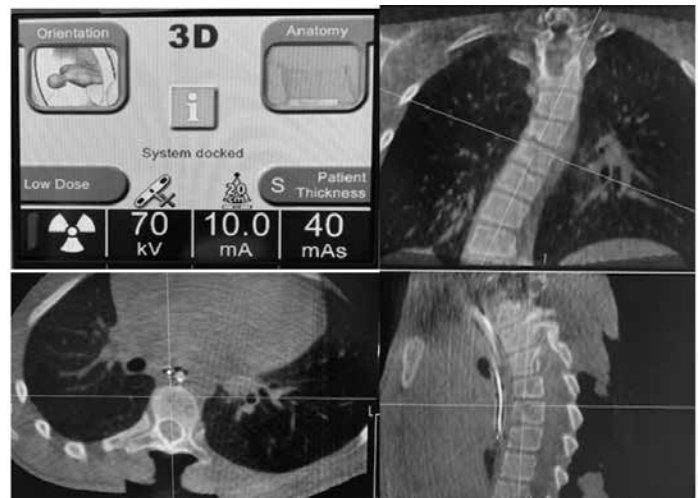


Image quality obtained w/ ultra low dose O-Arm.

89. A Modified Position for Optimized Skeletal Maturity Assessment of AIS Patients with Low-Dose Stereoradiography: Results of a Randomized Study on Image Quality and Dosage

Victoria Blouin; Victor Jullien; Olivier Chémaly, MD; Sylvain Deschenes, PhD; Marjolaine Roy-Beaudry, MSc; Soraya Barchi, BSc; John (Jack) M. Flynn, MD; Stefan Parent, MD, PhD

Summary

Our study evaluated a hands-on-wall position for low-dose stereoradiography of AIS patients. Skeletal maturity assessment of the hand and wrist was reliable and valid; sagittal spino-pelvic evaluation was comparable to standard positioning.

Hypothesis

Hand-on-wall position is valid to assess skeletal maturity of AIS patients.

Podium Abstracts

Design

Prospective Study

Introduction

A hands-on-wall (HOW) position for low-dose stereoradiography of adolescent idiopathic scoliosis (AIS) patients would allow for skeletal maturity assessment of the hand and wrist. Our aims were two-fold: confirm the reliability and validity of skeletal maturity assessment using the HOW X-rays and compare the spino-pelvic parameters to those of standard hands-on-cheeks (HOC) stereoradiographs.

Methods

Seventy AIS patients underwent two successive stereoradiographs and a standard hand and wrist X-ray on the same day. Patients were randomly assigned to begin with HOW and then HOC, or vice versa while also receiving a randomized radiographic dosage exposure (low vs. micro-dose). Raters assessed digital skeletal age (DSA), Sanders Simplified Skeletal Maturity (SSMS) and Thumb Ossification Composite Index (TOCI). 3D reconstructions of the spine and pelvis bones were performed for each stereoradiograph to measure twelve clinically relevant spino-pelvic parameters. Blind assessment of image quality was performed by 2 orthopedic surgeons with a quality questionnaire.

Results

Inter-rater and intra-rater reliabilities were excellent for DSA, SSMS and TOCI with both standard X-rays and HOW (ICC>0.95). Strong correlation was found between ratings of both imaging types (ICC>0.95). For 3D reconstructions, kyphosis, lordosis and spinal length were slightly decreased in the HOW position (figure), but within the 5° clinical margin of error. All other parameters didn't differ significantly between positions (p<0.05). Radiographic dosage didn't impact these findings as coronal images resulted in similar quality images. Dose-Area Products indicate that radiation was decreased between 2 and 7 times when imaging in low-dose mode, depending on patient's size.

Conclusion

The results suggest that HOW stereoradiographs allow clinicians to assess skeletal maturity of the hand and wrist with adequate reliability and validity. HOC and HOW positions rendered clinically equivalent spinal and pelvic parameters.

Take Home Message

Scoliosis clinics should adopt the HOW position to reliably assess skeletal maturity, without significant impact on the spinal and pelvic evaluation and without additional radiation exposure, cost or time.

	Mean difference (HOC - HOW)	95% confidence interval	N	P-value
Kyphosis T1-T12 (°)	2.70	[1.07, 4.33]	57	.002
Kyphosis T4-T12 (°)	2.50	[1.20, 3.80]	57	.000
Lordosis L1-L5 (°)	2.09	[0.87, 3.31]	57	.001
Lordosis L1-S1 (°)	0.14	[-1.43, 1.72]	57	.855
Cobb (°)	-1.93	[-5.87, 2.01]	52	.329
Max Cobb (°)	3.35	[-4.67, 11.37]	52	.406
Max planar angle (°)	-7.06	[-20.74, 6.63]	52	.305
Pelvic tilt (°)	0.32	[-0.83, 1.47]	57	.577
Pelvic incidence (°)	-1.25	[-3.17, 0.66]	57	.194
Sacral slope (°)	1.58	[-0.03, 3.18]	57	.054
Length T5-L3 (mm)	-1.17	[-2.30, -0.05]	57	.042
Total length (mm)	-0.65	[-1.90, 0.59]	57	.297

90. Does Vertebral Body Tethering Cause Disc and Facet Joint Degeneration? A MRI Study with Minimum 2-Years Follow-Up

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Summary

This study reports MRI findings of 25 rapid and steady growing adolescents (Sanders 2-7) who had undergone thoracoscopic Vertebral Body Tethering (VBT). At a mean follow-up of 29 months (24-62) after surgery, radiographic degenerative findings were not present in 97.7% of the intermediate and adjacent discs and 99.3% of facet joints. One case (4%) that had an increase in disc scores already had multi-level moderate degeneration preoperatively, while another case (4%) displayed a single-level new-onset grade-2 bilateral facet degeneration.

Hypothesis

VBT may cause degeneration at both intermediate and adjacent levels

Design

Retrospective analysis of a prospectively collected data

Introduction

Disc health after various growth modulation techniques have been assessed in animal models, and tethering was claimed to prevent degeneration due to its less rigid nature compared to other growth-friendly techniques. Yet, the results of animal studies wherein tethering is applied on healthy spines to create a deformity cannot be extrapolated to humans, in which tethering is used for deformity correction. Our aim was to investigate the integrity of discs and facet joints that are subject to compressive forces and relative stabilization during growth modulation.

Methods

Demographic, perioperative and radiographic data were collected. Overcorrection, mechanical and pulmonary complications, and reoperations were recorded. Preoperative and ≥2y follow-up MRIs were evaluated. Discs were assessed using Pfirrmann grade. Facet joint degeneration was graded on a scale of 0-3. Changes from preop to follow-up MRIs were analyzed using Mc-

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Nemar's Test and Related Samples Marginal Homogeneity Test.

Results

25 (23F, 2M) consecutive patients were included (mean f-up 29 (24-62) mts). The mean age at surgery was 12.2 (10-14) and median Sanders stage was 3 (1-7). A mean of 7.7 ± 1.1 (6-11) levels were tethered. Preop mean height of 155.3 (130-178) was increased to 163.4 (149-187) at latest f-up. The mean preop MT curve magnitude of $46^\circ \pm 7.7^\circ$ was corrected to $23.3^\circ \pm 5.9^\circ$ at first erect, which was modulated to $12^\circ \pm 11.5^\circ$ during follow-up. Complication profile is given in Figure. A total of 217 levels were evaluated. Analyses of disc and facet scores revealed no significant differences between patients. Deterioration of previously degenerated discs was noted in one patient, while previously healthy lower adjacent facet joints were degenerated in another patient.

Conclusion

Radiographic degeneration was not observed in discs and facet joints at a mean of 29 months after growth modulation with VBT surgery. Studies with longer follow-up are warranted to further analyze the effects of relative stabilization and altered biomechanical loads.

Take Home Message

Intermediate and adjacent discs and bilateral facet joints subject to compression and relative stabilization during a mean of 29-months of growth modulation with VBT did not demonstrate radiographic degenerative findings.

	Before Follow-up MRI n (%)	After Follow-up MRI n (%)	Total n (%)
Broken Tether	1 (4%)	5 (20%)	6 (24%)
Overcorrection	5 (20%)	1 (4%)	6 (24%)
Implant-related complications	3 (12%)	0	3 (12%)
Tether Release	1 (4%)	1 (4%)	2 (8%)
Conversion to fusion	0	2 (8%)	2 (8%)

91. Tether-Based Modulation of Scoliosis Reflects IVD Deformation: Development of Growing Pig Model

Benjamin Sinder, PhD; Alessandra Fusco, DVM; Jason B. Anari, MD; Edward Vresilovic, MD; Vincent Ruggieri, BS; Sriram Balasubramanian, PhD; Thomas P. Schaer, VMD; Patrick J. Cahill, MD; Brian D. Snyder, MD, PhD

Summary

Vertebral body tethering (VBT) scoliosis correction predisposes growth modulation via Heuter-Volkman principle, but most deformity correction is achieved by manipulating the intervertebral disc (IVD). The effect of mechanical stimuli on influencing spine growth with respect to the development of the IVD has been little studied. In this proof-of-principle study we develop a growing pig model where deformation of the spine and intervening discs is related to the tether induced bending moment detected by an implanted spring in-line with the tether.

Hypothesis

Most scoliosis correction and growth modulation is achieved by manipulating the non-osseous tissues.

Design

Non-survival in-vivo validation study to measure applied moment vs. spine deformity

Introduction

Modulating spine growth by applying asymmetric compression to the convexity of scoliosis is central to VBT. However, IVD deformity contributes most to AIS and manipulation of non-osseous tissues is essential to correction. Tension in the tether and the applied lateral bending moment is fundamental to understanding how perturbations to the mechanical milieu can be harnessed to correct pathoanatomy. We present a growing pig model where deformation of the spine is related to the tether induced bending moment calculated non-invasively by the force measured by a spring in-line with the tether.

Methods

With IACUC approval, posterior based, 2-level bilateral pedicle screw constructs with X-links were placed @ T9-10 & L4-5 in a 16 kg 6-wk pig (Fig. 1). Transversely seated lateral offset connectors @ T9 & L5 were used to attach a 1.7mm CoCr cable via custom connectors to fix the cable @ T9 and incorporate a calibrated spring in-line with the cable @ L5. Scoliosis was induced by varying the tension applied to the cable. Cobb angle and spring length (tether force) were measured by fluoroscopy and CT. Spring length was measured with calipers to validate radiographic measurements. Applied moment = tensile force x lateral-offset from cable to apex of scoliosis.

Results

Radiographically measured spring length agreed with caliper measurements ($R^2=0.94$). The spring quantified the tether force and allowed calculation of the applied bending moment. A 400N tether force induced 72-degree scoliosis. The induced deformity is non-linearly related to the applied tether force/bending moment, reflecting a low stiffness functional range (laxity facets, IVD, ligament/muscle) and progressive stiffening effect (facet contact, progressive loading of soft tissue restraints).

Conclusion

We developed a growing pig model where deformation of the spine and intervening discs can non-invasively be related to the tether induced bending moment detected by an implanted spring in-line with the tether.

Take Home Message

Tether induced deformity correction is non-linearly related to the applied bending moment, reflecting initial low stiffness laxity of IVD, ligament/muscle and progressive stiffening of soft tissue restraints and facet contact.

Podium Abstracts

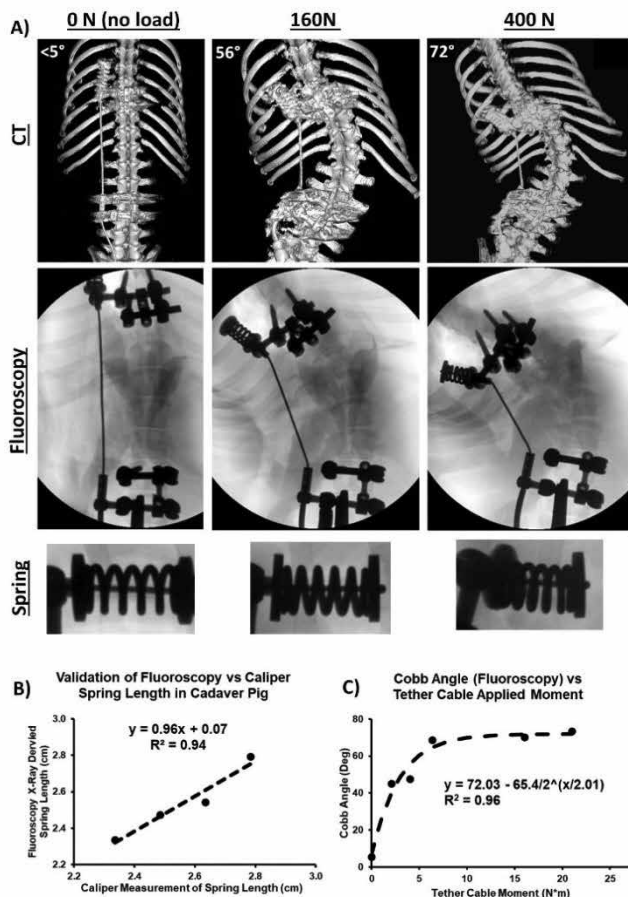


Figure 1: A) Deformity induced in a 16 kg 6-wk pig by tensioning tether attached to bilateral pedicle screw constructs with X-links @ T9-10 & L4-5. CoCr cable (1.7mm dia.) attached via custom connectors to transversely seated lateral offset connectors @ T9 & L5. Calibrated spring in-line with the cable @ L5. Scoliosis (CT/Fluoroscopy) induced by varying tension applied to the cable. B) Radiographically measured spring length agreed with caliper measurements ($R^2=0.94$). C) Induced scoliosis is non-linearly related to the applied tether force/bending moment, reflecting a low stiffness functional range (laxity facets, IVD, ligament/muscle) and progressive stiffening effect beyond functional range (facet contact, loading soft tissue restraints).

92. Pulmonary Function in Idiopathic Scoliosis after Fusion and Non-Fusion Surgeries: A Matched Cohort Analysis

Caqlar Yilgor, MD; Baron Lonner, MD; Burt Yaszay, MD; Dan Hoernschemeyer, MD; Stefan Parent, MD, PhD; Peter O. Newton, MD; Ahmet Alanay, MD; Harms Non-Fusion Study Group

Summary

Minimum 2-years follow-up pulmonary function tests (PFT) in idiopathic scoliosis were analyzed in curve-size, correction percentage and baseline PFT-matched cohorts of Vertebral Body Tethering (VBT), Anterior Spinal Fusion (ASF) and Posterior Spinal Fusion (PSF). Surgical approach, technique and location of surgery affected the observed changes in percentages of predicted Forced Vital Capacity (FVC%) and Forced Expiration Volume in one second (FEV1%).

Hypothesis

Pulmonary function differs according to surgical approach and technique

Design

Prospectively collected fusion data and retrospectively collected

non-fusion data

Introduction

Literature suggests superiority of posterior approaches in terms of pulmonary function in idiopathic scoliosis surgery. Effect of VBT surgery on PFTs; however, may differ from historic anterior fusion series. Our aim was to evaluate pulmonary function after VBT, ASF and PSF.

Methods

A multicenter database was queried for JIS and AIS patients having baseline and ≥ 2 y follow-up PFTs. Demographic profile of VBT cases were used to compile ASF and PSF comparative cohorts (Age:8-17y, Risser:0-4, H:130-185cm, W:25-70kg). Upper thoracic, main thoracic and thoracolumbar curve sizes, correction percentages at First Erect as well as baseline FVC% and FEV1% were matched between cohorts. Patients were divided into 3 main (VBT, ASF, PSF) and 6 subgroups including Video-assisted thoracoscopic surgery (VATS)-VBT, Video-assisted thoracotomy (VAT)-VBT, VATS-ASF, open ASF, PSF and PSF with thoracoplasty. Subgroups were further divided using the location of surgery. Paired samples t tests were used to compare baseline and follow-up PFT results within groups.

Results

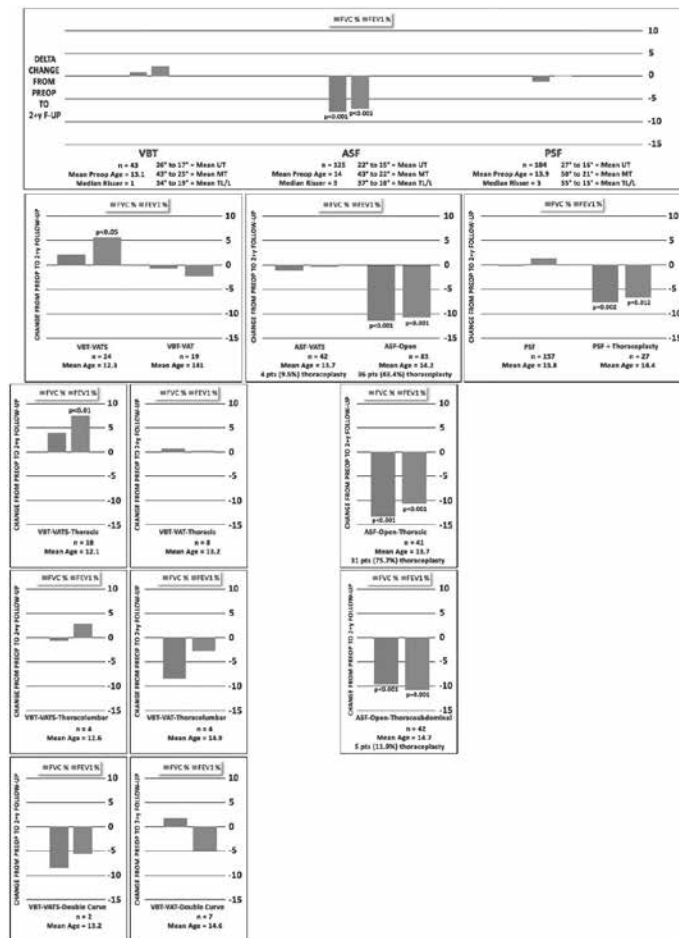
352 patients (302F, 50M) were included in VBT (n=43), ASF (n=125) and PSF (n=184) groups. VBT patients were significantly younger than ASF and PSF patients (13.1, 14 and 13.9, respectively). The time when the follow-up PFTs were obtained was similar between groups (mean 2.6 (2-7.7) years). VBT, in general, did not significantly affect PFT results. Among different approaches, thoracic VATS-VBT resulted in increased FEV1%. ASF, in general, caused decrease in PFT results. Further analysis showed that VATS-ASF preserved both FVC% and FEV1%, while performing thoracotomies with internal thoracoplasty, and thoracoabdominal approaches caused significant decrease. PSF preserved pulmonary function, while addition of external thoracoplasty caused significant decrease (Fig).

Conclusion

VBT, VATS-ASF and PSF were found to preserve pulmonary function. Anterior fusion with thoracotomy and both internal and external thoracoplasties caused deterioration in PFTs.

Take Home Message

Changes in FVC% and FEV1%, 2-years following scoliosis surgery, is dependent on technique, approach and surgical location. VBT, as well as PSF and thoracoscopic-ASF were found to preserve pulmonary function.



93. Quantifying Spine Surgery Among Patients with Morquio's Disease: A Report of 12 Consecutive Cases

Juan S. Uribe, MD; *Fernando Rios, MD*; Oscar Castro, MD; Gregory M. Mundis, MD

Summary

This is a retrospective review of consecutive patients with clinical and genetic diagnosis of Morquio's disease with an associated spine disorder related to Mucopolysaccharidoses, requiring surgical intervention at a single tertiary care center.

Hypothesis

There is a paucity of knowledge in the literature for the management of Morquio's disease (MD). The aim of this study is to present our single center experience in surgical management and complications of this entity.

Design

Retrospective review of consecutive cases

Introduction

Mucopolysaccharidoses (MPS) are a complex group of congenital diseases, caused by a deficit of certain lysosomal enzymes. MD or type IV MPS is characterized by the deficit of N-acetylglactosamine-6-sulfato sulfatase enzyme (GALNS). Occipito-cervical instability and craniocervical congenital anomalies are common with MD.

Methods

We performed a retrospective review of consecutive patients with clinical and genetic diagnosis of MD with an associated spine and/or spinal cord disorder related to MPS that required surgery at a single tertiary care center. A total of 12 patients were identified between 2002-2018. Demographic data, comorbidities, imaging studies, spinal abnormalities, neurological status pre- and post-surgery and intraoperative data were collected on all patients.

Results

19 spinal procedures were performed on 12 patients with 5.9 years of follow up (3-13). Average age at time of surgery was 8.1 (1-19). 41.7% were male, 67% type A and 33% type B MPS. The index surgery for 11/12 patients was an occipito-cervical arthrodesis (OCA) with decompression, and for 1/12 a C2-3 laminectomy and fusion (7 yrs later requiring OCA). 7/12 required 1 additional surgery and 1 patient required 4. Complications occurred in 5/12: 1 vertebral artery dissection, and 4 pseudoarthrosis (2/6 that used ICBG, 1/2 DBM, and 1/1 with allograft; 2/2 patients that used BMP and showed solid fusion). 10/12 saw at least one grade improvement in motor function, 1 with no change and 1 with 1 motor grade worsening. Of 3 that presented with paraparesis, 2 were able to ambulate at follow up.

Conclusion

Despite the high complication rate and revision for pseudoarthrosis, surgical decompression and fusion for occipital cervical instability in patients with Morquio's ultimately results in improvement in motor function and stability

Take Home Message

Careful consideration should be made with patients with Morquio's disease to include the occiput and using BMP when fusion is indicated

94. Spinal Fusion for Spine Deformity in Children with Arthrogryposis Multiplex Congenita

Dietrich Riepen, MD; Brian Wahlig, BS; *Karl E. Rathjen, MD*; Kiley F. Poppino, BS

Summary

Surgical management of scoliosis in Arthrogryposis Multiplex Congenita (AMC) is associated with high complication and reoperation rates.

Hypothesis

Surgical management of scoliosis in Arthrogryposis Multiplex Congenita (AMC) is associated with high complication and reoperation rates.

Design

Retrospective Case Series

Introduction

This study describes complications associated with spinal fusion for scoliosis in patients with AMC.

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Methods

IRB-approved retrospective chart review of all pediatric AMC patients treated with spinal fusion between 1990-2017. Patients treated with growing rods were excluded.

Results

Of 417 patients with AMC, 87 had scoliosis (20.9%) and 26 had scoliosis surgery. After excluding 5 patients who received growing rods, the remaining 21 patients were 57.1% male and 71.4% Caucasian. 71.4% had arthrogryposis not otherwise specified, 19.1% had amyoplasia, and 9.5% had distal arthrogryposis. G-tube was present in 23.8%, and 9.5% had a tracheostomy. Preoperative halo traction was used in 33.3% for a median of 39 days (range 29-1023). At spinal fusion, mean age was 12.5 years (range 6.3-17.2) and mean BMI was 17.1 (range 11.9-23.7). 14/21 (66.7%) underwent posterior spinal fusion (PSF) while 7/21 (33.3%) underwent combined anterior/posterior spinal fusion (ASF/PSF). Average percent correction of major coronal plane curve Cobb angle was 35.4%. Overall, 9/21 (42.8%) had at least one complication, specifically 3/14 PSF patients (21.4%) and 6/7 ASF/PSF patients (85.7%). Early (<90 days) complications included deep infection (6/21, 28.6%), superficial wound dehiscence (2/21, 9.5%), prolonged ICU admission >72 hours (1/21, 4.8%), and pneumothorax requiring reoperation (1/21, 4.8%). Late complications included symptomatic hardware (2/21, 9.5%), hardware failure (1/21, 4.8%), distal junctional kyphosis (1/21, 4.8%), and coronal plane progression requiring extension of fusion (1/21, 4.8%). All 9 patients with complications required reoperation, with a mean of 3.6 reoperations (range 1-10). 6/9 (66.7%) required reoperation within 30 days.

Conclusion

Complication rates after spinal fusion for spine deformity in arthrogryptic patients are high, especially in patients undergoing ASF/PSF. Deep infection is common, and curve correction is modest.

Take Home Message

Complication rates after spinal fusion for spine deformity in arthrogryptic patients are high, especially in patients undergoing ASF/PSF. Deep infection is common, and curve correction is modest.

95. Complications of the Magnetically Controlled Growing Rod vs. the Spring Distraction System in the Treatment of Early Onset Scoliosis

Justin V. Lemans, MD; Casper S. Tabeling, MD; René M. Castelein, MD, PhD; Moyo C. Kruyt, MD, PhD

Summary

In EOS patients treated with a Magnetically Controlled Growing Rod (MCGR) or Spring Distraction System (SDS), respectively 71% and 61% of patients suffered from at least 1 complication, with a follow-up adjusted complication rate of 0.35 (MCGR) and 0.33 (SDS) complications/patient/year. The most common complication in the MCGR group was failure to lengthen, for the SDS group, this was implant prominence. Annual implant growth was

significantly higher in the SDS group (10.1 mm/year), compared to the MCGR group (6.3 mm/year).

Hypothesis

MCGR and SDS have comparable complication rates and complication profiles.

Design

Comparative cohort study

Introduction

In Early Onset Scoliosis (EOS), magnetically controlled growing rods (MCGRs) offer non-invasive distractions. However, implant-related complications are common, which adversely affects its cost-effectiveness. We developed the Spring Distraction System (SDS), a growth-friendly concept that exerts continuous distraction forces with a helical spring. The current study compares complication rate and-profile between EOS patients treated with the MCGR or the SDS.

Methods

This single-center retrospective study compared consecutive EOS patients treated with either MCGR or SDS between 2013-2018. Baseline demographics, and data regarding implant- or procedure-related complications, as well as cumulative implant growth were measured by 2 independent observers. Complication rate, complication profile, complication-free survival and implant growth were compared between groups.

Results

Fourteen MCGR patients (4.1 year follow-up) and 18 SDS patients (3.0 year follow-up) were included. The groups were similar with respect to age, sex, etiology, BMI and pre-operative Cobb angle. Follow-up adjusted complication rate was 0.35 complications/patient/year for MCGR patients and 0.33 complications/patient/year for SDS patients. Complications can be observed in Table 1. The most common complication in the MCGR group was failure to distract (8/20 complications). For the SDS group, this was implant prominence (5/18 complications). Median complication-free survival was 2.6 years, with no difference between groups ($p=0.673$). Annual implant growth was significantly higher in the SDS group (10.1 mm/year), compared to the MCGR group (6.3 mm/year).

Conclusion

Complications are common in both MCGR and SDS treatment, with a median time to complication of 2.6 years. The high incidence of failure to distract leads to significantly reduced spinal growth in MCGR patients compared to their SDS counterparts.

Take Home Message

While MCGR and SDS have a comparable follow-up adjusted complication rate, MCGR complications often lead to malfunctioning of the implant, ultimately leading to lower annual growth compared to SDS.

	MCGR	SDS
Neurological injury	1	0
Anchor complications	4	3
Proximal anchor	2	0
Apical anchor	1	0
Distal anchor	1	3
Rod complications	2	4
Rod fracture	2	3
Rod slippage	0	1
Failure to distract	8	2
MCGR actuator failure	8	0
Side-to-side connector failure	0	2
Rod growing out of connector due to fast growth	0	1
Proximal junctional kyphosis	3	0
Implant prominence	0	5
Wound dehiscence	0	1
Superficial SSI	1	0
Deep SSI	0	1
Late superficial SSI	1	1
Total number of complications	20	18
Complications per patient	1.4	1.0
Complications per patient per year	0.35	0.33

Table 1: Incidence of implant- or procedure-related complications

96. Increased Age-Adjusted Body Mass Index (BMI) is Associated with Higher Risk of Postoperative Complications in Neuromuscular Scoliosis (NMS) Surgery

Chun Wai Hung, MD; Lorenzo Deveza, MD, PhD; Dallas Vanorny, MD, PhD; Frank T. Gerow, MD; William A. Phillips, MD; Darrell S. Hanson, MD; Benny T. Dahl, MD, PhD, DMSci

Summary

Higher age-adjusted BMI is associated with increased complications.

Hypothesis

Age-adjusted BMI z-score is statistically associated with increased risk of complications in NMS.

Design

Retrospective cohort

Introduction

Higher rates of complications have been associated with surgical scoliosis correction for those with neuromuscular scoliosis. BMI has been identified as a possible predictor for complications. BMI-for-age calculated with the appropriate z-score may be a more accurate assessment. To date, no studies have examined the relationship between age-adjusted BMI (BMI z-score) with complications in neuromuscular scoliosis surgery. The goal of this study is to examine the association of age-adjusted BMI with risk of postoperative complications.

Methods

This is a single center retrospective review of all pediatric patients undergoing spinal instrumentation for neuromuscular scoliosis during a four-year period from July 2012 to June 2016 with minimum 2 years follow-up. BMI and BMI z-scores (age-adjust-

ed) were calculated. Logistic regression analyses of the association between BMI Z-score, and weight Z-score and complications were performed. Significance was assumed at $p < 0.05$.

Results

147 NMS patients (13.1+3.5yo, 54% female) were identified. BMI z-score was associated with a statistically significant increased risk of SSI (surgical site infection) (OR = 1.5, CI [1.1 – 2.9], $p=0.008$), deep SSI (OR 2.0, CI [1.0 – 4.3], $p=0.04$), but not superficial SSI. BMI z-score was also statistically associated with readmission in 30 days (OR 1.7, CI [1.1-3.1], $p=0.03$), return to OR in 90 days (OR 1.8, CO [1.1-3.4], $p=0.03$), and ER in 90 days (OR 1.5, CI [1.0 – 2.4], $p=0.05$). BMI z-score was associated with lower risk of pneumonia (OR 0.8, CI [0.5-1.1], $p=0.04$). Weight z-score was associated with SSI risk (OR 1.3, CI [0.6-1.3], $p=0.04$).

Conclusion

Age-adjusted BMI is associated with increased risk of surgical site infection, return to OR, and ER. BMI has a role in predicting a patient's nutritional status and ability to both heal from surgery and the risk of developing complications. The age-adjusted-BMI, may be a more valuable screening tool for optimizing patients prior to surgical intervention.

Take Home Message

Higher age-adjusted BMI is associated with increased complications.

BMI z-score Logistic Regression Analysis

	OR	CI-lower	CI-upper	p-value
All Complications	1.022	0.784	1.352	0.406
Mortality in 30 days	1.417	0.514	8.803	0.842
Mortality in 1 year	1.039	0.552	2.878	0.945
SSI	1.496	1.078	2.859	0.008
SSI Deep	1.983	1.042	4.286	0.0389
SSI Superficial	1.338	0.803	2.52	0.13
Loss of Signals	0.765	0.529	1.148	0.875
Pneumonia	0.766	0.516	1.142	0.0411
Readmission in 30 days	1.74	1.055	3.144	0.0344
Return to OR in 90 days	1.81	1.057	3.414	0.026
ER in 90 days	1.525	1.036	2.433	0.05
Failure in 1 year	1.948	0.75	6.667	0.116

97. The Influence of Viral Respiratory Season on Perioperative Outcomes in Children Undergoing Spinal Fusion Surgery for Neuromuscular Scoliosis

Nicholas P. Gannon, MD; Zachary A. Quanbeck, MD; Daniel J. Miller, MD

Summary

Analysis of a national pediatric inpatient dataset suggests that spinal fusion surgery for neuromuscular scoliosis in children is associated with a higher rate of respiratory failure, but not in-hospital mortality, when performed during peak viral season (November–March).

Podium Abstracts

Hypothesis

Spinal fusion for neuromuscular scoliosis in children has an increased risk of pulmonary complications and mortality when performed during peak respiratory viral season.

Design

Retrospective review of a national pediatric hospital inpatient database.

Introduction

Complications are common following spinal fusion for neuromuscular scoliosis. Concern exists as to whether it is safe to perform these complicated procedures in winter months when viral respiratory illness is more common.

Methods

The Health Care and Utilization Project (HCUP) Kids' Inpatient Database (KID) from 2006-2012 was reviewed. Children 20 years or younger who underwent spinal fusion for neuromuscular scoliosis were included. Patients were grouped by date of surgery during peak (November-March) or non-peak (April-October) viral season. Continuous variables were compared using t-tests and categorical variables were compared using the Rao-Scott Chi-square test. Weighted logistic regression models were performed.

Results

This study identified 5,082 records, including 1,711 and 3,371 patients who had surgery in peak and non-peak viral seasons, respectively. Patients who had spinal fusion during peak viral season were more likely to experience respiratory failure ($p=0.0008$) but did not demonstrate an increased incidence of aspiration pneumonia ($p=.26$) or mortality ($p=0.68$) (Table 1). Respiratory failure was associated with age at time of surgery ($p=0.0031$), tracheostomy ($p<0.0001$), and number of chronic conditions ($p<0.0001$). In-hospital mortality was associated with number of chronic conditions ($p<0.0001$).

Conclusion

Spinal fusion for neuromuscular scoliosis in children performed during peak viral season has a higher risk of respiratory failure without an increased risk of mortality or other complications.

Take Home Message

Spinal fusion surgery for neuromuscular scoliosis in children is not associated with increased in-hospital mortality when performed during peak viral season (November–March).

Variable	All Participants (n=5,082)	Season of Surgery		p-value
		Peak Viral (Nov-Mar; n=1711)	Non-peak Viral (Apr-Oct; n=3371)	
Demographics				
Age, mean (SE)	13.7 (0.06)	13.8 (0.08)	13.7 (0.07)	0.45
Hospital Region				0.47
Northeast	743 (14.6%)	261 (15.3%)	481 (14.3%)	
Midwest	1386 (27.3%)	482 (28.2%)	904 (26.8%)	
South	1587 (31.2%)	498 (29.1%)	1089 (32.3%)	
West	1366 (26.9%)	469 (27.4%)	896 (26.6%)	
Has Tracheostomy	189 (3.7%)	62 (3.6%)	127 (3.8%)	0.83
Number of chronic conditions, mean (SE)	5.02 (0.07)	4.99 (0.11)	5.03 (0.08)	0.71
Outcomes				
In-hospital Mortality	267 (5.3%)	94 (5.5%)	173 (5.1%)	0.68
Aspiration Pneumonia	80 (1.6%)	21 (1.2%)	58 (1.7%)	0.26
Respiratory Failure	1670 (32.9%)	502 (29.3%)	1168 (34.6%)	0.0008
Any respiratory complication	666 (13.1%)	213 (12.5%)	453 (13.4%)	0.44
Length of stay (days), mean (SE)	9.5 (0.26)	9.7 (0.36)	9.5 (0.31)	0.61
Total charges, mean (SE)	\$188,697 (6785.7)	\$183,096 (7974.8)	\$191,507 (7191.9)	0.26

Table 1: Weighted demographic & outcome information overall and by season of surgery (table displays weighted n and percent unless otherwise specified)

98. Intrusion of the Spine into the Chest Causes Airway Narrowing and Impaired Lung Function in AIS

James A. Farrell, PhD; Enrique Garrido, MD; Ludvig Vavruch, MD, PhD; *Tom P. Schlösser, MD, PhD*

Summary

3-D airway dimensions, chest deformity, lung volumes and lung function were evaluated on preoperative CT scans of thoracic AIS patients to better understand the mechanisms behind lung function impairment in severe deformity. It demonstrated that spinal chest intrusion often causes narrowing of right-sided bronchi to the middle and lower lobe in thoracic AIS, especially in hypokyphotic patients. The restrictive and obstructive ventilatory dysfunction correlates with rib hump size, intrusion of the endothoracic hump and narrowing of the right hemithorax.

Hypothesis

Ventilatory dysfunction in AIS patients is not only restrictive, but frequently has an obstructive element as a result of spinal chest intrusion.

Design

Retrospective, multicenter cohort study.

Introduction

Right-sided bronchial narrowing has been reported in thoracic AIS. The aim of this study is to describe the relation of chest and spinal deformity parameters, bronchial narrowing and lung volumes with pulmonary function in preoperative AIS.

Methods

Spinal radiographs, low-dose CT scans of the spine including the chest and pulmonary function tests were retrospectively collected for 85 preoperative thoracic AIS patients in two centers and compared to 14 matched controls. 3-D lung and airway reconstructions were acquired. Correlation analysis was performed between radiographic spinal parameters, CT-based chest deformity parameters (rib-hump index (RHi), spinal penetration index, endothoracic hump ratio, hemithoracic-width ratio), lung volume asymmetry and bronchial diameters vs. percent-predict-

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ed spirometry results.

Results

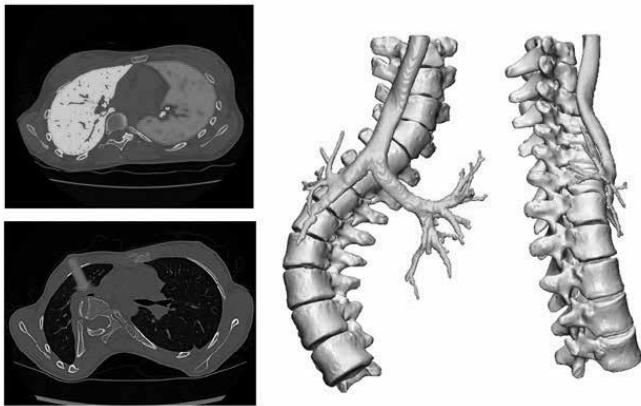
41 (48%) patients had a FEV1% or FVC% below 65% and 17 (20%) had obstructive lung disease. All chest deformity parameters correlated significantly with FEV1% and FVC%, RHi was the strongest correlate ($r_s = -0.52$ and -0.54 respectively). AIS patients with impaired pulmonary function had a smaller thoracic kyphosis, larger rib hump, increased spinal and thoracic rotation, a narrower right hemithorax and increased intrusion of the spine into the chest. Increased spinal intrusion correlated with right-sided bronchial narrowing, relative right lung volume loss and decreased FEV1% and FVC%. Multivariate regression including spinal and thoracic deformity parameters, lung volume asymmetry and airway parameters could explain 57% of the variance in FEV1% and 54% of FVC%.

Conclusion

Chest intrusion by the endothoracic hump is related to right-sided bronchial narrowing and lung function loss in preoperative AIS. The findings support that ventilatory dysfunction in thoracic AIS is not only restrictive but frequently has an obstructive component, especially in patients with hypokyphosis. RHi is the most predictive chest parameter for lung function loss.

Take Home Message

Spinal intrusion and endothoracic hump formation in AIS is linked to hypokyphosis and can cause right-sided airway narrowing and FEV1% loss in preoperative AIS patients.



3-D CT.

99. Impact of Low vs. High Implant Density on Perioperative Parameters and Estimated Surgical Cost for Lenke 1A AIS Patients

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Summary

Lenke 1A AIS patients who underwent posterior spinal instru-

mented fusion were randomized to more screws (implant density > 1.8 screws per level fused) vs. fewer screws (implant density < 1.4). There was no statistically significant difference in operative time, blood loss, or length of stay, or coronal/sagittal Cobb angle as previously reported. There was an estimated 27% implant hospital cost savings in the low vs. high implant density cohort.

Hypothesis

For Lenke 1A curves patterns treated with posterior instrumented fusion, use of more vs. fewer screws would result in reduced operative time, blood loss, length of stay, and estimated implant cost.

Design

Subanalysis of prospective multicenter randomized trial.

Introduction

Implant costs are reported to comprise up to 25-40% of the total AIS surgical costs. This clinical trial subanalysis evaluated patients with Lenke 1A curve patterns who were randomized to more vs. fewer screws (high or low density). We sought to determine if assignment to the low implant density resulted in decreased operative time, blood loss, estimated hospital implant costs, and length of stay.

Methods

At 14 sites, patients with Lenke 1A curves between 45-65 degrees were randomized to a high- (>1.8 screws per level fused, HD) vs. low- (<1.4 screws per level fused, LD) implant density. Patients were followed prospectively for 2 years. Screw cost was set at \$750, and varied from \$350 to \$1000 on sensitivity analysis. Implant costs were assumed to comprise 26% of total Medicare-normalized surgical costs (Baky et al., 2020).

Results

There was no difference in age, gender, preop curve magnitude, or race between the 2 groups. Similarly, there was no difference in operative time, blood loss, or length of stay. On multivariate analysis, study site was predictive of operative time, ($p < 0.001$), length of stay ($p < 0.0001$) but not blood loss. Number of levels fused correlated with surgical time ($p = 0.002$). Estimated implant costs were \$14.6K (SD 2.1K) in the HD cohort vs. \$10.6K (SD 1.4K) in LD cohort ($p < 0.0001$), and on sensitivity analysis varied from \$7K vs. \$5K with low cost screws and \$14K vs. \$19.5K with assumption of high cost screws, resulting in 27% implant hospital cost savings and overall 8% perioperative cost savings.

Conclusion

For Lenke 1A curves between 45-65 degrees treated with low- vs. high implant density, there was no noted difference in EBL, operative time, LOS, or 2-year coronal curve correction as previously reported, but a nearly 27% estimated savings in implant costs or estimated 8% reduction in overall perioperative costs.

Take Home Message

Implant density did not to impact operative time and LOS, which varied primarily by site. A mean estimated 27% implant cost savings was achieved in the low implant density cohort.

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Overall Perioperative Results

	High Density	Low Density	P-Value
Operative Time	210 (70)	207 (70)	0.74
Levels Fused	11 (7-15)	10 (7-13)	0.16
Reoperation	5	6	0.46
EBL (ml)	522	545 (43)	0.65
Length of Stay (days)	4.1 (1.8)	3.9 (1.3)	0.39
Estimated Implant Cost (SD)	\$14.6K (2.1)	\$10.6K (1.4)	<0.0001
Estimated Implant Cost, Low (SD)	\$7K (1.0)	\$5K (0.7)	<0.0001
Estimated Implant Cost, High (SD)	\$19.5K (2.8)	\$14K (1.9)	<0.0001

100. Adolescent Athletes Return to Sports Rapidly after Posterior Spine Fusion (PSF) For Idiopathic Scoliosis (AIS)

Tyler Tetreault, MD; Hannah Darland, BA; Angela Vu, BS; Patrick Carry, MS; Sumeet Garg, MD

Summary

No consensus exists regarding return to sports for patients with AIS treated with PSF. The purpose of this study was to determine how rapidly athletes return to baseline sports activity following PSF for AIS using validated patient reported outcome measures. When released to unrestricted activity at 4-8 weeks, athletes rapidly return to baseline levels of sports performance, with over half achieving this metric by 3 months. PROMIS physical activity and pain scores improve in the first 12 months after surgery.

Hypothesis

Athletes undergoing PSF will return to baseline levels of sports performance within 3 months post-operatively.

Design

Prospective cohort study

Introduction

No consensus exists regarding timing for return to sports for patients with adolescent idiopathic scoliosis (AIS) treated with posterior spine fusion (PSF). Our program allows unrestricted return to sports after a 6-week post-operative appointment.

Methods

Athletes meeting inclusion criteria were consecutively enrolled. Inclusion criteria included competition at a junior varsity level or greater for > 3 months yearly, major Cobb angle of 40-75°, age 10-18 years, and one year of follow-up. Athletes completed pre-operative sports performance and Patient Reported Outcomes Measurement Information System (PROMIS) physical activity, pain interference, and depressive symptoms questionnaires. Self-assessments were repeated monthly until one year after PSF.

Results

A total of 26 athletes were enrolled. The median time to return to sport was 2.7 months [range: 0.6 to 13 months]. At twelve months, 90.1% [95% CI: 36.9 to 74.9%] of the athletes reported they had returned to sport at their presurgical level of play. Participation in contact sports was associated with a longer return to sport relative to participation in non-contact/limited contact

sports [Hazard Ratio: 0.37, 95% CI: 0.14 to 0.97, p=0.0427]. There was a significant increase in PROMIS physical activity scores [mean change per month: 0.77, 95% CI: 0.35 to 1.19, p=0.0004], decrease in the odds of a symptomatic pain interference score [Odds Ratio (OR) per month: 0.75, 95% CI: 0.58 to 0.96, p=0.0208], and an increase in the odds of a symptomatic depressive symptom score [OR per month: 1.18, 95% CI: 1.01 to 1.39, p=0.0421] during the first twelve months after surgery. Conditioning and flexibility were the most common barriers to returning to sport.

Conclusion

Adolescent athletes return to pre-surgical level of sports rapidly following PSF for AIS without any apparent associated complications during the first year post-op.

Take Home Message

Early unrestricted return to sports should be permitted for adolescent athletes after PSF For AIS.

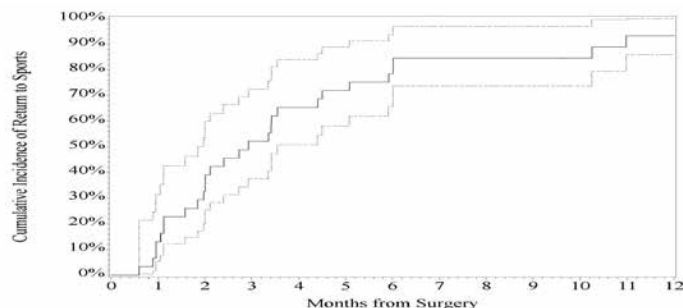


Figure 1. Cumulative Incidence of Return to Sports During the First Post-Operative Year

101. Pregnancy and Childbirth after Adolescent Idiopathic Scoliosis Surgery: A Study of 80 Pregnancies

Léonard Chatelain, MD; Laura Marie-Hardy, MD; Marc Khalifé, MD; Glorion Christophe, PhD; Christian Garreau de Loubresse, MD, PhD; Pierre Guigui, MD; Emmanuelle Ferrero, MD, PhD

Summary

This study aims at characterizing the course of pregnancy and childbirth after a spinal fusion for Adolescence Idiopathic Scoliosis (AIS), in terms of access to epidural anesthesia, delivery modalities and low back pain. Fifty patients were reviewed, for a total of 80 pregnancies, from 1988 to 2018. Of the 80 pregnancies, 83.8% were delivered by the vaginal route, and a functional epidural anesthesia was performed for 48.8% of the pregnancies. Back pains were attributed to about half of the pregnancies.

Hypothesis

Patients who underwent spinal fusion for AIS experience a pregnancy similar to the general population, in terms of access to spinal block, delivery modalities and low back pain.

Design

Retrospective, multicentric study.

Introduction

AIS is a common spinal disease affecting 2% of adolescents and

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women in 90% of the cases. When a surgical treatment is opted for, many questions are frequently asked by families and patients about the course of pregnancy after spinal fusion. This subject remains debated, and has never been studied with modern AIS correction techniques.

Methods

In this study, 428 women who underwent surgery between 1977 and 2014 were reviewed from two university hospitals. Among them, 50 women had pregnancy, for a total of 80 pregnancies. Occurrence of low back pain during pregnancy and at follow-up were recorded using ODI. Surgical data were collected (approach, last instrumented vertebra (LIV)...). Pregnancy characteristics were evaluated (number of births, anesthesia, type of delivery...).

Results

Of the 50 women, 34 had posterior surgery and 16 anterior surgery. The deliveries took place from 1988 to 2018. Of the 80 pregnancies, 83.8% were delivered by the vaginal route, and a functional epidural anesthesia was performed for 48.8% of them. Among the reasons for not having access to a spinal block, half were due to a direct refusal by the anesthesiologist. When the neuraxial anesthesia could be placed functionally, it was effective 92.3% of the time. Only 7 pregnancies suffered complications. Back pains were attributed to about half of the pregnancies. The level of fusion was correlated with the realization of a C-section, and conversely with access to the epidural anesthesia.

Conclusion

The rate of neuraxial anesthesia for childbirth is 80% on average, which is far from the rate obtained in this study. The more the LIV is caudal, the more difficult the spinal block is. The epidural analgesia is thus reduced from 53% in L2 to 40% in L4, with a minimum of 25% in L5. Moreover, back pain during pregnancy also increases with the LIV (32% in L2, 60% in L4). The C-section rate is similar to that of the general population in France (16,4%).

Take Home Message

Although a normal pregnancy with vaginal delivery seems to be the rule for women undergoing spinal fusion for AIS, access to epidural anesthesia still seems to be problematic.

102. Validation of Patient-Reported Outcomes Measurement Information System (PROMIS) Computerized Adaptive Testing (CATs) for Children with AIS

Stuart L. Mitchell, MD; Kevin McLaughlin, PT, DPT; Keith Bachmann, MD; Reider Lisa, PhD; Paul D. Sponseller, MD

Summary

In pediatric-aged patients with adolescent idiopathic scoliosis, the Patient-Reported Outcomes Measurement Information System (PROMIS) computerized adaptive testing (CAT) measures may offer advantages over the gold-standard SRS-22r. Using data from 200 prospectively-enrolled patients, we found evidence to support the use of 6 PROMIS CATs in children at all stages of treatment for AIS. PROMIS Mobility, Anxiety, Depressive Symptoms, Physical Stress Experiences, Pain Behavior, and Pain Inter-

ference all correlated moderately or strongly with their complementary SRS domains and weakly with unrelated domains.

Hypothesis

Pediatric PROMIS CATs are valid for use in children with AIS.

Design

Cross-sectional validation study

Introduction

Our objective was to assess the validity of 8 pediatric Patient-Reported Outcomes Measurement Information System (PROMIS) computerized adaptive testing (CATs) measures among children with AIS.

Methods

200 children ages 10–17 with AIS completed 8 PROMIS CATs (Table) and SRS-22r on iPads. Treatment categories were: observation (24%), bracing (47%), indicated for PSF (16%), and status-post PSF (13%). ANOVA was used to determine differences by treatment category (known group analysis). Spearman correlation coefficients (r) were calculated between complementary domains of PROMIS and SRS (convergent validity) and between unrelated PROMIS CATs (discriminant validity).

Results

On known group analysis, there were significant differences in PROMIS Mobility, Physical Stress Experiences, Pain Behaviors, and Pain Interference and all SRS domains ($P < 0.05$) except for Mental Health ($P = 0.15$). All PROMIS CATs were moderate-to-strongly correlated ($|r| \geq 0.57$) with their complementary SRS domains (Table) except PROMIS Physical Activity was weakly correlated with SRS Function ($r = 0.34$) and PROMIS Peer Relationships correlated weakly with SRS Self-Image ($r = 0.33$). All unrelated PROMIS CATs were only weakly correlated ($|r| < 0.40$).

Conclusion

We found evidence supporting 6 PROMIS CATs to evaluate PROs in children with AIS. PROMIS Mobility, Anxiety, Depressive Symptoms, Physical Stress Experiences, Pain Behavior, and Pain Interference all correlated moderately or strongly with their complementary SRS domains and weakly with unrelated domains. Additionally, PROMIS Mobility, Physical Stress Experiences, Pain Behaviors, and Pain Interference were all able to differentiate among patients undergoing different forms of treatment (known groups).

Take Home Message

This study supports the use of 6 PROMIS CATs to evaluate patient-reported outcomes in children with AIS within domains of physical function, mental health, and pain.

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PROMIS CAT	SRS Function	SRS Mental Health	SRS Pain	SRS Self-Image
Physical Activity	0.34*			
Mobility	0.64*			
Anxiety		-0.62*		
Depressive Symptoms		-0.72*		
Physical Stress Experiences			-0.57*	
Pain Behaviors			-0.71*	
Pain Interference			-0.72*	
Peer Relationships				0.33*

Table. Convergent validity analysis of PROMIS CATs and complementary SRS-22r domains. Note: (*) designates significant value ($P < 0.05$) indicating domains are not independent; negative values indicate an inverse relationship.

103. Shorter and Sweeter: The 16-Item Version of the SRS-Questionnaire Shows Better Structural Validity Than the 20-Item Version in Young Patients with Spinal Deformity

Anne F. Mannion, PhD; Achim Elfering, PhD; Tamas Fulop Fekete, MD; Ian J. Harding, MD, FRCS; Marco Monticone, MD; Peter M. Obid, MD; Thomas Niemeyer, MD; Alba Vila-Casademunt, MS; Francisco Javier S. Perez-Grueso, MD; Javier Pizones, MD, PhD; Ferran Pellisé, MD, PhD; Sarah Richner-Wunderlin, MS; Laura Zimmerman, BS; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Juan Bago, MD, PhD

Summary

Previously, in patients with adult spinal deformity, 16 of the non-management items of the SRS-questionnaire showed a better fit to the theoretical four-factor model than did all 20 items. Here, we analysed whether this was also true for younger (<20y) deformity patients. Confirmatory factor analyses on 3270 datasets revealed weak loading for the same items (3,14,15,17) as previously identified. We recommend these be removed, to provide a shorter, improved version of the SRS instrument for use with all deformity patients.

Hypothesis

A 16-item version of the SRS-instrument fits the four-factor structure of the SRS-questionnaire in young deformity patients better than does the original 20-item version.

Design

Cross-sectional evaluation of the SRS-22 structure and its equivalence across different language versions in young (<20y) deformity patients.

Introduction

Previously, in patients with adult spinal deformity, 16 of the non-management items of the SRS-22-questionnaire showed a significantly better fit to the theoretical four-factor model (pain, function, self-image, mental health) than did all 20 items. The worst-fitting item per domain was recommended for exclusion (respectively: Q17, sick days; Q15, financial difficulties; Q14 personal relationships; Q3, nervous). Whether the same phenomenon is observed in data from younger (<20y) patients, for whom the questionnaire was originally designed, is not known.

Methods

Confirmatory factor analysis was performed on the 20 non-management items of the SRS-questionnaire completed by 3271 adolescents with spinal deformity (2746 English-speaking, 206 Spanish, 223 Italian, and 96 German; 75% female; mean age, 14.8 ± 2.2 y), to compare the relative fit of the data to a single-factor, 20-item 4-factor, and 16-item 4-factor structure. Item loading and the goodness of fit were determined from the root mean square error of approximation (RMSEA) and the comparative fit index (CFI). Equivalence of item-loading was compared across languages.

Results

Compared with the 20-item version, the 16-item solution significantly increased the fit ($p < 0.001$) across all language versions, to achieve good model fit (CFI=0.96, RMSE=0.06; Figure). For both 16-item and 20-item models, equivalence across languages was not reached, with some items showing weaker item-loading for some languages.

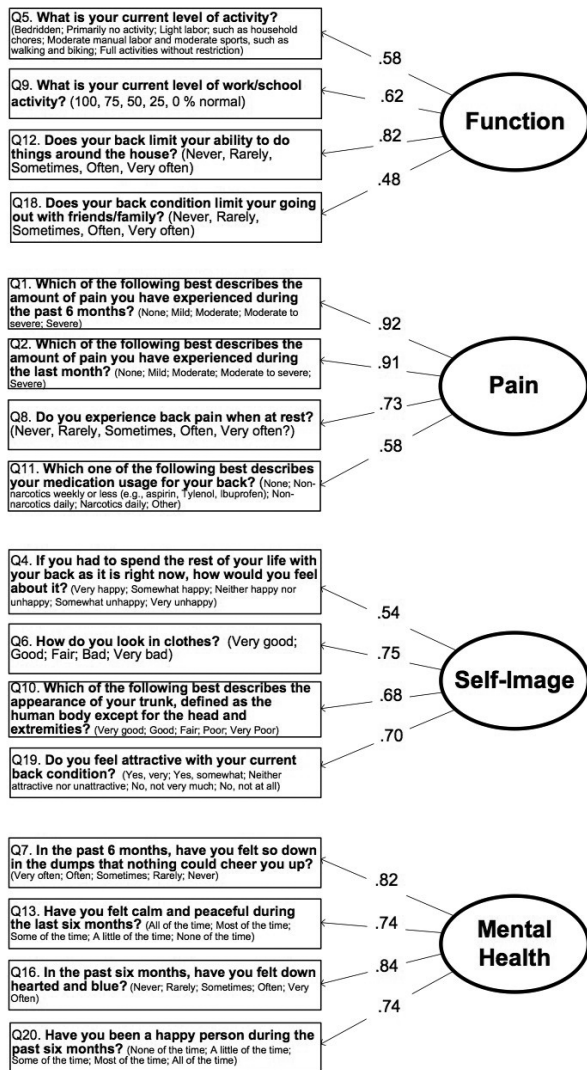
Conclusion

Also in patients with adolescent idiopathic scoliosis, the shorter version of the SRS-questionnaire shows a better fit to the intended 4-factor structure. Questionnaire completion can be a burden for patients; if a shorter, more structurally valid version is available, it should be implemented throughout.

Take Home Message

Use of this shorter, more structurally valid version of the SRS-instrument, with removal of ill-fitting items, should deliver more meaningful information on patient-reported outcomes whilst reducing the burden on patients.

16 SRS



CFA, 16 items

104. Actual Condition and Characteristics of Back Pain in Non-Operative Patients with Adolescent Idiopathic Scoliosis

Kei Watanabe, MD, PhD; Masayuki Ohashi, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD

Summary

The scoliosis group experienced significantly more severe pain with longer duration as well as more frequent recurrences, and showed significantly back pain in the upper right and middle back compared to the no scoliosis group.

Hypothesis

Patients with adolescent idiopathic scoliosis (AIS) complaint of more back pain in specific regions compared to adolescents without AIS.

Design

Retrospective case-control study

Introduction

There have been a few studies regarding detail of back pain in AIS as prevalence, location, and severity.

Methods

A total of 144 female patients with AIS who underwent corrective fusion from 2008 to 2019 were included (scoliosis group). Questionnaire surveys regarding back pain were conducted before surgery. Healthy 2,910 pupils in the third year of junior high school were selected as a control (no scoliosis group).

Results

Mean main thoracic and thoracolumbar/lumbar curves were $52.5 \pm 14.2^\circ$ and $29.3 \pm 11.9^\circ$, respectively. Characteristics of back pain (scoliosis group / no scoliosis group) showed the lifetime prevalence (61.1%/27.5%)(OR, 4.14; $P < 0.001$), experiences of longer duration (≥ 3 months) (10.4%/3.6%)(OR, 3.12; $P = 0.0005$), frequent recurrences (46.5%/19.1%)(OR, 3.68; $P < 0.001$), and absence from school life (7.6%/2.0%)(OR, 4.01; $P = 0.0004$). Regarding pain location, the scoliosis showed significantly more back pain in the right upper and middle back compared to the no scoliosis group (Table).

Conclusion

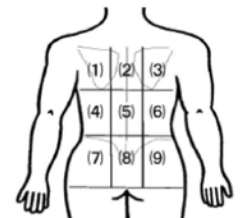
These findings suggest that there may be a relationship between pain around the right scapula and the rib hump that is common in AIS.

Take Home Message

AIS patients show disease specific back pain that is related to the rib hump deformity.

Table Location of back pain among pupils with the lifetime prevalence

	Scoliosis group		No scoliosis group		P value
	N = 88	N = 734	No.	%	
Location of the severest back pain					
Region 1 (upper left)	4	4.5	27	3.7	0.6945
Region 2 (upper centre)	5	5.7	31	4.2	0.5429
Region 3 (upper right)	12	13.6	39	5.3	0.0065
Region 4 (middle left)	15	17.0	31	4.2	<0.0001
Region 5 (middle centre)	12	13.6	127	17.3	0.3742
Region 6 (middle right)	8	9.1	25	3.4	0.0236
Region 7 (lower left)	9	10.2	91	12.4	0.5476
Region 8 (lower centre)	16	18.2	360	49.0	<0.0001
Region 9 (lower right)	7	8.0	93	12.7	0.1784



Location of back pain among pupils with the lifetime prevalence

105. Patient Specific Rods for AIS Surgery Prevent Junctional Decompression

Kariman Abelin Genevois, MD; Davide Sassi, MD; Thomas Chevillotte, MD; Pierre Grobost, MD

Summary

Customized implants reduce bone-screw constraints as they perfectly match within individual anatomy and spino pelvic alignment. Although customized rods have been commercialized in the early 2010, their application to AIS 3D deformity remains confidential. As we developed a new classification system describing the different sagittal patterns AIS produces, surgical guidelines have been derived in order to enhance sagittal correc-

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tion in AIS.

Hypothesis

Guidelines given by the AIS sagittal classification leads to predictable and adequate restoration of sagittal profile and reduce junctional kyphosis.

Design

Monocentric prospective study with minimum 2 years follow-up

Introduction

Patient specific rods (PSR) are specifically bent and adjusted according to the "ideal" sagittal alignment of the patient based of preoperative planning. This technology has been developed for the management of adult spinal deformity in order to allow a proper restoration of spino pelvic balance. Adolescent Idiopathic Scoliosis is a tridimensional deformity and requires a suspended correction of the thoracic or thoracic lumbar spine. The main goals of surgery are coronal balance and sagittal restoration or maintenance of thoracic kyphosis. While frontal realignment is well understood, the amount and distribution of TK is still debated.

Methods

All patients surgically treated for AIS using PSR, starting from April 2017 were included. All PSR were implanted without any modification. Radiographic frontal and sagittal spino pelvic parameters were evaluated pre and postoperatively. Patients were stratified according to their final sagittal alignment (Abelin Genevois classification). SRS 22 questionnaires were completed pre and post operatively at final follow up. PJK and DJK incidence were estimated.

Results

Seventy eight patients followed at least one year were consecutively enrolled in this study (mean age 16,7 years; mean Cobb angle 55°). Forty five patients completed clinical and radiographic follow up of minimum 2 years. SRS 22 Score was significantly higher at final FU (from 3.48 to 4,18). Main Cobb angle correction was 61%. While preoperative sagittal pattern was pathological in 57%, all patients achieved a sagittal type 1. None experienced PJK. One patient developed DJK requiring revision due to a level mistake (transitional vertebral anomaly). Mean T4T12 TK was corrected from 20,3° to 30,2°. The correction was highly faithful to the preoperative planning (planned TK : 31,6°) as for LL.

Conclusion

Patient specific rods for AIS surgery achieved and maintained a satisfactory sagittal alignment and clinical outcome, with almost no PJK at 2 years follow up.

Take Home Message

By strictly applying the correction principles of the AIS sagittal classification, use of PSR allows to faithfully reproduce the preoperative simulation of sagittal correction, while minimizing the risk of complications.

106. Lowest Instrumented Vertebral Discordance in Adolescent Idiopathic Scoliosis: When Coronal and Sagittal Parameters Conflict

Dale Segal, MD; Jacob Ball, BS; Eric Yoon, BS; Tracey P. Bastrom, MA; Michael G. Vitale, MPH; Harms Study Group; *Nicholas D. Fletcher, MD*

Summary

498 patients who underwent selective thoracic PSF for AIS with five years follow up were evaluated for development of DJK based on the relationship of the LIV to the coronally-determined LTV and the stable sagittal vertebrae on lateral radiograph. Patients with LIV proximal to the SSV showed a 10-18% incidence of DJK compared to a 0% incidence when the LIV was at the level of the SSV. Surgeons should consider the coronal LTV and SSV when determining LIV.

Hypothesis

Fusion to the coronal last touched vertebrae (LTV) would result in a higher rate of distal junctional kyphosis (DJK) when this was proximal to the stable sagittal vertebrae (SSV).

Design

Retrospective review of patients undergoing selective thoracic fusion with 5 year follow up.

Introduction

Typically selection of lowest instrumented vertebra (LIV) in AIS is based on the coronal radiograph. Fusion often extends to the LTV. Increasing evidence suggests that fusions proximal the the SSV on the lateral radiograph can result in DJK. No studies have evaluated the situation when LTV and SSV are not the same. The purpose of this study is to compare patients with AIS that have a discordance between the LTV and the SSV.

Methods

A multi-center database of prospectively enrolled subjects was reviewed for patients with AIS that had Lenke type 1, 2 and 3 curves treated with a selective thoracic PSF. Patients were separated into two groups, I and II. Group I had a SSV proximal to the LTV whereas group II had an SSV that was distal to the LTV. Comparisons were made for patients that were fused to the SSV(a), LTV(b) or between(c). Distal junctional angle (DJA) >5° and increasing kyphosis at the end of the fusion construct were evaluated as risk factors for DJK. Spinopelvic parameters were evaluated as risk factors for the development of DJK.

Results

Group I included 293 patients and the rate of DJK was 0.0% in group Ia, Ib, and Ic. Group II included 205 patients and the rate of DJK was 4.3%, 18.5% and 10.0% in groups IIa, IIb and IIc, respectively(p<0.001). The rate of DJK was 22.9° when the DJA > 5° vs. 1.4% when the DJA<5°(p<0.001). Patients who developed DJK had an average preoperative thoracic kyphosis of 40.4° compared with 30.7° in those who did not(p<0.001)

Conclusion

There was a low risk for progression of DJK when the SSV was proximal to the LTV however those with SSV distal to the LTV represent a high-risk group. Furthermore, having a distal junc-

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tional angle 5° or greater increased the risk of developing DJK by roughly 16-fold. An elevated preoperative thoracic kyphosis was identified as a risk factor for developing DJK as well.

Take Home Message

Attention should be given to patients with an SSV distal to the LTV, particularly if the plan is to fuse to the LTV, due to the risk of DJK.

DJK in Discordant Subgroups

Group	No DJK	DJK	P-Value
1a: SSV above LTV fused to SSV	19 (100.0%)	0 (0.0%)	<0.001
1b: SSV above LTV fused to LTV	186 (100.0%)	0 (0.0%)	
1c: SSV above LTV fused between	88 (100.0%)	0 (0.0%)	
2a: SSV below LTV fused to SSV	67 (95.7%)	3 (4.3%)	
2b: SSV below LTV fused to LTV	53 (81.5%)	12 (18.5%)	
2c: SSV below LTV fused between	63 (90.0%)	7 (10.0%)	

107. Can Placement of Hook at the Upper Instrumented Level Decrease the Proximal Junctional Kyphosis Risk in Adolescent Idiopathic Scoliosis?

Mehmet Erkilinc, MD; Melanie Coathup, PhD; Michael G. Liska, MD Candidate; John Lovejoy, MD

Summary

Type of instrumentation at the Upper Instrumented Level (UIV) Level of Posterior Spinal Fusion (PSF) surgery for Adolescent Idiopathic Scoliosis patients impacts Proximal Junctional Kyphosis (PJK) incidence.

Hypothesis

In order to decrease PJK incidence, placing hooks instead of pedicle screw at the UIV of an all pedicle screw construct allows a transition from 3 column fixation to less rigid posterior column fixation followed by proximal unfused motion segments.

Design

A Retrospective Case Series

Introduction

Proximal Junctional Kyphosis is a commonly encountered clinical and radiographic phenomenon after pediatric and adolescent spinal deformity surgery that may lead to postoperative deformity, pain, and dissatisfaction. The purpose of the study was to identify whether the placement of transverse process hooks is an effective way to prevent PJK.

Methods

Nemours Health Foundation Database of AIS patients with a minimum of 2 years of follow-up was retrospectively analyzed. Patients' preoperative and two-year postoperative sagittal radiographs were analyzed. Patients were divided into two groups based on the type of instrumentation at the UIV level. The first group was the patients who were placed hooks at the UIV level and the second group was the patients who were placed pedicle screw. The proximal junctional angle measured for all patients and PJK incidence was calculated for each group. PJK defined as having a proximal junctional Cobb angle $\geq 10^\circ$ and at least 10° greater than the pre-operative measurement between the caudal endplate of the Upper Instrumented Vertebrae (UIV) and the cephalad endplate of 2 levels above the UIV.

Results

There were 329 patients, 157 were placed transverse process

hooks at the UIV level and 172 patients were placed pedicle screw. PJK incidence was found 3.1 % (5/157) in the hook group and 13.3 % (23/172) in the screw group. A chi-square test of independence was performed and placing a hook at the UIV level was found statistically significant associated with the decreased PJK incidence ($p=0.000941$, $<.01$).

Conclusion

Placement of transverse process hooks at the UIV level in posterior spinal fusion surgery for AIS patients was associated with decreased risk of PJK.

Take Home Message

Placing hooks instead of the screw at the UIV level can prevent PJK in AIS patients who underwent posterior spinal fusion surgery with all screw construct.

108. Is Quality of Life Affected by Concomitant Isthmic Spondylolisthesis when Undergoing Surgery for Adolescent Idiopathic Scoliosis and Non-Surgical Management of The Spondylolisthesis?

Matias Pereira Duarte, MD; Julie Joncas, RN; Stefan Parent, MD, PhD; Hubert Labelle, MD; Soraya Barchi, BSc; Jean-Marc Mac-Thiong, MD, PhD

Summary

The presence of a concomitant isthmic spondylolisthesis does not affect the quality of life (QoL) outcomes after surgery for Adolescent Idiopathic Scoliosis (AIS). The improvement in QoL after surgery was similar for AIS patients with and without concomitant spondylolisthesis. This study suggests that for AIS patients with concomitant spondylolisthesis, isolated AIS surgery with non-surgical management of the spondylolisthesis will improve QoL.

Hypothesis

Improvement in Quality of Life (QoL) scores after surgically treated adolescent idiopathic scoliosis (AIS) is expected when there is a concomitant spondylolisthesis, in a similar degree as in those without it.

Design

Observational Cohort study.

Introduction

A significant proportion of individuals with AIS have a concomitant isthmic spondylolisthesis. When surgery is required for AIS, patients and families typically ask whether the QoL can deteriorate if the spondylolisthesis is managed non-surgically. Unfortunately, the expectations in QoL following AIS surgery in patients treated non-surgically for a concomitant spondylolisthesis remains unknown.

Methods

A retrospective review of a prospective cohort of 464 individuals undergoing AIS surgery between 2008 and 2018 was performed. All patients undergoing surgery for AIS and with a minimum 2 years follow-up were included. We excluded patients with prior surgery for spondylolisthesis and patients scheduled for addressing both at once. QoL scores were measured through SRS-23

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questionnaire. Comparisons were performed using Student t and Chi square tests.

Results

36 patients (15.2±2.6 y.o) with concomitant isthmic spondylolisthesis were operated for AIS, and 428 patients (15.5±2.4 y.o) without it. The two groups were similar in terms of age, sex, preoperative and postoperative Cobb angles. Preoperative and postoperative QoL scores were similar between the two groups (Table). QoL improved significantly for all domains in both groups, except for pain in patients with spondylolisthesis. There was no need for surgical treatment of the spondylolisthesis and no slip progression during the follow-up duration.

Conclusion

Patients with concomitant non-surgically managed isthmic spondylolisthesis can expect similar postoperative QoL scores and improvement after surgical treatment of AIS as those without it. There was no progression of the spondylolisthesis or need for spondylolisthesis surgery despite the presence of spinal fusion above the spondylolisthesis level.

Take Home Message

In the presence of concomitant AIS and spondylolisthesis, surgical treatment of AIS with non-surgical management of the spondylolisthesis can provide significant improvement in QoL.

	AIS			AIS + Spondy			P value PreOp AIS Vs AIS+S	P value PostOp AIS Vs AIS+S
	PreOp	PostOp 2 years F-up	p	PreOp	PostOp 2 years F-up	p		
Function	4,08	4,29	<0.1 x10 ⁻⁴	4,03	4,23	0,027	0,666	0,437
Pain	3,81	4,08	<0.1 x10 ⁻⁴	3,91	4,21	0,052	0,498	0,305
Self-Image	3,27	4,02	<0.1 x10 ⁻⁴	3,33	4,26	<0.1 x10 ⁻⁴	0,625	0,462
Mental-Health	3,84	4,06	<0.1 x10 ⁻⁴	3,76	4,09	0,005	0,567	0,827

109. Surgical Strategies and Outcomes of Posterior Lumbar Hemivertebra Resection and Short Fusion in Patients with LumboSacral Deformity Due to Severe Sacral Tilt

Shengru Wang, MD; Jianguo Zhang, MD

Summary

Lumbosacral region plays important roles in the coronal balance of spine. So far no studies focused on the lumbosacral deformity (LD) due to sacral tilt in patients undergoing lumbar hemivertebra resection for congenital scoliosis.

Hypothesis

Lumbosacral deformity due to severe sacral tilt may exist in patients with lumbar hemivertebra, which may play important roles in correction surgeries. Additional attentions should be paid to patients and strategies should be taken to deal with lumbosacral deformity during surgeries.

Design

Retrospective study

Introduction

This study was conducted to introduce surgical strategies to restore coronal balance with limited fusion during the surgery of early lumbar hemivertebra resection in patients with LD due to severe sacral tilt.

Methods

Sacral tilt is defined as the sacral tilt angle $\geq 5^\circ$ and severe sacral tilt is defined as sacral tilt angle $>10^\circ$. From July 2004 to

December 2017, seventy-three patients treated with posterior hemivertebra resection and short fusion in our institution were evaluated. Severe sacral tilt was noted in 26 (M/14, F/12) patients, all were enrolled in this study. Under-correction of the primary lumbar curve as compensation for LD due to sacral tilt and short fusion was performed in these patients. Patients were retrospectively reviewed through their prior charts and radiographic imaging to evaluate their outcomes.

Results

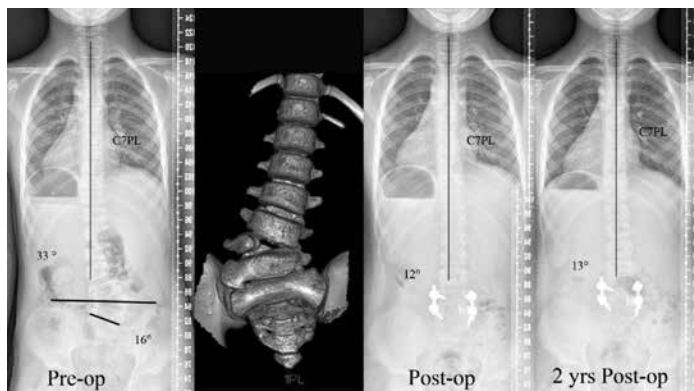
The mean age at the time of surgery was 3.7 (2-9) years old with a total of 31 lumbar hemivertebra excised. On average, there were 2.8 (2-5) fused segments for each patient. Sacral tilt had minimal improvement from 14.5° preoperatively to 13.6° postoperatively (P=0.15) but remained stable at follow-up. Overall lumbar curve pre-surgically was 41.9° , 11.7° immediately postoperatively, and 14.6° at final follow-up. The segmental scoliosis was pre-surgically 39.1° , 9.7° immediately postoperatively, and 11.2° at final follow-up.

Conclusion

Lumbosacral deformity due to sacral tilt is seen in patients with congenital scoliosis due to lumbar hemivertebra. Under-correction of the lumbar curve and segmental scoliosis as compensation for sacral tilt and short fusion after hemivertebra resection may be helpful to restore coronal balance and preserve mobile segments in patient with pronounced lumbosacral curve due to severe sacral tilt.

Take Home Message

Avoidance of maximal correction of the lumbar curve may be helpful to achieve good coronal balance with limited fusion in patients with lumbar hemivertebra and severe sacral tilts.



110. Long-Term Outcome after Surgical Treatment of Scheuermann Kyphosis (SK) - Minimum of Ten-Year Follow-Up

Ujjwal K. Debnath, MD, FRCS; Nasir A. Quraishi, PhD, FRCS

Summary

A retrospective review of 51 patients surgically treated patients (anterior fusion & posterior spinal fusion (AF/PSF)-32 and posterior spinal fusion (PSF)-19) with SK is presented. Good to excellent clinical and radiographic results were observed in both groups. There was no difference in mean thoracic kyphosis (TK) correction or functional outcome between the two groups. Correction of TK had good correlation with ODI. AF/PSF had higher

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complications. Single posterior approach can achieve sagittal correction with less risk of complications.

Hypothesis

Posterior spinal fusion (PSF) is sufficient to achieve kyphosis correction in SK

Design

Retrospective observational study with a minimum follow-up of 10 years post SK surgery

Introduction

The current trend is towards PSF for SK. This study aims at evaluating the long-term outcome after SK surgery i.e. anterior fusion/posterior spinal fusion (AF/PSF) or PSF

Methods

51 patients (30 M: 21F) were reviewed. 19 patients had PSF (Group 1) and 32 had AF/PSF (Group 2). The clinical data included age at surgery, gender, flexibility, instrumented levels, implant density, length of stay, posterior osteotomies, and complications. The radiological indices were recorded in the pre-operative, 2 year post-operative and final follow-up. Complications and difference in outcome between the two groups were analyzed.

Results

The mean age at surgery was 20.6 years with long FU (mean: 14 years; range: 10-16 years). The mean age was 18.5 ± 2.2 years and 21.9 ± 4.8 years in groups 1 and 2 respectively. The average number of pedicle screws used per patient was 25 ± 5 and 17.5 ± 3 in group 1 and 2 respectively. The mean length of hospital stay was 6.5 ± 2 days and 10.5 ± 7 days in group 1 and 2 respectively. The mean pre- and 2 years post-operative ODI was 32.6 ± 12.8 and 8.4 ± 5.4 respectively in group 1 ($p < 0.0001$) and 30.7 ± 11.7 and 6.4 ± 5.7 respectively in group 2 ($p < 0.0001$). The final SRS-22 scores in group 1 and 2 were 4.1 ± 0.4 and 4.0 ± 0.35 respectively ($p = 0.88$). The preoperative flexibility index was 49.2 ± 4.2 and 43 ± 5.6 in groups 1 & 2 respectively ($p < 0.0001$). The mean thoracic kyphosis (TK) were $81.4 \pm 3.8^\circ$ & $86.1 \pm 6.0^\circ$ for groups 1 & 2 respectively which corrected to $45.1 \pm 2.6^\circ$ & $47.3 \pm 4.8^\circ$ respectively at final follow-up ($p < 0.0001$). But there was no significant difference in correction between the two groups. JK was noted in 12 patients (Proximal-7 and distal-5).

Conclusion

Clinico-radiological outcome are comparable in both groups. AF/PSF had much higher complications than PSF group. The sagittal profile and spinal balance can be achieved through single posterior approach with less risk of complications.

Take Home Message

No difference in mean TK correction or functional outcome between the two groups. Single posterior approach is sufficient to achieve sagittal correction with a balanced spine with fewer associated complications.



Pre-op Lat view of 21,M, 70° kyphosis



6 year post op Lat view of 21,M with correction

Lateral X-rays of 21y, pre & 6y post surgery

111. Distal Adding-on in AIS Results in Diminished Patient Reported Outcomes at 10 Years

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Summary

This study investigated associations between the various definitions of distal adding-on defined in the literature and patient reported outcomes (PROs), as measured by the SRS-22, at 10 years following posterior spinal fusion (PSF). Patients with adding-on as defined by Cho et al. (2012) had an increased risk of worsening pain and activity by 1.75 and 1.51 times ($p = 0.023$ and $p = 0.002$), respectively. Other definitions did not demonstrate any similar associations.

Hypothesis

There is a clinically relevant definition of distal adding-on associated with worsening PROs at 10 years following PSF.

Design

Retrospective cohort study

Introduction

The long-term significance of distal adding-on in AIS remains unclear, partly due to the myriad definitions in the literature. Previous studies with 2- and 5-year follow up have not shown an impact on PROs. The purpose of this study was to investigate associations between various definitions of adding-on in the literature and PROs at 10 years following PSF to identify a clinically relevant definition.

Methods

Patients with Lenke Type 1 or 2 AIS that reached 10 years following PSF were identified in a multicenter international registry. Adding-on was identified from 10-year postop radiographs using 5 published definitions and a 6th group based on expert spine surgeons' visual confirmation for patients meeting any of these definitions (Table). Worsening of PRO was defined as a decrease

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from preop to 10-year postop in SRS-22 domain score \geq the minimal clinically important difference.

Results

150 patients (14.6 \pm 2.1 yo, 77% F, preop curve 53 \pm 10 $^\circ$) were included. Worse pain scores were noted in 49 (33%) patients, self-image scores in 1 (0.7%), and activity scores in 70 (47%). 4 of the 6 definitions of adding-on (Sponseller, Wang (2), Lakhali) were not associated with worsening of PROs. By visual assessment, 37 (25%) patients demonstrated adding-on and these patients had increased risk of worsening pain (62% vs. 36%, $p=0.019$). By Cho's definition, 39 (26%) patients had adding-on and increased risk of worsening pain (59% vs. 36%, $p=0.03$) and activity (78% vs. 54%, $p=0.03$). Their risk of worsening pain and activity increased by 1.75 and 1.51 times ($p=0.023$ and $p=0.002$), respectively. Adding-on was not associated with changes in self-image. No patient or preop radiographic measures were associated with worsening PROs.

Conclusion

Cho's definition of adding-on was associated with worsening PROs at 10 years following PSF. Previous studies showed no deterioration in PROs at 2 and 5 years. Consistent use of this definition will allow us to compare studies and obtain meaningful information in AIS patients.

Take Home Message

Cho's definition of adding-on was meaningful in AIS because it was associated with worsening pain and activity at 10 years, a finding not described in previous 2- and 5-year studies.

Table. Incidence of Adding-on by Definition

Author, Year	Definition	# of Patients with Adding-on
Sponseller, 2009	• Increase in number of vertebrae in curve either proximally or distally AND $>6^\circ$ increase in Cobb angle	37 (24.7%)
Wang, 2011	• Increase in number of vertebrae in curve distally AND >5 mm increase in lowest instrumented vertebra +1 (LIV+1) translation • Increase in number of vertebrae in curve distally AND $>5^\circ$ increase in angulation of 1 st disc below LIV	10 (6.7%)
Cho, 2012	• $\geq 5^\circ$ increase in Cobb angle AND increase in number of vertebrae in curve distally • $\geq 5^\circ$ increase in angulation of 1 st disc below LIV	39 (26.0%)
Wang, 2013	• >10 mm increase in LIV (not LIV+1) translation	0 (0.0%)
Lakhali, 2014	• Increase in number of vertebrae in curve distally AND >10 mm increase in LIV+1 translation • Increase in number of vertebrae in curve distally AND $>5^\circ$ increase in angulation of 1 st disc below LIV	4 (2.7%)
Visual Assessment	• Assessment of radiographs by two experienced spine surgeons	37 (24.7%)

112. Loss of Lumbar Lordosis Below the LIV Occurs Due to an Increased Instrumented Lumbar Lordosis Following Posterior Fusion and Instrumentation for Double Major AIS

Sai Susheel Chilakapati, MS; Kiley F. Poppino, BS; Daniel J. Sucato, MD, MS

Summary

In a consecutive series of AIS double major scoliosis the global lumbar lordosis increased from the preoperative to the 2-year radiographs. However, segmental lordosis revealed that the instrumented lumbar spine had increased lordosis at the expense of a relative loss of lumbar lordosis in the uninstrumented spine below the LIV. Care should be taken to maintain normal lordosis

in the instrumented segments to preserve normal sagittal balance and avoid potential long-term problems.

Hypothesis

Posterior spinal fusion and instrumentation (PSFI) may negatively affect segmental lordosis in Lenke 3, 4, and 6 curves.

Design

Retrospective

Introduction

Proper sagittal alignment is important for long-term health, yet limited knowledge exists on the impact of surgical correction on the sagittal spine for AIS. The purpose of this study was to characterize the sagittal plane in patients with double major curves fused into the lumbar spine to determine the effects of PSFI.

Methods

A consecutive series of AIS patients undergoing a PSFI at single institution from 2012-2017 with Lenke 3, 4, or 6 curves were analyzed. Sagittal measurements included: pelvic incidence (PI), lumbar lordosis (LL), and segmental lordosis. The difference in segmental lumbar lordosis between the preoperative and 2-year radiographs were reviewed.

Results

There were 77 patients at 13.5 years with preoperative coronal Cobb of 67.3 $^\circ$ (46-113 $^\circ$) and 66.4% (30-96%) correction at 2-years. There was no change comparing preoperative and 2-year thoracic kyphosis (23.0 \pm 13.4 $^\circ$ to 20.3 \pm 7.8 $^\circ$) ($p>0.05$) and PI (49.9 \pm 13.4 $^\circ$ to 51.1 \pm 15.7 $^\circ$) ($p>0.05$), LL increased from 57.6 \pm 12.4 $^\circ$ to 61.4 \pm 12.3 $^\circ$ ($p=0.002$) with a significant increase in segmental lordosis between T12 and LIV of 9.3 $^\circ$, with loss of lordosis between LIV and S1 of 15.1 $^\circ$ ($p<0.001$). An increase in segmental lordosis occurred at each instrumented level: T12-L1 (+3.23 $^\circ$), L1-L2 (+5.7 $^\circ$) and L2-L3 (+1.7 $^\circ$) ($p<0.001$) and a compensatory loss of lordosis at every level below the LIV: L3-L4 (-1.7 $^\circ$), L4-L5 (-3.5 $^\circ$), L5-S1 (-2.0 $^\circ$) ($p<0.001$). Preoperative LL in L4-S1 segments comprised 70% of the global LL (34-114%) decreasing to 56% (24-88%), $p<0.001$ at 2 years. Changes in sagittal measurements did not correlate with reoperation at 2-year follow-up.

Conclusion

When performing PSFI for double major scoliosis, global PI was maintained at 2-years, however, there was increased lordosis in the instrumented lumbar segments and decreased lordosis below the LIV. This compensatory relative kyphosis below the fusion may lead to poor long-term outcomes due to sagittal imbalance.

Take Home Message

Global lumbar lordosis increased at 2 years, however, there was increased LL in the instrumented lumbar segments and decreased lordosis below LIV.

113. National Trends in Performing Osteotomies for AIS in North America: Greater Incidence is Associated with Significant Complications and Greater Cost

Kiley F. Poppino, BS; Chan-Hee Jo, PhD; Daniel J. Sucato, MD, MS

Summary

Using the KID inpatient database, 28,184 AIS patients were evaluated and demonstrated a significant increased utilization of Ponte osteotomies without differences in age, gender, hospital type or region. However, the incidence of blood transfusions and neurologic deficits were significantly higher in the osteotomy group with a 34% increase in the total charges. The clinical outcome of patients undergoing a PSF for AIS needs to be significantly greater when using these osteotomies to justify the higher incidence of complications and cost.

Hypothesis

We hypothesize that the incidence of the use of osteotomies in adolescent idiopathic scoliosis (AIS) is increasing with greater operative time and cost to the system.

Design

Review the Kids' Inpatient Database (KID) database from 2000 to 2016.

Introduction

The use of Ponte osteotomies in kyphotic deformities is well-established, however, their use in AIS is controversial. The purpose of this study was to characterize and compare the demographics and clinical outcomes of idiopathic patients undergoing posterior spinal fusion (PSF) with osteotomies using a national inpatient sample.

Methods

Using the Healthcare Cost and Utilization Project's Kids' Inpatient Database (KID) from 2000 to 2016, patients with ICD-9 and ICD-10 diagnosis codes for idiopathic scoliosis, ages 10-18, who underwent PSF were identified. For national estimates, weights provided by the Agency of Healthcare Research and Quality were used. Patients who had an osteotomy (O+) and those who did not (O-) were compared.

Results

We identified 28,184 patients, (76.5% female, age 14.1 years). O+ occurred in 5.03% of the cases with a significant increase in rate over time (2000:0.54% to 2016:11.11%, $p<0.001$). No differences were seen between groups in age, gender, hospital type (urban vs. rural), or geographic region in the US. A higher postoperative rate of neurologic complications (1.0% v 0.4%, $p=0.023$), and rate of transfusions (23.6% vs. 18.5%, $p=0.009$) was seen in the O+ group. The LOS was not different between the groups (5.4 vs. 5.1 days, $p=0.094$), however, the average total hospital charges were significantly higher in O+ patients (\$177,033 vs. \$132,232, $p<0.001$).

Conclusion

The use of Ponte osteotomies in AIS has steadily increased over the last decade in the US without regional differences. The use of osteotomies was associated with a doubling of the neurologic deficit rate, an increased blood transfusion rate, and 34% higher hospital charges despite similar LOS. This trend in the use of Ponte osteotomies should be evaluated carefully to determine whether a substantially greater outcome can justify the increased healthcare cost and complications.

Take Home Message

Ponte osteotomies are more frequently utilized in AIS surgery today with increasing cost to the system with higher complications and incidence of transfusion to the patients.

114. Does Intraoperative Vancomycin Powder Affect Postoperative Infections in Adolescent Idiopathic Scoliosis?

Supriya Singh, MD; Garshana Rajkumar; Sachini Jayasinghe; Arvinder Ghag, MD; Michael P. Glotzbecker, MD; Baron Lonner, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Harms Study Group; *Firoz Miyanji, MD*

Summary

This study compares wound complications, infection rates, and reoperation rates for adolescent idiopathic scoliosis (AIS) patients treated with intraoperative vancomycin powder compared to those who were not. The results show that in AIS patients receiving intraoperative vancomycin powder, the rate of deep wound infection and associated reoperation is significantly lower than the no vancomycin group.

Hypothesis

Intraoperative vancomycin powder does not affect the rate of postoperative wound infections in AIS.

Design

Retrospective multicentre review

Introduction

The routine use of intraoperative vancomycin powder to prevent postoperative wound infections has not been borne out in the literature. The goal of this study is to determine the impact of vancomycin powder on postoperative wound infection rates and determine its potential impact on microbiology.

Methods

AIS patients that underwent a posterior fusion from 2004-2016 were analyzed. A retrospective comparative analysis of postoperative infection rates was done between patients that received vancomycin powder to those who did not. Statistical significance was determined using Chi-squared test. Additionally, the microbiology of infected patients was examined.

Results

765 patients in the vancomycin group (VG) were compared to 504 patients in the non-vancomycin group (NVG). NVG had a significantly higher rate of deep wound infection ($p<0.0001$) and reoperation rate compared to VG ($p<0.0001$). Both groups were compared for age, gender, race, weight, surgical time, blood loss, number of levels instrumented, and preop curve magnitude. There were significant differences between the groups for race ($p<0.0001$); surgical time ($p=0.0033$), and blood loss ($p=0.0021$). In terms of microbiology, VG grew *S.aureus* (n=2), *P.acnes* (n=2), and *Serratia* (n=2), whereas NVG grew *Proteus* (n=1) and *P.acnes* (n=1). The remaining cultures were negative.

Conclusion

Vancomycin appears to contribute significantly to deep wound infection prevention and associated reoperations. Vancomycin does not seem to alter the microbiology of deep wound infec-

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tions. It should be noted that the VG included a surgical time range up to 2018 as compared to NVG, 2016. Other institutional changes may have occurred over this time, in addition to the use of vancomycin, which may have affected the infection rates.

Take Home Message

Intraoperative use of vancomycin powder reduces deep wound infection rates and associated reoperation surgery in AIS.

Variables	Vancomycin (N=765) N(%) or mean (StDev)	No Vancomycin (N=504) N(%) or mean (StDev)	Group Comparison (p value)
Gender (Male)	134 (17.5)	99 (19.6)	0.3439
Age (yr)	14.7 (4.2)	14.9 (2.2)	0.0091
Race (White)*	543 (74.6)	252 (52.0)	<0.0001
Weight (Kg)	56.9 (4.2)	55.7 (13.5)	0.1360
Surgical Time (mins)*	276.4 (105.1)	257.5 (114.3)	0.0033
Estimate Blood Loss (ml)*	612.8 (337.3)	682.4 (410.0)	0.0021
Number of Levels Instrumented	11.0 (2.1)	11.3 (2.1)	0.0383
Preop Main Curve Magnitude	57.9 (12.7)	56.5 (12.9)	0.0686
Follow up (years)	2+ (2005-2018)	2+ (2004-2016)	

Outcomes	Vancomycin (N=765) N(%)	No Vancomycin (N=504) N(%)	Group Comparison (p value)
Wound Complication	31 (4.1)	29 (5.8)	0.1622
Superficial Wound Infection	8 (1.0)	2 (0.4)	0.2008
Deep Wound infection*	4 (0.5)	19 (3.8)	<0.0001
Reoperation Rate*	5 (0.7)	20 (4.0)	<0.0001

*denotes statistical significance

115. Prophylactic Use of Local Vancomycin Does Not Decrease Acute Surgical Site Infection in Adolescent Idiopathic Scoliosis

Stephen Stephan, MD; De-An Zhang, MD; Marilan Luong, MPH; Robert H. Cho, MD; Selina C. Poon, MD

Summary

Perioperative surgical site infections for adolescent idiopathic scoliosis after posterior spinal fusion range from 0.3-1.6%. Prophylactic and local administration of vancomycin powder into the wound has been shown to decrease rates of surgical site infections among the adult population, and many pediatric deformity surgeons have adopted its use in the adolescent idiopathic scoliosis population. However, efficacy has not been established in this population.

Hypothesis

The purpose of this study is to investigate the efficacy of local administration of vancomycin in pediatric patients undergoing primary posterior spinal fusion for adolescent idiopathic scoliosis in decreasing the incidence of surgical site infections.

Design

Retrospective cohort study

Introduction

Pediatric patients undergoing posterior spinal fusion with instrumentation continue to be at risk for surgical site infections. Various studies have demonstrated infections rates for primary posterior spinal fusion to range from 0.4% to almost 40%, largely dependent on the underlying etiology of scoliosis.

Methods

A multicenter, retrospective database review was performed

from June 2010 to February 2019. ICD and current procedural terminology codes (CPT) were used to identify adolescent idiopathic scoliosis patients who underwent primary posterior spinal fusion. Identified patients were then separated into two groups. The vancomycin cohort had application of prophylactic, local vancomycin into the wound prior to closure and the non-vancomycin cohort did not. Demographic and surgical data was compiled, as well as microbial data, and surgical site infections rates were compared.

Results

A total of 1,917 adolescent idiopathic scoliosis patients underwent posterior spinal fusion from June 2010 to February 2019. Differences in age at surgery, body mass index, sex, and presence of at least one osteotomy were not significant in both groups ($p>0.05$). The vancomycin cohort had 1,252 (65.3%) patients with six (0.48%) diagnosed surgical site infections, compared to 665 (34.7%) patients with five (0.75%) in the non-vancomycin cohort ($p=0.451$). Four (66.7%) gram-negative bacteria were isolated in the vancomycin cohort and one (20%) in the non-vancomycin cohort.

Conclusion

The prophylactic use of local vancomycin did not demonstrate significantly decreased rates of surgical site infections in adolescent idiopathic scoliosis patients undergoing primary posterior spinal fusion (0.48% vs. 0.75%). Further studies are required to elucidate the effectiveness of the use of vancomycin in this population.

Take Home Message

We demonstrate no difference in the incidence of acute surgical site infections in adolescent idiopathic scoliosis patients undergoing spinal fusion who received prophylactic, local vancomycin in their surgical wound.

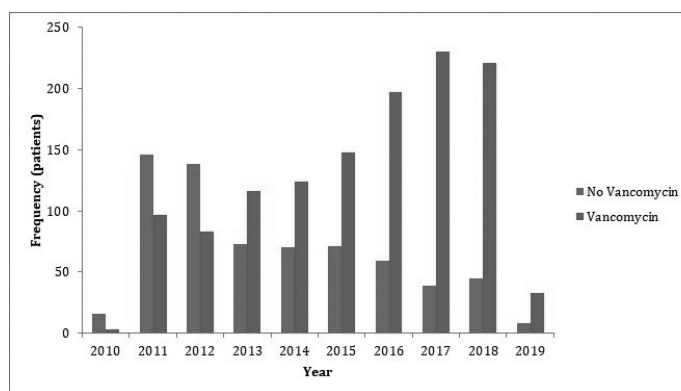


Figure 1: Frequency of Use of Prophylactic, Local Vancomycin Powder

116. Intraoperative Navigation for Pedicle Screw Placement in Adolescent Idiopathic Scoliosis: No Clinical Benefit and Increased Cancer Risk

Peter M. Obid, MD; Sebastian Zahnreich, PhD; Thomas Niemeyer, MD; Georgi Wassilew, MD; Tamim Rahim, MD

Summary

We compared radiation exposure of 40 consecutive AIS patients

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treated with pedicle screw instrumentation using freehand technique (FH) to 40 patients that received minimally-invasive pedicle screw instrumentation using intraoperative navigation (IN). There were no screw related complications in either of the groups. Use of IN significantly increased radiation exposure. Corresponding cumulative lifetime attributable cancer risk for a 15-year-old female was calculated as 0.0022% for the freehand technique group and 0.015% for the intraoperative navigation group.

Hypothesis

Routine use of intraoperative navigation for pedicle screw placement in AIS reduces implant related complications.

Design

Retrospective analysis of prospectively collected data.

Introduction

Previous studies have shown the possible application of IN in surgery for AIS. However, a clinical benefit compared to FH technique could not be shown. Additionally, all studies showed a significantly higher radiation exposure for the patient. But the exact risk for the patient has not been quantified so far. The aim of this study is to calculate the cumulative lifetime attributable cancer risk.

Methods

Retrospective analysis of prospectively collected data: (1) 40 consecutive AIS patients treated with pedicle screw instrumentation using FH technique. (2) 40 consecutive patients that received minimally invasive pedicle screw instrumentation using IN (Cone Beam CT). Dose area product (DAP) and effective dose (ED) was calculated for both groups. IN is not routinely used for AIS surgery in our department. Therefore, AIS patients were compared to patients with degenerative disorders. Screw related complications were analysed for both groups. Cumulative lifetime attributable cancer risk was calculated.

Results

Mean age at surgery in the FH group was 15.2 years (SD ± 1.3 , range 13- 18). On average 8.8 segments were fused (SD ± 2.3). 626 pedicle screws were implanted (implant density: 86.6%). Mean DAP was 936.16 mGy/cm² (SD ± 527.8) corresponding to an average ED of 0.24 mSv. Mean age at surgery in the IN group was 70.3 years (SD ± 9.2 , range 57- 86). Mean DAP was 6,133.76 mGy/cm² (SD $\pm 2,250.12$) corresponding to an average ED of 1.55 mSv as calculated for 15-year-old female adolescents for comparability. There were no screw related complications. Difference of DAP and ED was highly significant ($p < 0.0001$) between FH technique and IN. Corresponding total lifetime cancer risk for the FH technique AIS group was 0.0022% and 0.015% for the IN group.

Conclusion

The use of intraoperative navigation for a "standard" AIS patient does not provide a clinical benefit, but increases risk of developing malignancies.

Take Home Message

Routine use of intraoperative navigation in AIS surgery does not provide a clinical benefit but increases risk of developing malignancies.

117. Comparison of Degenerative Lumbar Scoliosis Correction and Risk for Mechanical Failure Using Posterior 2-Rod Instrumentation vs. 4-Rod Instrumentation and Interbody Fusion

Yann Philippe Charles, MD, PhD; Vincent Lamas, MD; Jean-Paul Steib, MD, PhD

Summary

Quality of life, sagittal alignment and mechanical complications were compared in degenerative scoliosis operated thoracolumbar instrumentation to the pelvis using 2 rods vs. 4 rods and interbody cages. Postoperative cranial migration of lumbar apex and lordosis length increase were identified as PJK risk factors. Non-union occurred only after 2-rod instrumentation.

Hypothesis

Degenerative scoliosis instrumentation to the pelvis is associated with PJK or non-union. The use of 4-rod instrumentation is intended to decrease the incidence of mechanical failure.

Design

Retrospective observational study.

Introduction

The aim of this study was to compare clinical outcomes, sagittal alignment and mechanical complications in patients with degenerative scoliosis operated by 2-rod vs. 4-rod instrumentation.

Methods

The study included 97 patients with average 3.9-year follow-up and compared 2-rod (2R) instrumentation with circumferential fusion at the lumbosacral junction (n=58) to 4-rod (4R) instrumentation with multiple-level interbody cages (n=39). Clinical scores were assessed: VAS, ODI, SRS-22, EQ-5D-3L. Radiographs were modeled using KEOPS software and measured coronal and sagittal alignment parameters, lumbar apex, number of vertebrae in lordosis and Roussouly type. The incidence of non-union and PJK were investigated.

Results

Clinical scores improved similarly in both groups ($p < 0.05$). In the 2R-group, lumbar lordosis increased from 42.6° to 52.8° postoperatively ($p < 0.0001$). During the first year, lordosis decreased to 47.3° ($p = 0.0086$), SVA ($p = 0.0003$) and pelvic tilt ($p = 0.0003$) increased. In the 4R-group, lumbar lordosis increased from 46.6° to 52.5° postoperatively ($p = 0.0140$) and remained stable. Non-union occurred in 56.9% in the 2R-group vs. 0% in the 4R-group ($p < 0.0001$). The number of vertebrae in lumbar lordosis increased from 4.8 to 6.0 (2R, $p < 0.0001$) and 5.5 to 7.2 (4R, $p < 0.0001$). PJK occurred in 13.8% (2R) vs. 15.4% (4R). In PJK, the length of lordosis increased, the lumbar apex shifted cranially and did not match with the Roussouly type: 36.2% (2R) vs. 23.1% (4R).

Conclusion

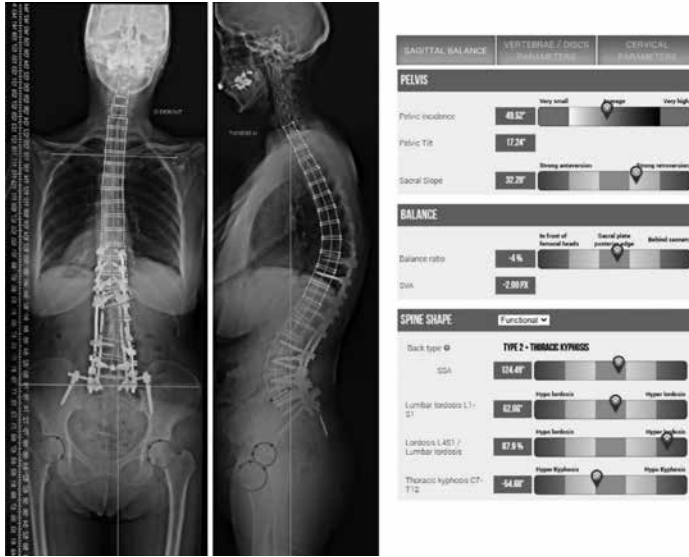
Four-rod instrumentation with interbody cages carried a lower risk of non-union and subsequent revision surgery than 2-rod instrumentation. The PJK incidence was comparable in both groups and related to mismatches between lumbar apex level and spinopelvic alignment type. Final clinical outcomes were

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similar with both techniques.

Take Home Message

Four-rod instrumentation combined with multi-level interbody fusion lowers the risk for non-union compared to 2-rod instrumentation with interbody fusion at the lumbosacral junction.



Segmental measurements after 4-rod instrumentation

118. Rod Failures Continue to Plague the Surgical Treatment of Adult Spinal Deformity (ASD)

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Summary

Rod failures remain a common complication when treating ASD with a rate of 21%. 9.3% rod failures occurred within 2 yrs. The most frequent sites of failure were in the lower lumbar spine. Unilateral failures underwent a lower rate of revision than bilateral. BMP increased rod survivability. Kaplan-Meier analysis demonstrated a survival rate of 89.7% at 2Y with a decrease of 5% per year. The failure rate has not improved when comparing first 5 yrs. to last 5 yrs.

Hypothesis

Rod failures will decrease over time as our surgical techniques and alignment strategies improve.

Design

Retrospective review of prospective multicenter database

Introduction

Rod failure and pseudarthrosis are common complications following the surgical treatment of ASD. Many strategies have been employed in mitigating these problems, such as interbody

fusion, multiple rods, use of more effective biologics, and optimizing spinal alignment. We aimed to study the frequency and type of rod failures in a large ASD population over time.

Methods

ASD patients with a fusion extended from minimum L1 to pelvis and min 2-yr f/up were included. Radiographs and records were examined to identify characteristics of the rod failures: timing, unilateral vs. bilateral, vertebral level, unilateral progressing to bilateral failure, revision and failure rates over time.

Results

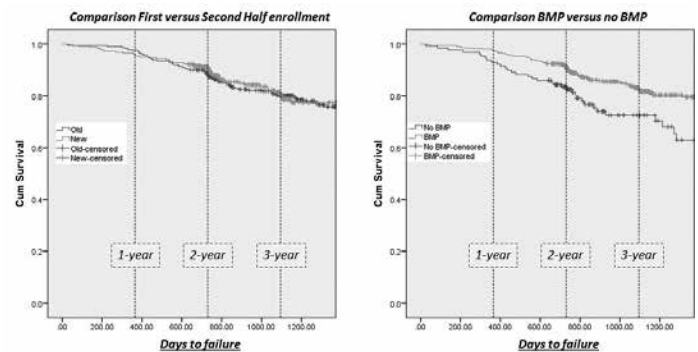
647/1052 pts from 2008 to 2018 met inclusion criteria (age: 64±10, 78% F, BMI: 28.3±5.7, Mean f/up 37mths±13). The UIV was T7 or above in 306 and T8 or below in 338 pts, 146 pts had a 3CO. 435 had interbody fusion with 187 ALIF, 202 TLIF, 135 LLIF. 286 pts (44%) had BMP used posterior only and 203 (31%) had BMP used in interbody and post. Rod failure rate was 135/647 (21%). 9.3% occurred by 2 yrs. Failure noted at 795 day +/- 485 (Median 733). Most frequent failures were in the lower lumbar spine L3-4 (32) 24%, L4-5 (34) 25% and L5-S1 (44) 32%. Of the 97 Unilateral failures, 35 (36.1%) were revised and only 8 progressed to bilateral failure. 46 Bilateral failure, 24 (52.2%) were revised. Kaplan-Meier analysis shows a survival rate of 89.7% at 2Y with decrease of 5% per year. No significant difference was found between first 5yrs and last 5yrs. Use of BMP improved survival rate to 91.2% compared to no BMP 83.4% at 2-yrs.

Conclusion

Rod failures remain a common complication after ASD surgery which worsens with time. Unilateral failures undergo a lower rate of revisions compared to bilateral. Survivability is improved with use of BMP. We must continue to seek solutions to improve rod durability challenges to improve long term outcomes.

Take Home Message

Rod failures continue to occur at unacceptable rates despite improvement in surgical techniques and improvement in our understanding of alignment goals.



119. Multiple Rod Constructs and Use of BMP2 Results in Lower Rod Fracture Rates in Adult Spine Deformity Patients Who Undergo Lumbar Pedicle Subtraction Osteotomy: Series of 141 Patients with 2-Year Follow-Up

Darryl Lau, MD; Qiunan Lyu, MD; Vedat Deviren, MD; Alexander Haddad, BS; Christopher P. Ames, MD

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Summary

141 adult spinal deformity (ASD) patients underwent lumbar pedicle subtraction osteotomy (PSO) with three different rod constructs (RC) used: standard, satellite, and nested. Standard RCs were associated with higher rod fracture (RF) rate, pseudoarthrosis, and reoperation for RF. Satellite and nested RCs were independently associated with decreased incidence of RF. The use of BMP2 was also independently associated with a decrease in rod fracture rates.

Hypothesis

RC utilizing multiple rods is associated with lower incidence of RF at 2-year follow-up.

Design

Single surgeon, retrospective comparative study.

Introduction

The incidence of rod fracture (RF) remains high following lumbar pedicle subtraction osteotomy (PSO). Various rod constructs (RC) are being used in attempt to solve this problem. This study compares the RF rate among three RC following lumbar PSO in adult spinal deformity (ASD) patients.

Methods

A retrospective review of ASD patients treated by lumbar PSO from 2007 to 2017 was performed. Minimum follow-up was 2-years. Three types of RC were compared: standard (2 main rods), satellite (2 main rods with a satellite rod), and nested (2 main rods and 2 short rods spanning osteotomy site). Multivariate analysis was used.

Results

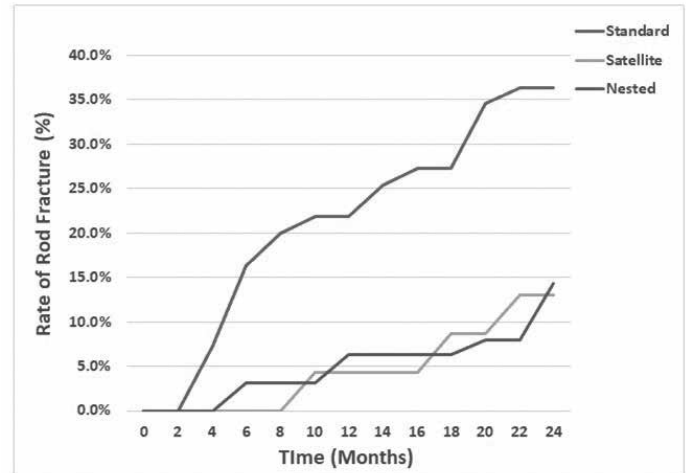
141 patients were included: 55 standard, 23 satellite, and 63 nested. Mean age was 64.9 years and 34.8% were male. Radiographic preoperative and postoperative results were: SVA (11.0 vs. 3.9 cm), LL (28.5 vs. 57.1 degrees), PT (30.6 vs. 21.0 degrees), PI (61.5 vs. 60.0 degrees), CSVL (2.2 vs. 1.5 cm), and scoliosis (18.9 vs. 11.3 degrees). Average time to RF was 12.4 months. Overall RF rate was 22.7% and bilateral RF occurred 5.0% of patients. Standard-RC had a significantly higher rate of bilateral RF (35.0% vs. 0.0% vs. 0.0%, $p=0.021$). Overall pseudoarthrosis and reoperation rate was 20.1% and 17.7%. Standard-RC experienced significantly higher rate of RF (36.4% vs. 13.0% vs. 14.3%, $p=0.009$), pseudoarthrosis (34.5% vs. 8.7% vs. 12.7%, $p=0.004$), and reoperation (30.9% vs. 4.3% vs. 11.3%, $p=0.003$) compared to the satellite-RC and nested-RC. Satellite-RC (OR 0.21, $p=0.016$), nested-RC (OR 0.24, $p=0.003$), and BMP-2 (OR 0.29, $p=0.006$) were independently associated with lower odds of RF.

Conclusion

Multiple RC are able to decrease rod related mechanical complications in ASD patient who undergo lumbar PSO. Specifically, the use of satellite-RC and nested-RC are able to decrease the rates of RF, pseudoarthrosis and reoperations for RF. The use of BMP2 is also associated with a reduction in RF.

Take Home Message

In ASD patients with lumbar PSOs, standard RCs are associated with increased rates of RF, pseudoarthrosis, and reoperation for RF. Satellite, nested RCs, and BMP2 are protective on multivariate analysis.



120. Assessing Pain as a Primary Factor in the Surgical Treatment of Adult Spinal Deformity Surgery in Patients over 60 Years of Age

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Summary

Pain outcomes were assessed in patients over the age of 60 undergoing adult spinal deformity surgery utilizing Health Related Quality of Life (HRQOL) measures. At 2 year post-op, significant improvements in leg and back pain were seen in the majority of patients. 5% and 15% of patients deteriorated in back and leg pain scores, respectively.

Hypothesis

In patients over the age of 60 undergoing spinal deformity surgery, a majority will experience significant pain relief at 1 and 2 years.

Design

Prospective, multi-centre cohort study.

Introduction

Adult spinal deformity is associated with significant pain and disability and multiple HRQOL scales have been developed to assess change in pain and function after corrective surgery. The present study utilizes data from an international prospective multi-centre cohort study to investigate the effects of deformity surgery on multiple pain scores in patients over 60 years of age.

Methods

Twelve centres recruited 255 patients undergoing surgery. Patients were assessed pre-operatively, as well as post-operatively at 10 weeks, 1 and 2-years using the Numeric Rating Scale (NRS) for back and leg, and pain subscores from the Scoliosis Research Society-22r (SRS-22r), Oswestry Disability Index (ODI), and the EuroQol 5-dimensions (EQ-5D).

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Results

179 (82%) patients completed the study. Baseline NRS scores for back pain were worse than leg pain, with mean (SD) scores of 6.1 (± 2.7) and 4.3 (± 3.3), respectively. NRS back pain decreased to 3.5 (± 2.3) at 10 weeks, and 2.6 (± 2.6) at 2-years. NRS leg pain decreased to 2.4 (± 2.6) at 10 weeks, and 2.3 (± 2.7) at 2 years. Similar and significant reductions were seen in other pain related HRQOLs. More than 20% improvement of the score range was achieved by two-thirds of patients on NRS back pain and more than half on NRS leg pain. Pain worsened compared with pre-op in 15.1% on NRS leg pain, 5.7% on NRS back pain, 5.3% on SRS-22r pain, and 6.9% on ODI pain.

Conclusion

This study demonstrates that all pain measures showed significant improvement at 1 and 2 years post-op, that was similar for all investigated age subgroups. Most of the patients concluded the study with some degree of pain, with the majority of patients reporting only mild pain. A small percentage (approximately 5%) of patients finished the study with severe disability in back or leg pain. 5.7% of patients reported worse back pain and 15.1% of patients noted worse leg pain at 2 years following surgery compared to pre-operatively.

Take Home Message

Adult deformity surgery is successful in relieving back and leg pain at 1 and 2 years, post-operatively. Most patients can still expect some degree of pain at 2 years post-op.

121. Comparing the Modified 5-Item Frailty Index vs. Chronological Age in Predicting Perioperative Complications and Discharge Disposition for Patients Undergoing Adult Spinal Deformity Surgery

Rahul Sachdev, BS; Kevin Y. Wang, BS; Richard L. Skolasky, PhD; Khaled M. Kebaish, MD; *Brian J. Neuman, MD*

Summary

This study of 188 ASD patients sought to directly compare age vs. frailty in their ability to predict discharge disposition and 30-day major complications. After controlling for potential confounders, both age ≥ 65 and frailty were independently associated with increased risk of non-home discharge. For 30-day major complications, while frail patients had significantly higher rates of complications, age ≥ 65 was an insignificant predictor. Both age and frailty should be assessed preoperatively as they are critical to predicting perioperative outcomes.

Hypothesis

Frailty status and age will be independently associated with discharge disposition and 30-day complications after ASD surgery

Design

Retrospective Review

Introduction

No studies have been done comparing the effects that chronological age vs. physiological age has on the perioperative course for patients who undergo ASD surgery. The aim of this study is to compare the impact of frailty (physiological age) vs. chrono-

logical age has on perioperative outcomes, including discharge disposition, length of hospitalization, and 30-day complications.

Methods

Using a single center database, 188 surgical ASD patients undergoing spinal fusions ≥ 4 levels who had ≥ 2 -year follow-up were identified. Patients were categorized by mFI-5 into one of three groups: robust (mFI-5=0), prefrail (mFI-5=1) and frail (mFI-5 ≥ 2). Age was treated as a dichotomous variable (<65 or ≥ 65). Outcomes of interest included discharge disposition (home vs. rehab), length of hospitalization (<9 vs. ≥ 9 days) and 30-day complications. Multivariable logistic regression was used to assess the impact of age and frailty has on postoperative outcomes, while controlling for baseline demographic and surgical characteristics.

Results

Of the 188 ASD patients who met the inclusion criteria, 98 (52%) were non-frail, (mFI-5=0), 76 (40%) were prefrail (mFI-5=1), and 14 (8%) were frail (mFI-5 ≥ 2). On multivariable logistic regression, both age ≥ 65 (aOR, 4.82; 95% confidence interval, 2.4–9.6) and mFI-5 ≥ 2 (aOR:4.50, 95% CI: 1.14, 17.7) were associated with higher likelihood of non-home discharge. For 30-day complications, patients with mFI-5 ≥ 2 had higher rates of complications (aOR:7.59, 95% CI: 1.92, 30.0), while age ≥ 65 was a non-significant predictor. Lastly, with regards to LOS, both age ≥ 65 and mFI-5 ≥ 2 were insignificant predictors.

Conclusion

It does appear physiological age is more important than chronological age in assess perioperative outcomes. Given this information, surgeons should work towards incorporating frailty assessment tools as routine component of preoperative workup.

Take Home Message

For patients undergoing ASD surgery, physiological age (frailty) places patient at risk for a complication over chronological age. This should be assessed preoperatively to identify those at risk for complications.

122. Matched Analysis Demonstrates Acute Rehabilitation or Skilled Nursing Facility Care Does Not Reduce Readmissions, Return to Surgery or Improve Outcomes Compared to Home Discharge Following Adult Spine Deformity Surgery

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Summary

Analysis of 158 matched surgically treated ASD patients prospectively enrolled into a multi-center study demonstrated postoperative discharge to skilled nursing or acute rehab facilities did not reduce 30-day readmissions, 90-day return to surgery, or postoperative complications compared to home discharge. One

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and minimum 2 year PROMs demonstrated home patients had better ODI, SRS-total, SRS-activity than nonroutine discharge. These data should be considered in conjunction with patient postoperative needs and cost and disease transmission risks for nonroutine discharge.

Hypothesis

Nonroutine discharge (skilled nursing or acute rehab facilities) will reduce complications and readmissions and improve outcomes compared to home discharge following ASD surgery

Design

Propensity score matched (PSM) analysis of ASD patients prospectively enrolled into a multicenter study.

Introduction

Concerns exist regarding disease transmission and cost associated with postoperative nonroutine discharge. Few data exist evaluating impact of nonroutine vs. home discharge on readmissions, complications and PROMs for ASD surgery.

Methods

Surgically treated ASD patients prospectively enrolled into a multicenter ASD study were divided into 2 discharge disposition groups, nonroutine (NON) and home (HOME). NON further divided into acute rehab (REHAB) or skilled nursing facility (SNF). Study inclusion criteria; 1) surgery ≥ 5 levels fused, 2) ≥ 2 year follow up. PSM was used to match NON vs. HOME for age, frailty, levels fused, and osteotomies. 30-day hospital readmission, 90-day return to surgery, postoperative complications, one and minimum 2 year PROMs were compared for NON vs. HOME and REHAB vs. SNF vs. HOME.

Results

From 2015 to 2019, 241 of 374 eligible treated patients were evaluated and 158 included in study after PSM (mean 2.7 year follow up). NON (n=106) and HOME (n=52) had similar age, ASD-frailty index, levels fused at surgery, and preop PROMs ($p > 0.05$; table). Duration of hospital stay, 30-day readmission, 90-day return to surgery, total complications/patient, and major complications/patient were similar NON vs. HOME, and similar REHAB (N=64) vs. SNF (N=42) vs. HOME ($p > 0.05$; table). At 1 year and last follow up HOME demonstrated better ODI, SRS-total and SRS-activity than NON, REHAB and SNF ($p < 0.05$; table).

Conclusion

Acute needs must be considered following ASD surgery, however matched analysis comparing hospital readmissions, return to surgery, complications and PROM outcomes demonstrated no benefit for REHAB or SNF vs. HOME.

Take Home Message

Matched analysis comparing hospital readmissions, return to surgery, complications and longer PROM outcomes demonstrated no benefit for skilled nursing or acute rehab vs. home discharge following ASD surgery.

	HOME (n=52)	NON (n=106)	p-value	REHAB (n=64)	SNF (n=42)	p-value
Last Follow-up (yrs)	2.7 (0.5)	2.7 (0.7)	>0.05	2.7 (0.7)	2.7 (0.7)	>0.05
Age (yrs)	67.6 (9.8)	67.6 (9.9)	>0.05	66.7 (9.8)	68.8 (9.9)	>0.05
Gender (%F)	76.9	71.7	>0.05	73.4	69.1	>0.05
BMI (kg/m ²)	29.6 (5.1)	28.9 (6.3)	>0.05	29.5 (6.2)	27.5 (6.4)	>0.05
Frailty	3.9 (1.3)	3.9 (1.5)	>0.05	3.8 (1.6)	4.0 (1.2)	>0.05
Levels Fused	13.7 (3.4)	13.8 (3.7)	>0.05	14.3 (3.6)	13.1 (3.8)	>0.05
3CO (%)	24.7	27.5	>0.05	30.5	21.9	>0.05
EBL (ml)	1783.0 (1015.5)	2094.9 (1731.0)	>0.05	2389.1 (1728.2) ¹	1646.4 (1656.2) ¹	<0.05 ¹
Hospital LOS (days)	10.4 (7.5)	9.7 (8.2)	>0.05	10.5 (9.9)	8.6 (4.7)	>0.05
SCU Admission (%)	60.4 ¹	75.5	>0.05	84.4 ^{1,2}	61.9 ²	<0.05 ^{1,2}
Preop Max Scoliosis	37.2 (19.3)	36.5 (22.7)	>0.05	38.1 (22.5)	34.2 (23.1)	>0.05
Last Max Scoliosis	18.3 (12.7)	19.6 (15.5)	>0.05	20.4 (16.4)	18.4 (14.3)	>0.05
Preop PI-LL	25.6 (21.8)	21.7 (22.0)	>0.05	22.7 (22.7)	20.2 (21.1)	>0.05
Last PI-LL	7.5 (12.9)	4.6 (14.7)	>0.05	5.7 (15.5)	3.1 (13.5)	>0.05
Preop SVA (mm)	101.8 (78.6)	89.2 (71.8)	>0.05	83.7 (71.4)	97.4 (72.6)	>0.05
Last SVA (mm)	51.2 (52.1) ¹	31.2 (54.6)	<0.05	27.0 (53.7) ¹	37.7 (56.1)	<0.05 ¹
Preop TPA	29.7 (15.7)	28.2 (13.8)	>0.05	28.3 (13.6)	28.2 (14.1)	>0.05
Last TPA	22.3 (9.4)	18.9 (10.7)	>0.05	19.1 (11.5)	18.5 (9.6)	>0.05
Preop ODI	49.0 (14.2)	48.4 (16.0)	>0.05	46.4 (18.0)	51.4 (12.0)	>0.05
1yr ODI	22.8 ¹	31.7	<0.05	28.7	36.4 ¹	<0.05 ¹
Last ODI	21.6 (19.9) ¹	28.2 (18.9)	<0.05	25.9 (19.4)	31.8 (17.8) ¹	<0.05 ¹
Preop SRS-22r Total	2.6 (0.6)	2.7 (0.6)	>0.05	2.7 (0.6)	2.6 (0.5)	>0.05
1yr SRS-22r Total	3.8 ¹	3.5	<0.05	3.6	3.4 ¹	<0.05 ¹
Last SRS-22r Total	3.8 (0.8)	3.5 (0.8)	>0.05	3.6 (0.8)	3.4 (0.7)	>0.05
All complications (%)	78.3	84.0	>0.05	81.3	88.1	>0.05
Major Complications (%)	34.0	47.2	>0.05	48.4	45.2	>0.05
30 Day Readmission (%)	6.6	6.6	>0.05	7.8	4.8	>0.05
90 Day Return to Surgery (%)	10.4	9.4	>0.05	7.8	11.9	>0.05

123. Adults with Scoliosis, Curve Progression is Faster after Age 50: Results from a Longitudinal Collection of Radiographical Data

Sabrina Donzelli, MD; Fabio Zaina, MD; Giulia A. Rebagliati, MD; Massimiliano Vanossi, Physiotherapist; Greta Jurenaite, MD; Stefano Negrini, MD

Summary

The understanding of the pattern of progression in adult scoliosis will improve the effectiveness of preventative interventions. We found in 767 participants ($48 \pm 17^\circ$ Cobb) that curve progression can be predicted by age. Before age 50, the expected progression will be 5° every 15 years, while in subjects older than 50 the 5° progression will happen in 10 years. In adults treated during growth with a primary thoracic curve, Cobb progression is increased.

Hypothesis

Baseline characteristics and historical data allow predicting the progression of scoliosis curves in adult patients.

Design

Retrospective cohort study

Introduction

Following up patients with spine deformities for all life is costly, and a better knowledge of the natural history would provide a better selection of subjects to be followed up in a shorter period, thus optimizing costs. We aimed to analyze the factors predicting the possible curve progression in a large cohort of adults followed up for a 5-year minimum period.

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Methods

Inclusion criteria: age >20, idiopathic scoliosis curves > 10° Cobb, 2 or more previous x-rays over a minimum 5-year period, no spine surgery. Outcome: Primary curve progression evaluated in consecutive x-rays (2 at minimum) during a 5-year minimum follow up. Prognostic factors: Baseline characteristics, sagittal parameters and historical data including bone and joint diseases, osteoporosis and early menopause. Age at x-ray as time variable. Statistics: mixed-effect multivariate growth model for two levels longitudinal data structure, with cubic splines and age knots.

Results

We included 767 participants (88.8% females, entry date mean age 34.0±12.4, while at the last x-ray mean age 47.8±13.0. Start Cobb 41.2±15.3, end Cobb 48±17°). In the sample, 65% had 2 x-rays, 19% had 3, 16% 4 or more. The 46% of the sample had a follow-up time between 5 to 10 years. Before age 50, the expected progression will be 5° every 15 years, while in subjects older than 50 the 5° progression will happen in 10 years. In adults treated during growth with a thoracic main curve, Cobb progression is increased by 0.34 when age is 35 to 50 (CI95% 0.30-0.40) and by 0.40 when age is 50 to 65 (CI95% 0.3-0.5).

Conclusion

The rate of progression increases after age 50, and a shorter follow up should be recommended. Larger dataset, with longer follow-up periods, are needed to provide a better understanding of scoliosis prognosis in adults.

Take Home Message

The rate of progression increases after age 50 when shorter follow up should be recommended. We need larger dataset and longer follow-up to understand scoliosis prognosis in adults better.

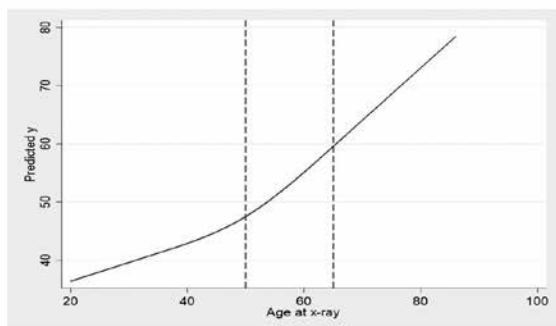


Figure 1: Plot of the average predicted values of the major Cobb angle at the following age intervals: 35, 50 and 65 obtained with the linear spline model.

124. Adult Spinal Deformity Surgery is Associated with Increased Productivity and Decreased Absenteeism from Work and School

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Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Alan H. Daniels, MD; International Spine Study Group

Summary

We hypothesized that adult spinal deformity (ASD) surgery would be associated with improved work- and school-related productivity, as well as decreased rates of absenteeism. ASD patients managed operatively exhibited an average increase in work/school productivity of 18.1% and decreased absenteeism of 1.1 per 90 days at 2-year follow-up, while patients managed non-operatively did not exhibit change from baseline.

Hypothesis

We hypothesized that ASD surgery would be associated with improved work- and school-related productivity, as well as decreased rates of absenteeism.

Design

Retrospective cohort study.

Introduction

ASD patients experience markedly decreased health-related quality of life along many dimensions. Surgery for ASD has been shown to increase HRQOL broadly.

Methods

Only patients eligible for 2-year follow-up were included, and those with a history of previous spinal fusion were excluded. The primary outcome measures in this study were SRS-22r questions 9 and 17. A repeated measures mixed linear regression was used to analyze responses over time among patients managed operatively (OP) vs. non-operatively (NON-OP).

Results

In total, 1,188 patients were analyzed. 66.6% (n=792) were managed operatively. The vast majority (78.9%, n=934) were female. Patients were relatively evenly distributed across age groups (27.6% 0-49; 21.1% 50-59; 30.1% 60-69; 21.2% ≥70). At baseline, the mean percentage of activity at work/school was 56.4% (SD 35.4%), and the mean days off from work/school over the past 90 days was 1.6 (SD 1.8) (Figure 1). Patients undergoing ASD surgery exhibited an 18.1% absolute increase in work/school productivity at 2-year follow-up vs. baseline (p<0.0001), while no significant change was observed for the non-operative cohort (p>0.5). Similarly, the OP cohort experienced 1.1 fewer absent days over the past 90 days at 2 years vs. baseline (p<0.0001), while the NON-OP cohort showed no such difference (p>0.3). These differences were largely preserved after stratifying by baseline employment status, age group, SVA, PI-LL, and deformity curve type.

Conclusion

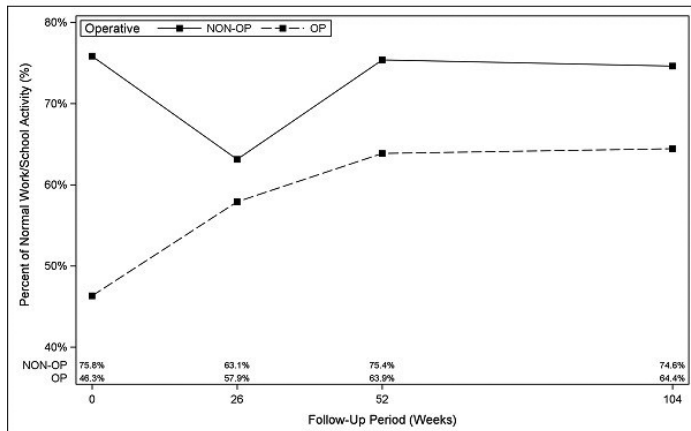
ASD patients managed operatively exhibited an average increase in work/school productivity of 18.1% and decreased absenteeism of 1.1 per 90 days at 2-year follow-up, while patients managed non-operatively did not exhibit change from baseline. Given the age distribution of patients in this study, these findings should be interpreted as pertaining primarily to obligations at work or within the home. Further study of the direct and indirect economic benefits of ASD surgery to patients is warranted.

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Take Home Message

ASD patients managed operatively exhibited an increase in work/school productivity and decreased absenteeism at 2-year follow-up, while patients managed non-operatively did not exhibit change from baseline.

Figure 1: Percent of Normal Work/School Activity, Operative vs. Non-Operative



125. Gain in HRQL after ASD Surgery is Maintained Between 2 and 5 Years' Follow-Up

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Summary

This study represents the largest prospective multicentre surgical cohort of adult spinal deformity (ASD) patients, with > 5 years of follow-up (5YFU), reported in the literature to date. It shows that ASD surgery provides stable and durable outcomes at 5YFU. Following surgery, a substantial proportion of patients report clinically relevant improvement and reach an acceptable symptom state, defined as ODI<18 or SRS22-subtotal>3.5. Post-operative major complications (MC) and unplanned reoperations (UR) are associated with a lesser gain in HRQL at 5YFU.

Hypothesis

ASD Surgical outcomes do not deteriorate after 2YFU

Design

Prospective observational cohort study

Introduction

Despite the increasing number of surgeries done for ASD, there is a lack of data with >5YFU. The aim of our study was to investigate the durability of ASD surgical outcomes and identify predictors of HRQL gain at 5YFU

Methods

We included all surgical patients enrolled in an international ASD database, operated before March 2015, and assessed 2YFU and 5YFU outcomes: adverse events (MC, UR), HRQL and standing radiographic parameters. We compared values at 2YFU and 5YFU for spinal alignment, HRQL gain, % of patients reaching

published MCID and PASS (patient acceptable symptom state) and adverse events, and identified predictors of the gain in HRQL at 5YFU using multivariable linear regression, controlling for confounding factors

Results

361 patients [77.8% women; mean (SD) age 52.1 (19.17) y), mean 8.9 fused levels, 16.6% 3CO, 36.3% pelvic fixation, 94.6% posterior only] met inclusion criteria. 316 (87.5%) completed 2YFU and 258 (71.5%), 5YFU. Lack of 5YFU data was related to site ($p<0.05$) but not to baseline characteristics (demographic, radiographic) or 2YFU outcome (HRQL, MC, RI, radiographic). There was no change ($p>0.05$) in coronal alignment, lumbar lordosis, LGap or SVA from six weeks postop to 5YFU. A significant increase in T2-T12 kyphosis (43.4 vs. 50.6, $p=0.02$), PT (18.1 vs. 21.7, $p=0.02$) and global tilt (18.6 vs. 24.4, $p=0.03$) was observed between 6w and 5YFU. The incidence of MC (24.9% vs. 10.5%, $p<0.001$) and UR (18.8% vs. 12.2%, $p<0.0018$) was greater during the first 2YFU than between 2-5YFU. Mean HRQL scores, proportion of patients reaching MCID and PASS, and satisfaction with treatment were similar at 2YFU and 5YFU (Table). Worse baseline HRQL and sagittal balance (Global Tilt, LGap) were associated ($p<0.05$) with a greater gain in 5YFU HRQL while postoperative MC and UR were associated with a lesser gain ($p<0.05$)

Conclusion

This study provides strong evidence to suggest that surgery for ASD is associated with durable outcomes that do not deteriorate over time. The extent of the gain in HRQL at 5YFU depends on baseline HRQL and sagittal alignment, as well as MC and UR

Take Home Message

The data suggest ASD surgery is associated with a stable gain in HRQL at 5YFU that exceeds MCID in 50% of cases, and is jeopardized by major complications and reinterventions

HROQL				
	Baseline	2y	5y	p value 2y-5y
ODI	37.2 (19.6)	27.2 (21.3)	28.1 (21.1)	0.67
SRS22-Subtotal	2.8 (0.7)	3.5 (0.8)	3.4 (0.9)	0.76
SRS22-Satisfaction		4.1 (1.1)	4.0 (1.0)	0.23
SF36-PCS	36.4 (9.5)	42.2 (10.4)	41.8 (11.2)	0.67
SF36-MCS	42.9 (12.2)	46.8 (12.3)	47.6 (11.3)	0.29
Proportion of patients reaching MCIDs				
ODI	Preop-2Y	39.9%		p=0.56
	Preop-5Y	37.0%		
SRS22 Subtotal	Preop-2Y	61.9%		p=0.357
	Preop-5Y	57.5%		
SF36 PCS	Preop-2Y	48.9%		p=0.93
	Preop-5Y	49.8%		
Proportion of patients reaching PASS (Patient Acceptable Symptom State)				
ODI <18	At 2Y	41.2%		p=0.49
	At 5Y	37.9%		
SRS22 Subtotal >3.5	At 2Y	45.3%		p=0.61
	At 5Y	47.9%		
Major complications				
Before 2Y				
Neurologic	17 (8.2%)			
Mechanical	109 (52.1%)			
Infectious	29 (13.9%)			
Medical	54 (25.8%)			
TOTAL	209 (100%)			
Between 2-5Y				
Neurologic	2 (2.8%)			
Mechanical	55 (78.6%)			
Infectious	4 (5.7%)			
Medical	9 (12.9%)			
TOTAL	70 (100%)			
Major complications				
Before 2Y	24.9% of the patients			p <0.001
Between 2-5Y	10.5% of the patients			
Reinterventions				
Before 2Y	18.8% of the patients			p = 0.018
Between 2-5Y	12.2% of the patients			

126. Neurologic Complications after Adult Spinal Deformity Surgery

Karnmanee Srisanguan, BS; Michael Dinizo, MD; Thomas J. Erri-co, MD; *Tina Raman, MD*

Summary

Adult spinal deformity (ASD) surgery can entail extensive correction for rigid deformities with an associated risk for neurologic complications. We report an 18.9% neurologic complication rate after ASD surgery. 11.7% of neurologic complications had an associated motor deficit. Complete resolution occurred in 29.6% patients, partial resolution in 24.6% of patients, and no resolution in 45.8% of patients. Higher BMI, PSO procedure, and history of revision surgery were predictors of sustaining a neurologic complication.

Hypothesis

The rate of complete resolution of neurologic complications after ASD surgery is high.

Design

Retrospective review of prospectively collected database.

Introduction

Existing reports of neurologic complications after ASD surgery often utilize multi-center databases with considerable heterogeneity. The rate of recovery at long term follow up has been less widely examined. We sought to describe the incidence of neurologic complications, and rate of resolution.

Methods

949 patients (Age: 45 ± 24 y; mFI: $.41 \pm .67$; Levels fused: 10 ± 4) underwent ASD surgery. Outcomes evaluated at a mean of 48.9 months follow-up were the rate of neurologic complications, and resolution of neurologic injury.

Results

The neurologic complication rate was 18.9% (179/949). Of the 179 neurologic complications, 150 (83.8%) were new onset postoperative radiculopathies with pain or sensory deficit, 21 (11.7%) were radiculopathies with motor deficit, 7 (3.9%) were spinal cord injuries, and 1 (0.6%) was cauda equina syndrome. 97/179 patients (54.2%) had either complete resolution (n=53, 29.6%) or partial resolution (n=44, 24.6%) of the neurologic injury at final follow-up, and 82 patients had no resolution (45.8%). Of those who had a postoperative motor deficit, mean strength grading at final follow-up was 4.14 ± 1.46 . Of the 179 patients, 30 (16.8%) required revision surgery. Age > 70, current smoking, revision surgery, higher BMI (28.6 vs. 24.3 mg/k², p<0.0001), higher preoperative SVA (103.8 mm vs. 71.4 mm, p<0.0001) and greater correction of SVA (34.4 mm vs. 17.8 mm, p=0.004) were associated with neurologic complications. Two attending spine surgeons were present for 18.9% of cases with no effect on rate of neurologic complications. BMI (OR:1.04, p=0.029), revision surgery (OR:2.5, p<0.0001), and PSO (OR:2.2, 0.007) were predictors of neurologic complications.

Conclusion

We report an overall neurologic complication rate of 18.9% after ASD surgery with a 29.6% rate of complete resolution and 24.6% rate of partial resolution. 11.7% of patients had an associated motor deficit with mean strength grade of 4.14 at final follow-up. Higher BMI, and history of revision surgery were predictors of neurologic complications.

Take Home Message

The neurologic complication rate after ASD surgery was 18.9%, with a 29.6% rate of complete resolution. Risk factors include age > 70, revision surgery, and greater correction of SVA.

127. Assessing Key Functional Outcomes after Multilevel Fusion for Adult Spinal Deformity in Patients Over Sixty Years of Age: A Prospective, Observational, Multicenter Study with 2-Year Follow-Up

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Summary

This prospective, international, multi-center study evaluated the changes in self-reported functional outcomes in 219 patients,

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over the age of sixty, with primary adult spinal deformity treated with fusion of at least 5 levels. At 24 months, 63% of patients can expect to walk a mile or more, 69% could stand and 95% could sit half an hour or more. This study provides important practical numbers in terms of expected functional outcome in older patients undergoing multilevel spinal deformity surgery.

Hypothesis

Specific functions that include standing, walking, will show the greatest improvements in functions following ASD surgery

Design

A prospective multicenter cohort study

Introduction

Functional disability is a common presentation of ASD. While several studies indicate that operative treatment can provide significant improvement in disability at 2-year follow-up, there is little information outlining and quantifying which key functions are most affected and improved from surgery.

Methods

Patients ≥ 60 years of age from 12 international undergoing spinal fusion of at least 5 levels due to primary ASD. Follow-up visits were performed at 10 ± 6 weeks, 12 ± 2 months, and 24 ± 2 months. The function was assessed using the SRS22r function domain, and with the personal care, walking, sitting, and standing sections from the Oswestry Disability Index.

Results

219 patients (mean age 67.5-year-old, 80.4% female) out of 255 enrolled met the inclusion criteria. Of them 179 (82%) patients completed the 2 years study period. SRS22r function domain mean (SD) score was 2.7 (0.7) at baseline and at 10 weeks and improved ($P < 0.001$) at 12 months (3.4[0.7]), and at 24 months (3.5[0.8]). From baseline to 24 months, ODI questions of walking (2.4 to 1.4), standing (3.1 to 1.7), and social life (2.6 to 1.3) showed the greatest improvements in an unadjusted mixed effect model. In terms of walking, pre-operatively vs. 2 years post-op, 26% vs. 63% of patients could walk a mile or more while 53% vs. 22% could walk 100 yards or less. Similarly, percentage of patients that could stand >10 minutes improved from 51% to 86%, and social life was not restricted in 36% of patients pre-operatively compared to 74% at 2 years.

Conclusion

This study provides important practical numbers in terms of expected functional outcomes in older patients undergoing multilevel spinal fusions for ASD. Specifically, significant improvements in standing, walking, and social life were recorded at 2-year follow-up. At 24 months, 63% of patients can expect to walk a mile or more, 69% could stand and 95% could sit half an hour or more.

Take Home Message

Significant functional improvements in standing, walking, and social life were recorded in patients greater than 60 years of age undergoing multilevel surgery for adult spinal deformity.

128. Complication Rates with MIS Deformity Surgery Depend More on Number of Posterior Levels Fused than Number of Interbody Grafts

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Summary

In a retrospective analysis of a multicenter database of patients who underwent circumferential MIS treat for ASD, complication rates increased as the length of posterior constructs increased. There is a significant inflection point in at the proximal lumbar spine where complications increase, suggesting that when possible selecting a UIV at the proximal lumbar spine is optimal while avoiding crossing the thoracolumbar junction. There was no impact on number of interbody levels fused.

Hypothesis

Minimally invasive spinal surgery (MIS) for adult spinal deformity (ASD) has been shown to have reduced complication rates when compared to open techniques. Amongst MIS surgery, there is an inflection point with regards to construct length and number of interbody levels where complication rates increase drastically.

Design

Retrospective review of prospective multicenter database

Introduction

Surgical management of ASD improves HRQoL. However, these procedures carry 40-86% risk of perioperative complications. This study aims to determine the optimal number of interbody levels and construct length in reducing complication rates.

Methods

Assessment of patients who underwent circumferential MIS treatment for ASD with inclusion criteria: age >18 years, major coronal Cobb $\geq 20^\circ$, SVA ≥ 5 cm, PT $\geq 25^\circ$ and/or TK $> 60^\circ$, with 1 year follow up. The patients were divided based on length of construct: thoracic to sacrum/pelvis, lumbar only, and lumbar to sacrum/pelvis. Surgical metrics, complications, and reoperation rates were compared.

Results

159 patients were evaluated. There were significantly higher all-complication rates with increasing construct length 30% lumbar only, 47.1% lumbar-sacrum, and 57.8% thoracic-sacrum ($p=0.036$). There were no differences in reoperation and major complications ($p=0.252$). There were increasing minor complication rates: 12.5% lumbar only, 20.6% lumbar-sacrum, and 35.6% thoracic-sacrum ($p=0.039$). Operative time ($p < 0.001$), blood loss ($p < 0.001$), and length of stay ($p < 0.001$) significantly increased as construct length increased. Multivariate analysis controlling for posterior construct length revealed that number of interbody levels did not impact complication rates.

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Conclusion

For patients with ASD undergoing circumferential MIS surgery, the length of posterior construct length increased complication rates without impact of number of interbody levels fused. There is an inflection point as the construct crosses the thoracolumbar junction, suggesting that in select cases there may be a benefit stopping a long construct in the proximal lumbar spine for reduced complication rates.

Take Home Message

In circumferential MIS surgery, there is a increasing complication rate with longer posterior constructs. There may be a benefit in stopping long constructs at the proximal lumbar spine.

129. COVID-19 Significantly Impacted Hospital Length of Stay and Discharge Patterns for ASD Surgery

Kevin Y. Wang, BS; Emmanuel McNeely, MS; Suraj Dhanjani, BS; Micheal Raad, MD; Varun Puvanesarajah, MD; Brian J. Neuman, MD; Jay Khanna, MD; Floreana N. Kebaish, MD; Hamid Hassan-zadeh, MD; Khaled M. Kebaish, MD

Summary

During the COVID-19 pandemic, surgeons found ways to provide appropriate care while conserving inpatient resources and limiting potential exposure. The aim of this study was to 1) determine the effect of the pandemic on length of stay (LOS) and discharge disposition following ASD surgery, 2) assess the implications of these changes on outcomes. Our results show that LOS for ASD surgery decreased during the pandemic, and that more patients were discharged home without an increase in complications or readmissions.

Hypothesis

ASD patients who underwent surgery during the pandemic had shorter LOS and greater rates of home discharge compared to before, without differences in outcomes.

Design

Retrospective review of an institutional surgical registry

Introduction

ASD surgery often requires extended LOS and non-routine discharge. Given resource limitations during the COVID-19 pandemic and caution regarding hospital stays, surgeons have modified standard postoperative protocols to minimize patient exposure. The primary aim of this study was to compare LOS and discharge disposition of ASD patients undergoing surgery before and during the pandemic. Secondary aims were to compare the rates of 30-day complications, readmissions, and ED visits.

Methods

We identified all patients who underwent elective thoracolumbar ASD surgery with ≥ 5 levels fusion at a tertiary care center during two distinct time intervals: Jul-Dec 2019 (Pre-COVID, N=60) and Jul-Dec 2020 (During-COVID, N=57). Outcome measures included LOS and discharge disposition (home vs. non-home), as well as 30-day major complications, reoperations, readmissions, and ED visits. Regression analyses controlled for demographic and surgical factors.

Results

Patients who underwent ASD surgery during the pandemic were younger (61 vs. 67 years) and had longer fusion constructs (9 vs. 8 levels) compared to before pandemic ($p < 0.05$ for both). On bivariate analysis, patients undergoing surgery during the pandemic had significantly lower LOS (6 vs. 8 days) and were more likely to be discharged home (70% vs. 28%) ($p < 0.05$ for both). After controlling for age and levels fused on multivariable regression, patients who had surgery during the pandemic continued to demonstrate a significantly lower LOS (IRR=0.83, $p = 0.015$) and greater odds of home discharge (OR=7.2, $p < 0.001$). Notably, there were no significant differences in reoperations, readmissions, ED visits, or major complications between the two groups. *All times are listed in US Central Time.*

($p > 0.05$ for all).

Conclusion

During the COVID-19 pandemic, the LOS for patients undergoing thoracolumbar ASD surgery decreased, and more patients were discharged home without adversely affecting complication or readmission rates.

Take Home Message

Shortened LOS, due to COVID-19, did not affect postoperative complication or readmission rates for ASD patients. Lessons learned during the pandemic may help improve resource utilization without negatively influencing outcomes.

130. The Lessons Learned from the COVID Pandemic Will Improve the Patient Experience in the Outpatient Setting

Kiley F. Poppino, BS; Charu Sharma, MS; Lindsay Phillips, MS; *Daniel J. Sucato, MD, MS*

Summary

We describe the impact of the COVID-19 pandemic on patient satisfaction in the setting of a pediatric outpatient scoliosis clinic at a single institution. The volume per clinic and volume per hour were decreased to help maintain social distancing and practice of safety measures and resulted in an increase in the rate of positive responses to visits beginning on time without a negative impact on the provider rating, recommendation of the facility or the perceived quality of care.

Hypothesis

N/A, QI

Design

Quality, safety, value initiative (QVSI)

Introduction

The novel coronavirus (COVID-19) pandemic has greatly affected the operational delivery of healthcare. While rapid adoption of telehealth has been noted, little is known about the impact of COVID-19 on patient satisfaction in the outpatient clinic setting.

Methods

Outpatient pediatric scoliosis visit data from a single institution were analyzed. Time was categorized as 6 months prior to COVID-19 (Prior-C group) outbreak (September 2019-February 2020) and 6 months into COVID-19 (During-C group) outbreak (March 2020-August 2020). The NRC Health Patient Satisfaction data was reviewed for real-time feedback.

Results

A total of 8,409 visits were examined, of which 2,044 completed NRC survey data (24.3%). Patients were 13 years old, with the majority of encounters being follow-up visits ($n = 1,150$, 56.2%). The planned reduction in outpatient visits was determined by the criteria of having only essential visits and to allow patient rooming into the clinic room immediately following registration. There was an average 29.8% reduction in clinic volume. When comparing the Prior-C and During-C groups there were no significant differences noted in the two-key metrics for the organization – Net Promotor Score and Provider Rating. A

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significant increase was noted in patient perception of hand washing in both groups: new patients ($p=0.017$) and follow-up patient ($p<0.001$). Also, a significant improvement was noted in percentage of positive response to, “if their treatment began on time” ($p<0.001$). Conversely, new patients reported a significant increase in not knowing who to call when needing help or having questions ($p=0.026$) and overall perception of registration desk courtesy decreased from 97.4% to 95.3% ($p=0.033$).

Conclusion

While COVID-19 has caused multiple operational challenges in the outpatient setting overall patient perception of quality of care was the same. Decreasing patient volumes/clinic demonstrated significantly improved clinic start times and may be appropriate moving forward. Continued review of the patient experience may be critical in the future to improve patient satisfaction.

Take Home Message

The lessons learned from the COVID pandemic should be employed in the future to improve patient satisfaction while maintaining patient volumes.

131. Effect of COVID-19 on Spine Deformity Care and Patient-Reported Outcome Measures

Suken A. Shah, MD; Michelle Claire Marks, PT; Maty Petcharporn, BS; Petya Yorgova; Irene Li, MS

Summary

Currently, the United States has the highest number of COVID-19 cases globally. In response to these growing numbers, hospitals have had to adapt their outpatient visits to meet patient needs. Due to government-imposed lockdowns and restrictions, the way spine deformity care is provided and research is conducted has changed.

Hypothesis

The study objective was to compare the mental health (MH) and satisfaction(S) from long term post-op patients. This was evaluated by a Scoliosis Research Society (SRS) 22/30-item questionnaire on a quarterly basis administered between 2019 and 2020 among patients from different pediatric hospitals. Additionally, we queried the database to determine follow up rates and use of telemedicine during this period.

Design

Multi-center prospective cohort study

Introduction

SRS-22 questionnaire is a widely used patient outcome tool. MH and S domains can be used as a proxy to check if the COVID-19 lockdown affected adolescents who underwent posterior spinal fusion for scoliosis.

Methods

The percentage change in long term follow up (FU) visits (6 month, 1year, and 2year) in 2019 vs. 2020 for each quarter were calculated. Percentage of telehealth visits with and without x-rays performed during the peak of the national COVID-19 lock-

down were estimated. Furthermore, patient mental health and satisfaction scores were evaluated using their SRS 22/30-item validated questionnaire responses from long term post-op visits and compared by quarter in 2019 vs. 2020.

Results

The number of newly enrolled patients dropped drastically by 70 % in Q2 of 2020 and quickly recovered back to its 2019 levels during Q3/Q4. The number of long-term FU telehealth visits went from zero in 2019 to 58 (34 with x-rays) in Q2/ Q3 of 2020. There was no statistically significant difference in patients MH from 2019 to 2020 compared by quarter (figure 1). The satisfaction with treatment was statistically significantly higher in Q1 of 2020 compared to Q1 of 2019 ($p=0.032$), figure 1.

Conclusion

COVID-19 changed the way spine care was provided and research visits were conducted; and, overall satisfaction levels and mental health scores were significantly impacted. Telemedicine increased the overall access to orthopedic care without compromising patient satisfaction. Although research enrollment patients receiving posterior spinal fusion decreased during the first two quarters of 2020, in the second half of 2020 the number of new posterior spinal fusion patients enrolled returned to its 2019 levels.

Take Home Message

The consistency in their mental health evaluations show patients were able to adapt to the realities of the pandemic. Patients showed increased satisfaction as the lockdown eased.

Figure 1	Variable	Year Qt	Mean	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
Mental Health (SRS 22)		2019 Q1	4.079	0.656	0.041	0.46
		2020 Q1	4.128	0.702	0.054	
Mental Health (SRS 22)		2019 Q2	4.089	0.730	0.041	0.393
		2020 Q2	4.153	0.736	0.062	
Mental Health (SRS 22)		2019 Q3	4.128	0.715	0.033	0.528
		2020 Q3	4.094	0.693	0.042	
Mental Health (SRS 22)		2019 Q4	4.089	0.702	0.052	0.791
		2020 Q4	4.066	0.703	0.070	
Satisfaction (SRS 22)		2019 Q1	4.557	0.621	0.039	0.032
		2020 Q1	4.681	0.513	0.039	
Satisfaction (SRS 22)		2019 Q2	4.547	0.622	0.035	0.285
		2020 Q2	4.471	0.824	0.070	
Satisfaction (SRS 22)		2019 Q3	4.562	0.643	0.030	0.764
		2020 Q3	4.577	0.651	0.040	
Satisfaction (SRS 22)		2019 Q4	4.500	0.687	0.051	0.108
		2020 Q4	4.625	0.479	0.048	
Total (SRS 22)		2019 Q1	4.281	0.397	0.025	0.236
		2020 Q1	4.331	0.461	0.035	
Total (SRS 22)		2019 Q2	4.280	0.459	0.026	0.902
		2020 Q2	4.286	0.564	0.047	
Total (SRS 22)		2019 Q3	4.297	0.456	0.021	0.889
		2020 Q3	4.292	0.444	0.027	
Total (SRS 22)		2019 Q4	4.267	0.400	0.030	0.714
		2020 Q4	4.285	0.384	0.038	

SRS-22/30 scores

132. Are AIS Patients Good Candidates for Telemedicine Consultation?: A Comparison of Satisfaction Scores between AIS and Non-AIS Patients During the COVID-19 Pandemic

Gabriel KP Liu, MD; Jun Hao Tan, MBBS; Leok-Lim Lau, FRCS; Hee-Kit Wong, FRCS

All times are listed in US Central Time.

*Denotes Non-CME Session

Summary

This was a retrospective review of consecutive patients who underwent telemedicine. Multivariate analysis showed that AIS patients and non-AIS patients requiring new investigations results reviewed have the highest satisfaction scores compared to non-AIS patients on routine follow-up. Furthermore, AIS patients and non-AIS patients requiring new investigations results reviewed are also more keen for another session of teleconsultation. AIS and non-AIS patients who require review of new investigation results experienced good satisfaction and are good candidates for telemedicine consultation.

Hypothesis

The aim of this paper is to compare the satisfaction scores of Adolescent Idiopathic Scoliosis (AIS) patients and non-AIS patients who underwent teleconsultation, with the hypothesis that AIS patients are ideal candidates for telemedicine.

Design

This was a retrospective review of all consecutive patients who underwent telemedicine during the COVID-19 pandemic from February to December 2020 in a single university hospital.

Introduction

Telemedicine is a rapidly evolving consultation tool. It prevents patients from having to travel long distances to see the specialist, allows patient consultation to occur in their own home, and reduces disease exposure in the hospital by maintaining social distancing during the COVID-19 pandemic.

Methods

Patients' demographics and consultation details were recorded. The telemedicine set-up and consultation duration, patient satisfaction scores (assessed via a 1-5 Likert scale) were analyzed.

Results

A total of 213 patients underwent telemedicine, of whom 47(22%) patients with Adolescent Idiopathic Scoliosis (AIS) were recruited. There were 39(83%) females, with a mean age of 14.5±2years. The mean AIS telemedicine set-up duration was 10.7±15mins, with mean consult duration of 12.4±8mins. 166(77.9%) non-AIS patients, of whom 87(40.8%) patients underwent telemedicine to learn of their investigation results. 79(37.1%) patients had routine follow-up consultation. The mean age was 46.9±16.9 years, with 80(48.2%) females. The mean set-up duration was 7.2±9.4mins, with mean consult duration of 13.7±7.8mins. Multivariate analysis showed that AIS patients and non-AIS patients requiring new investigations results reviewed have the highest satisfaction scores compared to non-AIS patients on routine follow-up (AIS: 80.8%, trace Ix: 80.3%, routine follow-up: 69.3%, $p=0.048$). Furthermore, they are also more keen for another session of teleconsultation (AIS: 78.8%, trace Ix: 79.5%, routine follow-up: 65.4%, $p=0.03$).

Conclusion

AIS and non-AIS patients who require review of new investigation results experienced good satisfaction and are good candidates for teleconsultation.

Take Home Message

AIS and non-AIS patients who require review of new investigation results experienced good satisfaction and are good candidates for telemedicine consultation.

133. Impact of COVID-19 on Pediatric Spine Patients: Post Traumatic Stress and Coping Responses

Emily Gale, PhD; Whitney M. Herge, PhD; Emily Stapleton, PsyD; Kiley F. Poppino, BS; Shelby P. Cerza, MA; Daniel J. Sucato, MD, MS

Summary

This study evaluated coping and stress responses to COVID-19 in a pediatric spine population.

Hypothesis

This was an exploratory study on the impact of a novel stressor; no a priori hypotheses were made.

Design

Cross-sectional electronic survey regarding patients receiving treatment for pediatric spine conditions.

Introduction

The novel coronavirus (COVID-19) has greatly impacted the physical and emotional wellbeing of people around the globe. In the US, many medical patients have delayed surgeries or delayed care due to COVID-19. Additionally, families are experiencing extraordinary stressors associated with the pandemic, including online school, loss of income, and loss of ordinary life. We sought to examine how pediatric spine patients and their families are responding to and coping with global pandemic stressors.

Methods

An anonymous survey was collected via our hospitals EMR between May and August 2020. Participants were asked about stressors, how they are coping using the BRIEF Cope and possible PTSD symptoms, in addition to demographic items.

Results

Of 1634 participants, 309 adults reported either receiving treatment or their child being treated for pediatric spine conditions. This spinal treatment subgroup was mostly female (85.4%), white (66.7%), employed (64.1%), and with a household income above \$75,000 (54.4%). On the BRIEF Cope, a scale measuring coping responses with scores ranging from "I don't do this at all" to "I do this a lot", participants reported using the following coping strategies most often: Acceptance, Religion, Active Coping, and Self-Distraction. PTSD scores were relatively low on the PCL-5, with 7.8% endorsing clinically significant symptoms. PTSD scores were significantly, positively correlated with the following coping skills: denial ($r=.24$), behavioral disengagement ($r=.47$), venting ($r=.22$), self-blame ($r=.55$). PTSD and positive reframing were significantly negatively correlated ($r=-.12$).

Conclusion

COVID-19 has emerged as a unique stressor to patients and families. In a pediatric spine population, negative coping skills

may be increasing the likelihood of PTSD symptoms. Healthcare and behavioral health providers need to take coping strategies into account when determining what supports would be best for patients and families.

Take Home Message

COVID-19 has emerged as a unique stressor to patients and families. Healthcare and behavioral health providers should take coping strategies into account when determining supports to aid patients and families.

134. A Dangerous Curve: Impact of the COVID-19 Pandemic on Brace Treatment in Idiopathic Scoliosis

Matias Pereira Duarte, MD; Julie Joncas, RN; Stefan Parent, MD, PhD; Olivier Chémaly, MD; Felix L. Brassard, MD; Jean-Marc Mac-Thiong, MD, PhD; Soraya Barchi, BSc; Hubert Labelle, MD

Summary

COVID-19 pandemic has created a worldwide social, economic and health crisis impacting on the normal life of adolescents. We report that during the first COVID-19 wave, the abandon rate for brace treatment in subjects with idiopathic scoliosis has significantly increased compared to previously reported rates at our center and in the literature. Significant increases in curve progression and surgical indication rates have been documented in subjects who have abandoned brace treatment, suggesting that preventives measures should be taken.

Hypothesis

COVID-19 pandemic associated to social distancing, teleworking and school closures has impacted negatively on patient adherence to brace treatment in Idiopathic Scoliosis (IS).

Design

Observational Cohort study.

Introduction

There is a significant positive association between hours of brace wear and rate of success in the treatment of IS. The abandon rate reported in the literature averages 18%. In a recent randomized trial conducted at our center; the abandon rate was 4%. We aim to document the abandon rate towards brace treatment during the COVID-19 pandemic and its impact on IS progression.

Methods

We reviewed a database of IS patients recruited between March-September 2020. Inclusion criteria were patients with IS under brace treatment according to SRS criteria. The patients were divided in 2 cohorts: those with a self-reported good adherence to treatment and those who voluntarily abandoned treatment during follow-up. Patients with irregular adherence were excluded. Data analysis included age, sex, Risser stage, type of brace, Cobb angles at 1st visit and last follow-up (mean 11 months) and % of progression. Unpaired student tests were used for comparison.

Results

154 patients met inclusion criteria. 20 patients were excluded due to irregular adherence. 89 patients (12.1 y.o.±1.4) reported

good adherence to treatment, while 45 patients (12.6 y.o. ±1.5) abandoned treatment, an abandon rate of 29%. The cohort of compliant patients started treatment with a mean main thoracic (MT) curve of 26° and finished with 27°. The mean difference between measurements was +0.65°±7,5; mean progression rate was 4.6%. However, patients who abandoned treatment started with a mean MT curve of 28° and finished with 33°, with a mean increase of +5°±8 and a mean progression rate of 11%. The differences between the 2 cohorts were statistically significant (p=0.002) (Fig). 4 patients from the abandon group were counselled for surgery because of curve progression.

Conclusion

The abandon rate of brace treatment in IS significantly increased during the COVID-19 pandemic. Patients who voluntarily discontinued treatment had significant increases in curve progression and surgical indication rates.

Take Home Message

Clinicians should be aware of the COVID-19 crisis' effect on brace treatment in IS. A contingency plan to counteract these effects needs to be created to prevent curve progression.

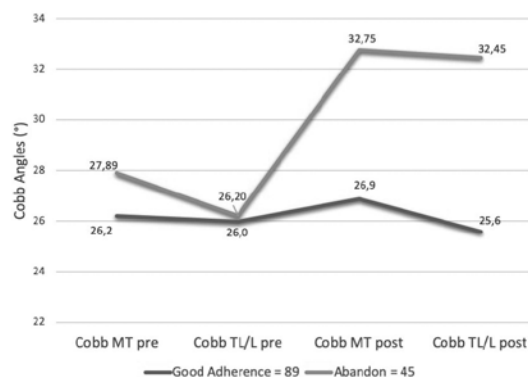


Fig. Main thoracic (MT) and thoracolumbar (TL) / lumbar (L) Cobb progression in patients with good adherence to brace treatment and those who abandoned treatment during COVID-19 Pandemic.

135. Identification of Anterior Cervical Spinal Instrumentation Using a Smartphone Application Powered by Machine Learning

John Schwartz, BS; Aly A. Valliani, BS; Brian H. Cho, BS; Varun Arvind, BS; Eric Geng, BS; Samuel K. Cho, MD; Jun S. Kim, MD

Summary

Implant identification is important for planning revision anterior cervical discectomy and fusion. Implant identification is often time-consuming and subject to bias. A machine learning algorithm was developed for the identification of instrumentation from smartphone photos of radiographs. The algorithm performed with 94.4% top-3 accuracy and 85.8% top-1 accuracy. It will be deployed as an accessible smartphone application for further evaluation, improvement, and eventual widespread use.

Hypothesis

A smartphone-deployable machine learning algorithm can be developed to identify ACDF plates from radiographs with strong performance.

All times are listed in US Central Time.

*Denotes Non-CME Session

Design

Cross-sectional study.

Introduction

The estimated revision rate for anterior cervical discectomy and fusion (ACDF) is between 10-20%. Identification of existing instrumentation is a critical step in planning revision surgery. In many cases, plate identification must be performed visually. This process may be time-consuming and subject to biases. A need exists for fast, objective methods for identifying instrumentation from radiographs. Machine learning algorithms may be applicable to the problem of ACDF plate identification. An algorithm that could be deployed on a smartphone would be useful due to the ubiquity of clinical smartphone use.

Methods

402 smartphone images of deidentified AP cervical spine radiographs containing 15 different types of ACDF plates were gathered from publicly available data sources via internet search. 275 images (~70%) were used to train and validate a convolution neural network (CNN) for classification of images from radiographs. 127 (~30%) images were held out to test algorithm performance using accuracy, positive predictive value, sensitivity, and f-1 score.

Results

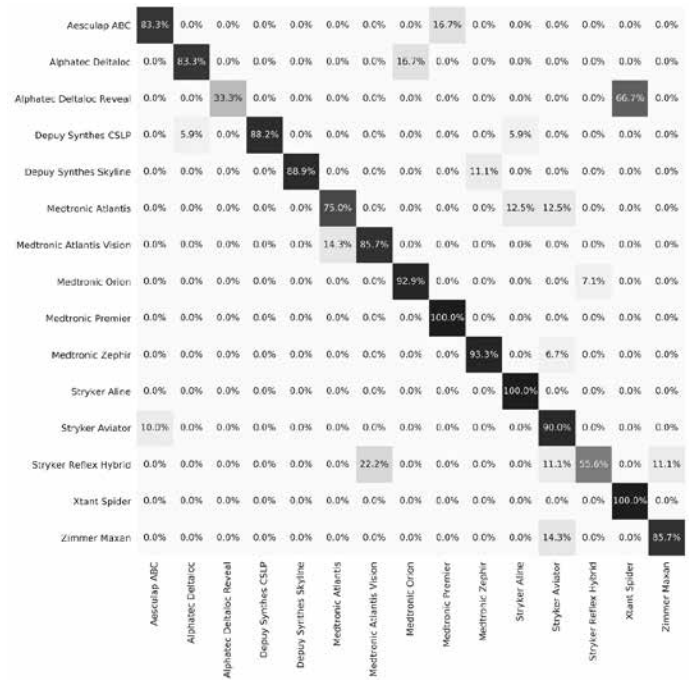
The algorithm performed with an overall accuracy of 94.4% and 85.8% for top-3 and top-1 accuracy. Overall positive predictive value, sensitivity, and f1-scores were 0.873, 0.858, and 0.855.

Conclusion

This algorithm demonstrates strong performance in the classification of ACDF plates from smartphone images. It will be deployed as an accessible smartphone application for further evaluation, improvement, and eventual widespread use.

Take Home Message

This study presents a smartphone-deployable algorithm for identification of ACDF plates from smartphone photos of AP cervical radiographs.



Normalized confusion matrix of algorithm evaluation on test dataset. Predicted class is on the x-axis and true class is on the y-axis. Darker colors represent higher values.

136. The Utility of Surgeon-Directed DICOM Manipulation Software as a Preoperative Surgical Planning Tool in Pediatric Craniovertebral Anomalies

Kshitij Chaudhary, MD; Arjun Dhawale, MD; Avi P. Shah, MD; Abhay Nene, MD

Summary

This is a retrospective review of 25 operated patients with pediatric atlantoaxial anomalies. The preoperative planning of these anomalies was done using CT angiograms. CT on PACS was compared with images generated using an open-source DICOM manipulation software. Any deviations with preoperative planning were recorded. Substantial new anatomical information was obtained using DICOM manipulation software over PACS images. Preoperative plan was executed in all but 4 patients. We conclude that DICOM manipulation gives more anatomical information compared to PACS images.

Hypothesis

Preoperative planning using DICOM manipulation software gives more preoperative anatomical information than studying PACS images.

Design

Retrospective Chart Review

Introduction

Orthogonal CT images are inadequate for planning screws for rigid craniovertebral (CVJ) instrumentation. Open source DICOM software, allows surgeons to perform multiplanar reconstructions in line with the screw trajectory. We have evaluated wheth-

er this method of preoperative planning can provide additional anatomical information compared to conventional CT images.

Methods

25 consecutive children were operated on between 2014 and 2019. The preoperative CT angiogram was available on PACS. The DICOM data was then transferred to the surgeon's laptop and loaded in an open-source DICOM software. The surgeon manipulated the DICOM images to determine an idealized path of screws. 3D volume rendering of the anatomy was generated. The surgeon compared the anatomical data obtained using the software with that from the PACS and graded it as; Grade A (substantial new information), Grade B (confirmatory with improved visualization and understanding), Grade C (no added information). Any deviations with preoperative planning were recorded.

Results

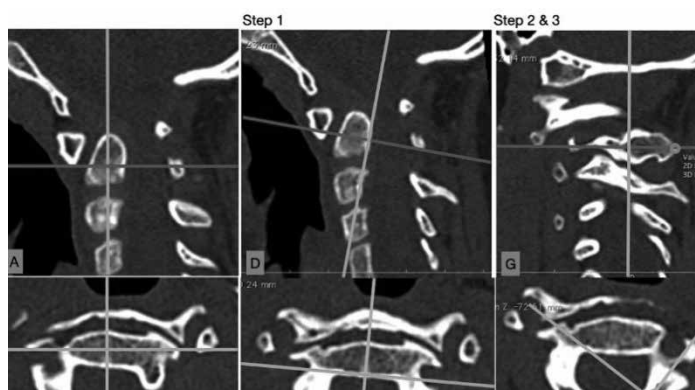
All children presented at a mean age of 7.2 years (2-12 years). Most common etiology was congenital anomalies (n=11) and skeletal dysplasia (n=7). Surgeries were occipitocervical fixation (n=18) and atlantoaxial fixation (n=7). In 18 (72%) patients, the surgeon noted substantial new information (Grade A) about CVJ anomalies on DICOM software compared to PACS CT. Concerning planning for fixation anchors, the surgeon graded the information obtained as Grade A in all patients (100%). In 4 (16%) patients, the surgery could not be executed precisely as planned. The average follow-up was 25 months.

Conclusion

Open source DICOM software can be a significant value addition to the surgeon's preoperative workflow in planning complex craniovertebral anomalies. Surgeon-directed DICOM manipulation gives more anatomical information compared to studying PACS images.

Take Home Message

Complex craniovertebral anomalies require extensive preoperative planning. The surgeon directed manipulating DICOM images provides more anatomical information as the surgeon can generate images in any plane desired.



Four Steps in Planning of C2 laminar screw trajectory on DICOM software

All times are listed in US Central Time.

137. Automated Clustering of Early Onset Scoliosis Patients Using Pre-Operative Clinical Indices

Girish Viraraghavan, MS; Patrick J. Cahill, MD; Jason B. Anari, MD; Sriram Balasubramanian, PhD

Summary

An automated method was developed to cluster Early Onset Scoliosis (EOS) subjects using only pre-operative clinical indices such as age at surgery, Cobb angle and kyphosis. Clustering was performed separately for each etiology, with statistical analysis showing that the clusters were significantly different from each other. For each etiology, the optimal number of clusters was three, that resulted in the highest accuracy.

Hypothesis

EOS subjects can be automatically clustered based on pre-operative clinical indices.

Design

Retrospective pre-operative radiographic images and clinical indices from EOS subjects were obtained from the Pediatric Spine Study Group (PSSG), which were used to automatically cluster EOS patients based on the pre-operative clinical indices.

Introduction

EOS is defined as onset of spinal curvature greater than 10° in children less than 10 years of age. Currently there is a lack of consensus on the treatment of EOS patients due to differences in selection of age of surgery and type of instrumentation. The current C-EOS system helps organize and simplify EOS pathology, but does not help achieve consensus for surgical treatment. There is a need for an evidence-based method of treatment planning that would help create a universal standard of care for EOS patients. The current study aims to create an automated method to cluster EOS patients based on pre-operative clinical indices.

Methods

A total of 1121 EOS subjects were used for the study, with the following distribution by etiology: congenital (269), idiopathic (201), neuromuscular (414), syndromic (233). Pre-operative clinical indices used for clustering were age at surgery, major curve Cobb angle (MCA), kyphosis (KY), deformity index (MCA/Ky), and levels involved in MCA and Ky, respectively. Fuzzy c-means clustering was performed for each etiology individually, with one-way ANOVA performed to assess statistical significance ($p < 0.05$).

Results

Fuzzy clustering algorithm resulted in three cluster per etiology as the optimal number. Statistical analysis showed that the clusters were significantly different for all the different clinical indices. Exemplar neuromuscular clusters (Fig 1) visualized based on MCA and KY.

Conclusion

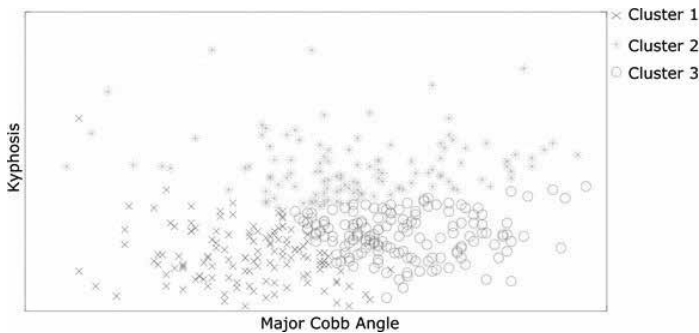
An automated framework was established to perform automated clustering of EOS subjects. New patients can be added to the already existing clusters automatically, given the clinical indices. The current study helps reduce the total number of C-EOS

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groups per etiology (12) to three groups.

Take Home Message

EOS subjects can be clustered automatically using the fuzzy clustering algorithm to three clusters per etiology.



Neuromuscular clusters (Three) visualized based on Cobb angle and kyphosis

138. Development and Validation of a Model to Predict X-ray Progression at a Follow-Up Visit Based on Ultrasound and Clinical Parameters for Adolescent Idiopathic Scoliosis (AIS)

Mahdieh Khodaei, PhD; Eric C. Parent, PhD; Lawrence H. Le, PhD; Sarah Southon, Nurse Practitioner; Doug L. Hill, MS; Kyle Stampe, MD; Eric M. Huang, MD; Edmond H. Lou, PhD

Summary

Four baseline parameters included X-ray Cobb, bone quality extracted from the ultrasound (US) reflection coefficient (RC) index, chronological age, and the menarche status plus the Cobb change measured from ultrasonographs at the baseline and follow-up visits were used for predictive model development. Fifty-six girls with AIS were used for model development and 19 were used to validate the model: $\text{Logit}(p) = 2.32 + 0.58(\text{US Cobb change}) - 81.01(\text{RC})$. The results achieved sensitivity 87%, specificity 91% and accuracy 89%.

Hypothesis

Using US imaging parameters with baseline clinical information could predict the progression of AIS.

Design

Prospective cohort study

Introduction

The cumulative radiation exposure of radiographs from monitoring scoliosis is associated with increased cancer risk. Researchers have developed models for predicting scoliosis progression, but most focus only on ultimate progression between the first diagnosis and the final outcomes. Ultrasound (US) imaging has been developed to monitor scoliosis. Curve angles measured on the US images are accurate and reliable. Osteopenia is also reported to be a prognostic factor for developing AIS. This study aimed to develop and validate a model using US parameters and baseline clinical information to predict curve progression at a follow-up between 6-12-months later in children with AIS.

Methods

Seventy-five females with AIS were enrolled with consent.

All times are listed in US Central Time.

Fifty-six (age 13.6 ± 1.6 yr, X-ray Cobb 26 ± 10) were randomly selected for predictive model development and 19(25%) (age 13.5 ± 2.1 yr, X-ray Cobb 30 ± 9) were used for model validation. Among the model development and validation cases, 25 and 8 cases respectively had curve progression >5 degrees as per SRS guidelines. The average time between baseline and follow-up visit was 8.5 ± 5.3 months. Full spine ultrasound scans were obtained in a standing position at the baseline and follow-up visits. The US curve angle and the bone quality (RC) were measured from these images. A multivariate logistic regression was used to identify the best predictors of progression among the 4 baseline parameters plus the US curve angle change between the baseline and the follow-up visits.

Results

Lower values for RC and higher US Cobb change were the best predictive factors. The predictive model was: $\text{Logit}(p) = 2.32 + 0.58(\text{US Cobb change}) - 81.01(\text{RC})$. The model achieved 87% sensitivity, 91% specificity and 89% accuracy during validation.

Conclusion

This study shows that bone quality and curve change measured with US can predict curve progression in females with AIS.

Take Home Message

A novel predictive model based on baseline bone quality and curve change on US images may help clinicians initiate appropriate treatment at follow-up visit while limiting exposure to harmful radiation.

139. Automatic Measurement of Cobb Angle Based on Artificial Intelligence Key Point Detection Technology

Xianglong Meng, MD, PhD; Yaozhong Xing, PhD; Yu Sun, PhD; Zian Zhao, PhD

Summary

The present study aimed to develop a rapid, robust, and fine-grained automatic measurement system for Cobb angle. Two CenterNet-based artificial intelligence (AI) models were used in sequence to segment each vertebra and locate vertebral corners in 151 cases of idiopathic scoliosis (Cobb angles range: $10^\circ - 93^\circ$) and normal adult cases without scoliosis. The automatic measurement system based on AI keypoint detection can identify each vertebra, obtain Cobb angles rapidly and accurately.

Hypothesis

An Automatic Measurement System Based on AI Object Detection and Keypoint Detection Technology Without Human Assistance Can Measure Cobb Angles Rapidly and Accurately

Design

Cobb angles measured from the AI system were compared to manual measurements performed by orthopedic experts.

Introduction

The use of AI in the field of scoliosis measurement is still immature. Previous studies have performed AI measurements based on mild scoliosis cases or chest X-ray images, or relied on redundant pixel-level segmentation of X-ray images, requiring exces-

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sive manual assistance. Therefore, the measurement methods in these studies may not apply to severe scoliosis.

Methods

A total of 151 anterior-posterior spinal X-rays were included in this study, including 134 cases of idiopathic scoliosis (Cobb angles range: 10°–93°) and 17 normal adult cases without scoliosis. We labeled all images and randomly chose 143 as the training set and 8 as the test set. Two CenterNet-based artificial intelligence (AI) models were used in sequence to segment each vertebra and locate vertebral corners. Cobb angles measured from the output of the models were compared to manual measurements performed by orthopedic experts.

Results

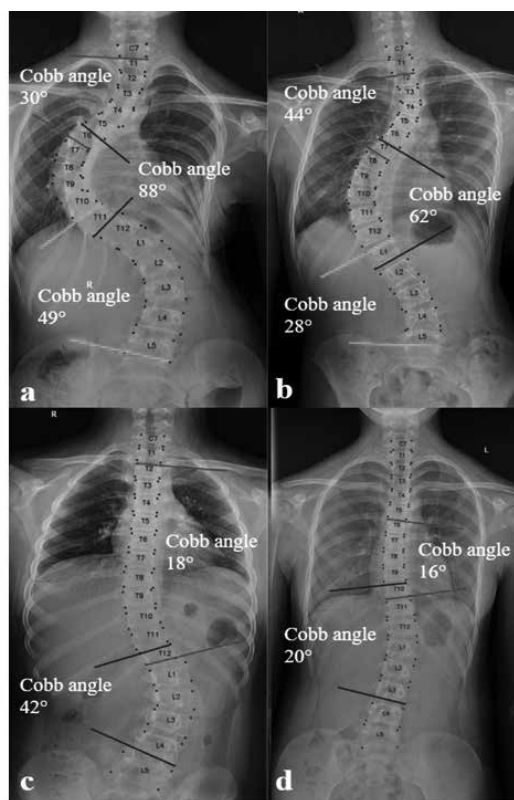
The mean Cobb angle in test cases was $25.19^\circ \pm 17.97^\circ$ (range 0.00°–91.00°) in manual measurements and $23.96^\circ \pm 17.70^\circ$ (range 0.00°–88.00°) in AI measurements. The system needed 4.45 seconds on average to measure each radiograph. The intra-class correlation coefficient (ICC) for the reliability of the AI measurement of Cobb angle was 0.984. The Pearson correlation coefficient between AI location and expert annotation was 0.989. The analytical result for the Spearman rank-order correlation was 0.985. Thus, the AI results highly matched the experts' annotation and had a high degree of reliability.

Conclusion

The automatic measurement system based on AI keypoint detection can identify each vertebra, obtain Cobb angles rapidly and accurately, including severe Cobb angles up to almost 90°, and locate multiple curves in the same scoliosis case simultaneously.

Take Home Message

The AI system processes AP spinal X-ray automatically and obtains Cobb angles as rapidly as 4.45 s. The AI keypoint detection technique is robust to measure Cobb angles up to 90°.



The Cobb angles measured by the AI system

140. Cluster Analysis to Identify Deformity and Disability Patterns in ASD Patients: A Step Toward a Clinically Relevant ASD Classification

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Summary

Adult spinal deformity (ASD) is a nebulous label used to describe a diverse medical condition comprised of numerous spinal deformities. An unsupervised cluster analysis was used to identify deformity and disability patterns for ASD patients prospectively enrolled into a multicenter surgical study. Four natural clusters based on deformity and clinical presentation emerged. These clusters may serve as a valuable first-step toward an ASD classification to enable better tailored treatment approaches and more meaningful patient counseling and outcomes assessments.

Hypothesis

AI-based unsupervised approach will identify patterns of deformity and disability for surgically treated ASD patients

Design

Retrospective analysis of a prospective, multi-center ASD study

Introduction

ASD is a broad term applied to different spine deformity types. This study aimed to investigate if a data-driven AI-based approach could form distinct cohorts within a heterogeneous ASD population.

Methods

From 2018-2020 ASD patients were enrolled into a prospective ASD study based on 3 criteria; deformity severity (PI-LL \geq 25°, TPA \geq 30°, SVA \geq 15cm, TCobb \geq 70°, or TLCobb \geq 50°), procedure complexity (\geq 12 levels fused, 3CO or ACR), and/or patient age (>65 and \geq 7 levels fused). Unsupervised cluster analysis was used to identify radiographic deformity patterns. Demographic and PROM data were compared between type of deformity.

Results

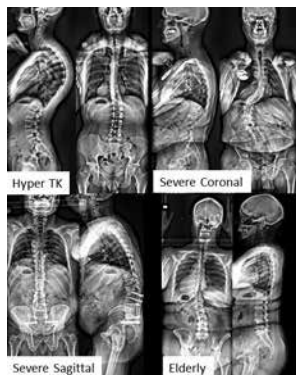
202/202 patients were evaluated (61.4yo \pm 14.1, 67.3% F, 49% revision). The 2-step cluster analysis identified 4 deformity patterns (see figure). The most important predictors were PI-LL and TPA. The “Hyper TK” group (n=21, 40yo) had a large TK (82.6° \pm 21.3), lumbar hyperextension (PI-LL:-25.7° \pm 13.5), and small TPA; the “Severe Coronal” group (n=59, 58yo) had large thoracic (42.3° \pm 18.9) and thoracolumbar scoliosis (58.0° \pm 13.5) with neutral sagittal alignment; the “Elderly” group (n=79, 68yo) had a moderate PI-LL (20.0° \pm 12.5) and global malalignment (TPA: 26.4° \pm 7.2) without coronal deformity, and the “Severe Sagittal” group (n=29, 63yo) had large PI-LL (52.6° \pm 13.1) and neutral coronal alignment. Comparison of clusters revealed significant differences in age, BMI, percentage of revision, NRS back and leg pain, ODI, VR12, and SRS domains (except Mental). The “Hyper TK” and “Coronal” groups were the least disabled and ~24% were revisions, while the “Elderly” and “Severe Sagittal” were the most disabled and >67% were revisions.

Conclusion

Analysis of surgically treated ASD patients demonstrated 4 natural clusters based on deformity and disability emerged. These clusters may serve as a valuable initial effort to create a clinically relevant ASD classification.

Take Home Message

Four deformity clusters were identified in a prospective cohort of ASD patients using unsupervised data-driven analysis. These clusters may serve as an initial step for a clinically relevant ASD classification.



	Hyper TK n=21 (11.2%)	Severe Coronal n=59 (31.4%)	Elderly n=79 (42.0%)	Severe Sagittal n=29 (15.4%)	p-value
% Revision	23.8%	23.7%	67.1%	79.3%	0.000
Age (yrs)	40.4 \pm 19.2	57.9 \pm 12.9	68.0 \pm 8.8	63.4 \pm 7.6	0.000
BMI (kg/m ²)	22.6 \pm 5.9	26.6 \pm 5.0	28.8 \pm 5.2	30.4 \pm 5.9	0.000
Edmonton Frailty	1.3 \pm 1.3	2.4 \pm 2.4	3.7 \pm 2.1	4.7 \pm 1.9	0.000
NRS Back	4.6 \pm 3	6.1 \pm 2.3	6.8 \pm 2.1	7.0 \pm 1.8	0.000
NRS Leg	1.3 \pm 2	3.9 \pm 3.1	4.7 \pm 3.3	4.6 \pm 3	0.000
ODI	26.7 \pm 16.9	33.5 \pm 17.2	48.4 \pm 14.9	50.7 \pm 14.8	0.000
VR12 PCS	40.0 \pm 11.4	34.0 \pm 10.5	24.8 \pm 8.8	26.4 \pm 8.8	0.000
VR12 MCS	45.5 \pm 10.2	33.9 \pm 10.1	31.3 \pm 10.9	31.1 \pm 10.7	0.028
SRS Activity	3.6 \pm 0.9	3.3 \pm 0.9	2.7 \pm 0.8	2.7 \pm 0.8	0.000
SRS Pain	3.2 \pm 1.0	2.8 \pm 0.8	2.3 \pm 0.8	2.5 \pm 0.8	0.000
SRS Appearance	2.4 \pm 0.6	2.7 \pm 0.7	2.4 \pm 0.7	2.1 \pm 0.6	0.009
SRS Mental	3.4 \pm 0.7	3.7 \pm 0.7	3.5 \pm 0.6	3.5 \pm 0.7	0.198
SRS Total	3.1 \pm 0.6	3.1 \pm 0.6	2.8 \pm 0.5	2.7 \pm 0.5	0.000

All times are listed in US Central Time.

141. The Use of Predictive Modeling to Determine Post-Operative Thoracic Kyphosis and Pelvic Tilt in Adult Spinal Deformity Surgery

Mellissa R. Delcont, MD, MS; David C. Ou-Yang, MD; Evalina L. Burger, MD; Vikas V. Patel, MD; Nolan M. Wessell, MD; *Christopher J. Kleck, MD*

Summary

A predictive model created based on radiographic data from over 500 patients was used to simulate post-operative changes in thoracic kyphosis and pelvic tilt after adult thoracolumbar spinal deformity surgeries. Results showed that patients undergo significant post-operative long-term compensatory changes in thoracic kyphosis and pelvic tilt, and that the predictive model is better than the prior planning technique at projecting these changes.

Hypothesis

The predictive model simulates post-operative thoracic kyphosis (TK) and pelvic tilt (PT) better than the previous strategy used for thoracolumbar adult spinal deformity (ASD) surgical planning.

Design

Retrospective study evaluating a predictive model’s use in ASD surgical planning.

Introduction

To minimize complications associated with ASD surgery, many surgeons pre-operatively plan sagittal plane correction. Unfortunately, it is unclear how the native spine will react post-operatively. In attempts to account for this compensatory response after fusion with upper instrumented level in the lower thoracic region, these authors initially planned TK restoration to 40 degrees (or left as is if initial >40 degrees). After measuring actual compensatory responses post-operatively, this pre-operative planning underwent iterative improvement and now utilizes a complex predictive model to simulate compensation.

Methods

Radiographic data from over 500 patients was utilized in training and testing the model. The model utilized projected lumbar lordosis and number of instrumented levels to predict post-operative TK and PT. The predictive model was utilized to simulate 12- and 24-month post-operative TK and PT for 42 patients who had surgeries previously planned using the older technique. The model and previous plan were compared.

Results

There were significant differences between measured pre-operative and post-operative TK and PT. The predictive post-operative TK and PT did not significantly differ from actual post-operative values, with better correlative values to actual TK than the previous plan.

Conclusion

Patients undergo significant long-term compensatory TK and PT changes, indicating need for predictive modeling to aid in surgical planning. The predictive model can project thoracolumbar spine compensation after deformity correction surgery. It is

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better than the prior planning strategy at anticipating long-term TK and possibly PT.

Take Home Message

Patients undergo significant long-term changes in TK and PT after adult thoracolumbar spinal deformity surgeries. A predictive model can project these post-operative changes better than the previous planning strategy.

142. Can Machine Learning Improve Our Ability to Predict Reoperations in Adult Spinal Deformity Surgery: A Leap Forward in Predictive Modeling

Joseph M. Lombardi, MD; Scott Zuckerman, MD; Meghan Cerpa, MPH; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary

ASD surgery carries unacceptably high rates of postoperative reoperation. Data from a single center ASD registry was utilized to build machine learning (ML) models which identifies clinical and surgical risk factors for reoperations. Our combined models were 95.3% specific, 60.7% sensitive, and had overall accuracy of 91.6%. Hyperlipidemia and preoperative sagittal imbalance carried the highest risk of reoperation. This is the most comprehensive and deformity-specific, single center predictive model developed with the potential for profound clinical and economic impacts.

Hypothesis

ML algorithms will provide novel predictive modeling for determining postoperative reoperations after ASD surgery.

Design

Retrospective cohort study

Introduction

ASD surgery requires a complex intervention in a heterogeneous, comorbid patient population. Rates of complications following ASD surgery approach 70% with reported reoperation rates exceeding 20%. ML algorithms are powerful modeling techniques which we investigated to increase our ability to predict postoperative reoperation.

Methods

A single-center, ASD registry of 246 patients who underwent spinal reconstructive surgery of > 6 levels from 2015-19 was queried for clinical and surgical data. A ML algorithm was designed to predict risk factors for return to OR (RTOR) at any time point following surgery. Logistic Regression, Random Forests, XGBClassifier and Neural Network models were trained on the data. We established the parameters using grid search & cross validation over 100 trials of randomized splits into training (90%) and testing (10%) datasets to calculate average metrics. Upsampling of the RTOR patients was performed in the training cohort to balance the data set. The first three models give us an insight to feature importance. RTOR can have multiple pathways, thus using an ensemble of these models allows us to genuinely combine different patterns learned by individual models.

Results

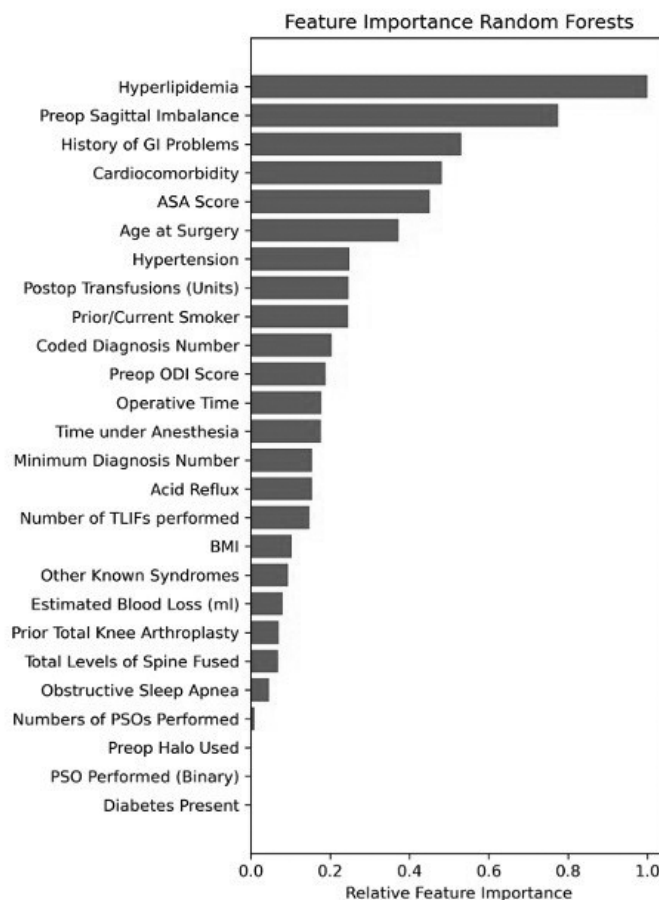
The Random Forest model performed best in our testing with 90.28% specificity and 67.59% sensitivity. However, when combining multiple models through soft voting analysis, specificity increased to 95.3% with a sensitivity of 60.7% and overall model accuracy of 91.6%. Hyperlipidemia, preoperative sagittal imbalance, and history of gastrointestinal disease were the biggest risk factors for RTOR in our patient population.

Conclusion

We designed a ML algorithm which predicted RTOR following ASD surgery at our center with 95.3% specificity, sensitivity of 60.7%, and overall model accuracy of 91.6%. History of HLD, preoperative sagittal imbalance, and GI disease were shown to be the biggest risk factors for RTOR.

Take Home Message

ML algorithms are novel instruments which predict reoperation following ASD surgery with 95.3% specificity. HLD, preoperative sagittal imbalance, and GI disease are the biggest risk factors for RTOR.



143. Predicting Readmission Following Fusion for Scoliosis in Pediatric Patients: A Machine Learning Approach

Alan H. Daniels, MD; Ashwin Veeramani

All times are listed in US Central Time.

*Denotes Non-CME Session

Summary

The goal of this study is to determine whether machine learning can accurately predict readmission following posterior fusion surgery for the treatment of adolescent idiopathic scoliosis. The capacities of five machine learning algorithms were analyzed to determine if they could pre-operatively predict readmission. Analysis of the algorithms indicated that they were able to accurately predict readmission, which affirms their promise as clinical tools for risk assessment of post-operative complications.

Hypothesis

A set of machine learning algorithms will be able to accurately predict readmission following AIS surgery.

Design

This study was an analysis of NSQIP pediatric data.

Introduction

Spine fusion surgery is a common treatment for scoliosis in pediatric patients. Hospital readmission within 30-days of surgery is a costly event. While studies have been undertaken to predict readmission within 30-days for orthopedic procedures, no research has been conducted on the utility of machine learning algorithms to predict postoperative complications for pediatric patients undergoing PSF.

Methods

The NSQIP pediatric database was queried to select patients who had undergone posterior arthrodesis surgery for scoliosis treatment. Predictive variables of interest were height, weight, age, race, ASA Class, and the presence or absence of comorbidities such as asthma, lung disease, cardiac risk factors, cognitive function, seizure presence, cerebral palsy, ACQ abnormality, and neuromuscular disorder. Python's Sci-Kit Learn package was utilized to run five machine learning algorithms: Logistic Regression (LR), Decision Tree (DT), Random Forest (RF), Gradient Boosting (GB), and Neural Network (NN). Patients were randomly split into two groups, where 70% of patients were used to train the algorithms, while the remaining 30% were used to test their validity. The area under the curve (AUC) and prediction accuracy were used to determine the capacity of the algorithms.

Results

In the final analysis, 17,873 patients were analyzed, 825 of which were readmitted within 30-days of surgery (4.62%). The machine learning algorithms exhibited AUC values between 0.513 and 0.736, with the GB algorithm performing the best and the DT algorithm performing the worst, and prediction accuracies between 92.8% (DTC) and 96.5% (GB).

Conclusion

Machine learning algorithms are potentially valuable tools for predicting readmission after pediatric spine fusion surgery. These algorithms may assist clinicians and patients in determining the best treatment care plans to optimize outcomes and minimize re-admission risk.

Take Home Message

Machine learning algorithms may serve as viable clinical tools for assessing complication risks after AIS surgery.

All times are listed in US Central Time.

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E-Poster Abstracts

200. Reducing the Pelvis Constriction Changes the Sagittal Plane: A Retrospective Case-Control Study of 37 Free Pelvis vs. 451 Classical Consecutive Very Rigid Sforzesco Braces

Stefano Negrini, MD; Fabrizio Tessadri, PO; Francesco Negrini, MD; Marta Tavernaro, PT; Fabio Zaina, MD; Andrea Zonta, MD; Sabrina Donzelli, MD

Summary

To check if the introduction of semi-rigid material on the pelvis (“Free Pelvis” - FPB) had a positive effect on the sagittal balance of the very-rigid Sforzesco brace (VRB), we compared radiographic in-brace and short-term results in AIS (43±12°). Groups were comparable at baseline. FPB causes less in-brace lumbopelvic strain, but without out-of-brace changes in short-term. It is worthwhile exploring if these in-brace changes can cause out-of-brace differences in the medium/long term.

Hypothesis

Does the “Free Pelvis” (FP) innovation change the sagittal plane results of very-rigid bracing (VRB) for adolescents with idiopathic scoliosis (AIS)?

Design

Case-control study.

Introduction

The sagittal plane preservation is one of the main aims of modern bracing. The Sforzesco brace, ancestor of very-rigid (VRB) group, has a push-up action to decrease brace’s adverse sagittal effects. Recently, semi-rigid material for the pelvis (FPB) has been inserted in the Sforzesco VRB to allow patients spontaneously achieving their in-brace sagittal balance. We aimed to compare the sagittal radiographic results of FPB vs. VRB.

Methods

We extracted from our prospective database all FPB and VRB at the first consultation. Inclusion criteria: AIS, age 10-16, VRB prescribed 20 hours/day, sagittal x-rays available at the first and either at the second consultation or in-brace (at 1-month). We checked in-brace and out-of-brace thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI) and tilt (PT), sacral slope (SS), and lumbosacral angle (LSA). We also checked TK/LL, PT/SS and LSA/LL ratios and PI-LL difference.

Results

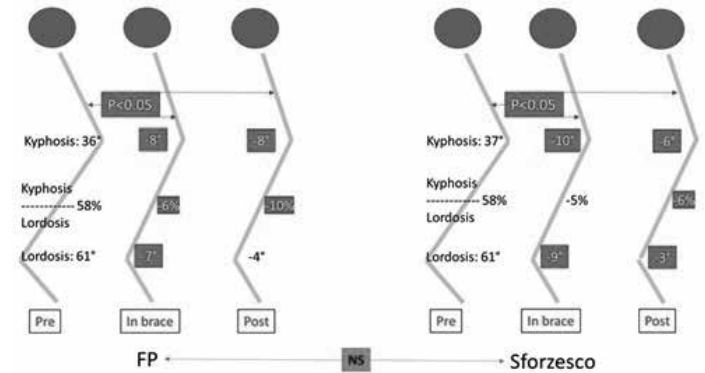
We included 451 (10.2% of 4431) VRB and 37 (38.5%) FPB, age 13±2, °Cobb 42±11° vs. 44±12°, and males 19% vs. 14%, respectively. At baseline, we found no differences between groups for sex, age, Risser, menarche, menarche age, weight, height, BMI; ATR, aesthetics (TRACE index), plumbline distances; previous, prescribed, declared and performed bracing; starting, in-brace and post-brace frontal °Cobb. We found similar statistically and clinically significant TK reductions in both groups, and some statistically, but not clinically significant changes of lumbopelvic parameters. Changes prevailed at in-brace radiograph and in VRB.

Conclusion

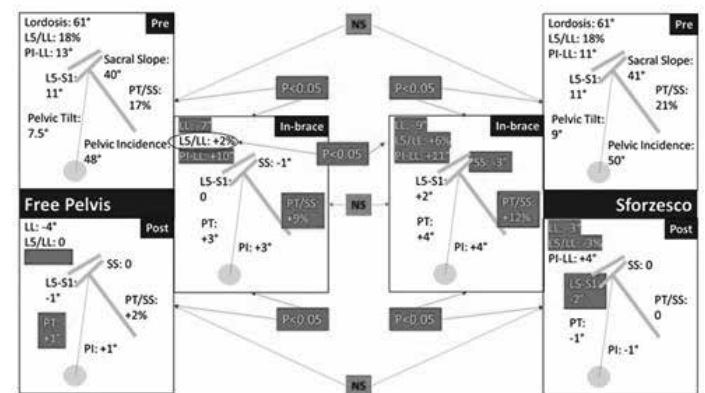
Free Pelvis innovation causes less in-brace lumbopelvic strain in VRB and slightly changes the short-term out-of-brace results. It is worthwhile exploring possible medium/long term changes.

Take Home Message

Semi-rigid material (“Free Pelvis”) changes more the in-brace than the short-term out-of-brace sagittal balance of very-rigid Sforzesco brace. It is worth exploring—medium and long-term changes.



A



B

Sagittal balance in-brace and out-of-brace effects of the Free-Pelvis innovation in very-rigid bracing. White numbers for p<0.05 variations.

201. Magnetically Controlled Growing Rods Graduation: Deformity Control with High Complication Rate

David E. Lebel, MD, PhD; Brett Roccos, MD; Ilkka J. Helenius, MD, PhD; Amit Sigal, MD; Muharrem Yazici, MD; Daniel Studer, MD; Carol C. Hasler, MD; Sebastien Pesenti, MD, PhD; Dror Ovadia, MD

Summary

MCGR treatment for the growing spine gained popularity over the last 9 years. We report our multi-center retrospective analysis of consecutive group of 47 MCGR graduates that were followed from their index procedure to their final fusion. Spinal growth, deformity control, and residual flexibility were comparable with previously reported studies. In our cohort, 45% of the patients had an unplanned return to the operating theatre and the metallosis rate was 47%. MCGR should be evaluated against the best available alternatives.

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Hypothesis

Final fusion might be more effective in bringing additional correction of the spine deformity after treatment with MCGR than that reported after traditional growing rods (TGR) due to less scarring and auto-fusion.

Design

Multicenter, Retrospective chart review of consecutive group of MCGR graduates

Introduction

Over the past 9 years, MCGR treatment for growing spine gained popularity with paucity of long term follow up data. We hypothesized that final fusion might be more effective in bringing additional correction of the spine deformity after treatment with MCGR than that reported after traditional growing rods (TGR) due to less scarring and auto-fusion.

Methods

Retrospective review of 47 patients with varied etiology, treated between 2011 and 2017 which graduated treatment were followed in five academic medical centers for average of 50 months (range, 10-88).

Results

The initial mean coronal deformity measured 69.6° (95%CI 65-74) was corrected to 40° (95% CI 36- 40) immediately after the MCGR implantation but progressed to 52.8° (95% CI 46 - 59) prior to the final surgery (P<0.01). Nevertheless, thoracic spine growth (T1-T12 height) improved from 187.3mm (95%CI 179-195) following index surgery to 208.9mm (195%CI 199 -218) prior to final fusion (P<0.01). Significant correction and spinal length were obtained at final fusion, but metallosis was a frequent observation (47%, 22/47). The average growth rate was 0.5 mm/month (95% CI 0.3-0.6). The overall complication rate within our cohort was 66% (31/47) with 45% (21/47) of unplanned returns to the operating theater. 32% (15/47) of the patients had an implant related complication.

Conclusion

Treatment of growing spine deformities with MCGR provides adequate control of spine deformity it is comparable to previously published data about TGR . The overall high complications rate over time and specifically implant related complications should encourage further discussion and refinement of the surgical indications.

Take Home Message

MCGR should be one of the treatment modalities for the growing spine only after considering all the available alternatives. Complication rate and metallosis are major concern.

202. Baclofen Pump Use: Complications After Growth-Friendly Instrumentation for Early-Onset Scoliosis

Amy L. Xu, BS; Majd Marrache, MD; Christina K. Hardesty, MD; Mari L. Groves, MD; Mark A. Erickson, MD; Robert F. Murphy, MD; George H. Thompson, MD; Paul D. Sponseller, MD; Pediatric Spine Study Group

Summary

Patients with neuromuscular early-onset-scoliosis and spasticity are more susceptible to complications within 1 year after growth-friendly spinal procedures if they are also treated with baclofen pumps. Pumps are independently associated with higher odds of deep surgical site infection, most commonly by *Staphylococcus aureus*, and spinal implant removal compared with matched controls. Pump implantation timing relative to spine surgery is not associated with postoperative complications.

Hypothesis

Complications within 1 year after growth-friendly spine surgery in early-onset scoliosis (EOS) patients is higher with baclofen pump use.

Design

Retrospective comparative study utilizing the Pediatric Spine Study Group database.

Introduction

Patients with EOS and spasticity commonly receive treatment with an intrathecal baclofen pump. We compared the odds of complications and secondary interventions after growth-friendly spine implant surgery for EOS in patients with and without baclofen pumps and performed a sub-analysis of complications in the pump cohort.

Methods

Using a prospectively maintained, multi-center database, we studied patients with neuromuscular EOS with baclofen pumps who underwent growth-friendly implant spine surgery from 1996-2019 (n = 25). Baclofen pumps were implanted before spine surgery in 18 patients, during in 2 patients, and after in 5 patients. These patients were matched 1:2 with 50 patients (control group) without pumps according to treatment center, diagnosis, surgery type, and curve magnitude. Univariate analysis and multivariate logistic regression were performed to compare complications and secondary interventions between the 2 cohorts. Alpha = 0.05.

Results

Patients with baclofen pumps had 5.8 times the odds (95% confidence interval [CI]: 2.0–17) of any complications ≤ 1 year postoperatively compared with controls. They also had 4.9 times the odds (95% CI: 1.6–14) of deep surgical site infection (DSSI) and 6.5 times the odds (95% CI: 1.7–24) of spinal implant removal. Differences in mechanical complication rates were nonsignificant. For the 12 patients (48%) with pumps who experienced infections, the most common microorganisms were *Staphylococcus aureus* (5 patients) and *Pseudomonas aeruginosa* (4). The pump/catheter was removed, in addition to antibiotic therapy or irrigation and debridement in 3 patients. Pump implantation timing was not associated with complication rates.

Conclusion

Patients with neuromuscular EOS and baclofen pumps are more likely to experience early complications, infections, and spinal implant removal after growth-friendly spine surgery. Complication rates did not differ according to pump implantation timing.

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Take Home Message

Patients with early-onset scoliosis and spasticity are more susceptible to early complications, surgical site infections, and requiring spinal implant removal after growth-friendly surgery if also treated with a baclofen pump.

Table 1 Multivariate Analysis of Complication Rates and Secondary Interventions for Patients with and without Baclofen Pumps who Underwent Growth-Friendly Spine Surgery for Early-Onset Scoliosis

Outcome	N (%)		P Value
	Pump Cohort (n = 25)	Matched Control Cohort (n = 50)	
Any complication	16 (64)	27 (54)	0.28
Complication timing			
Early*	14 (56)	9 (18)	<0.01
Late†	12 (48)	22 (44)	0.74
Complication type			
Mechanical	9 (36)	15 (30)	0.61
Deep surgical site infection	12 (48)	8 (16)	<0.01
Secondary intervention type			
Unplanned surgery	12 (48)	17 (34)	0.19
Change in treatment	8 (32)	7 (14)	0.06
Implant removal	9 (36)	4 (8.0)	<0.01

*Defined as ≤1 year after surgery.

†Defined as >1 year after surgery.

203. 18% of Patients with MCGR Experience Minimal Lengthening Episodes and the Majority Successfully Lengthen on Subsequent Attempts

Edward Compton, BS; *Lindsay M. Andras, MD*; Ali Siddiqui, MD; Alexander Nazareth, MD; Kenneth D. Illingworth, MD; Purnendu Gupta, MD; Michael G. Vitale, MPH; John T. Smith, MD; Pediatric Spine Study Group; David L. Skaggs, MD

Summary

18% of MCGR patients experienced an episode of minimal lengthening, and 91% of those patients successfully lengthened after at least 2 subsequent lengthening attempts.

Hypothesis

We hypothesized that MCGR patients that experience episodes of minimal distraction will successfully lengthen afterwards.

Design

Retrospective case series

Introduction

There is limited information in the literature on MCGR distraction per lengthening episode and outcomes after episodes of minimal rod distraction. The purpose of this study is to investigate the outcomes of MCGR patients with episodes of minimal rod lengthening.

Methods

A multicenter, retrospective review of MCGR patients between 2014-2017 was conducted. Inclusion criteria were age < 10 years at MCGR implantation, ≥1 year follow-up, and at least one lengthening attempt. Minimal lengthening was defined as a lengthening attempt with intended lengthening ≥ 3mm and actual lengthening < 1mm.

Results

205 patients met inclusion criteria; 36/205 (18%) patients had at least 1 minimal lengthening with the following diagnoses: neuromuscular (N = 13), idiopathic (N= 9), congenital (N=9) and syndromic (N=5). Mean age at index surgery for patients with at least 1 minimal lengthening was 7.4 years (range: 4.1 to 9.9 years) and mean follow-up was 2.3 years (range: 1.0 to 3.9

years). Of the 36 patients with at least 1 minimal lengthening, 6/36 (17%) had revision surgery following first minimal lengthening and 8/36 (22%) had 1 minimal lengthening and no further documented lengthening attempts. Of the remaining 22 patients with minimal lengthening and further documented lengthening attempts, 15/22 (68%) had a single minimal lengthening followed by subsequent successful lengthening; 5/22 (23%) had 2 consecutive minimal lengthening episodes followed by subsequent successful lengthening; 2/22 (9%) did not have subsequent successful lengthening despite a minimum of two further lengthening attempts. Among patients with minimal lengthening that attempted subsequent lengthening, 20/22 (91%) were successful after two subsequent lengthening attempts.

Conclusion

18% of EOS patients treated with MCGR had minimal lengthening episodes resulting in < 1mm of distraction; of those patients that attempted further lengthening, 91% had successful subsequent lengthening.

Take Home Message

Minimal lengthening occurs in approximately 1/5th of MCGR patients. Further lengthening attempts should be considered for patients that experience minimal lengthening as subsequent successful lengthening was achieved in most cases.

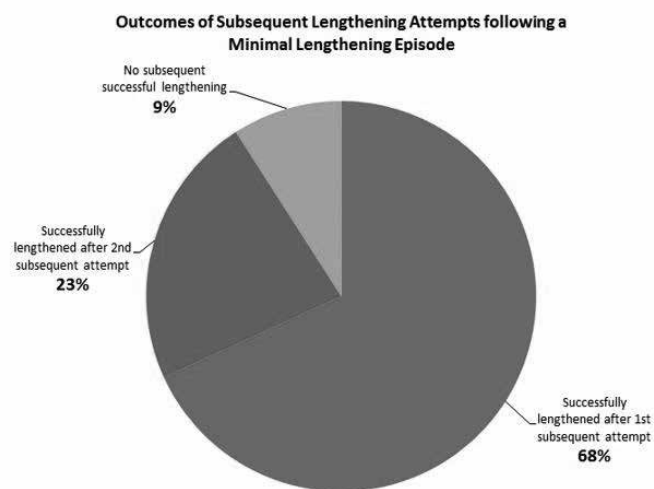


Figure 1

204. Characterizing Mortality in Patients with Early Onset Scoliosis

Ryan Guzek, BS; Robert F. Murphy, MD; Christina K. Hardesty, MD; John B. Emans, MD; Sumeet Garg, MD; John T. Smith, MD; George H. Thompson, MD; Benjamin D. Roye, MD; Michael P. Glotzbecker, MD; Peter F. Sturm, MD; Brian D. Snyder, MD, PhD; Selina C. Poon, MD; Connie Poe-Kochert, RN; Jason B. Anari, MD

Summary

Early onset scoliosis (EOS) may contribute to premature death in patients with life-threatening comorbid conditions. We chronicle the natural history of deceased EOS patients and examine the relationship between operative intervention and lifespan. Operative treatment was more common than non-operative

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treatment alone among deceased patients. However, operatively treated patients were found to have a longer lifespan than those non-operatively treated. Fatal and non-fatal complications were most likely to involve the cardiopulmonary system.

Hypothesis

Operatively treated patients with EOS will have a longer lifespan than those treated non-operatively.

Design

Retrospective review

Introduction

Early onset scoliosis is a spinal deformity that occurs in patients younger than age 10. In severe chest and spine deformity, this may result in thoracic insufficiency, respiratory failure, and premature death. The purpose of this study is to describe the natural history of mortality in patients with EOS.

Methods

A multicenter prospective registry was queried for all patients with EOS who are deceased, without exclusion. Demographics, underlying diagnosis, EOS etiology, operative and non-operative treatment data, complications, and date of death were retrieved. Descriptive statistics and survival analysis with Kaplan-Meier (KM) curves were performed.

Results

130 of 8,580 registry patients were identified as deceased, a mortality rate of 1.6%. Mean age at death was 10.6 years. The most common EOS etiology among the deceased cohort was neuromuscular (56.2%). Operative treatment was more common than non-operative treatment or observation alone among deceased patients ($p < 0.001$). However, the mean age of death for those patients operatively treated (12.3 years) was older than those non-operatively treated (7.0 years) or observed (6.3 years) ($p < 0.001$). KM analysis confirmed an increased survival time in those patients with a history of spine operation ($p < 0.0001$) (Figure). Overall, cardiopulmonary related complications were the most common (47.6%), followed by implant-related (21.0%) and wound-related (9.6%) ($p < 0.001$). Primary cause of death could be identified for 78 (60.0%) patients, of which 57 (73.1%) were cardiopulmonary related.

Conclusion

The mortality rate seen in EOS patients (1.6%) is similar to that of common childhood diseases like cystic fibrosis (1.3-1.7%). This study highlights the impact of surgical intervention on the lifespan of these patients. Fatal and nonfatal complications are most likely to involve the cardiopulmonary system.

Take Home Message

This study represents the largest collection of EOS mortality to date, providing a modern-day examination of the natural history and effects of surgical intervention on patient prognosis.

Figure 1: Survival Curve by History of Spine Operation

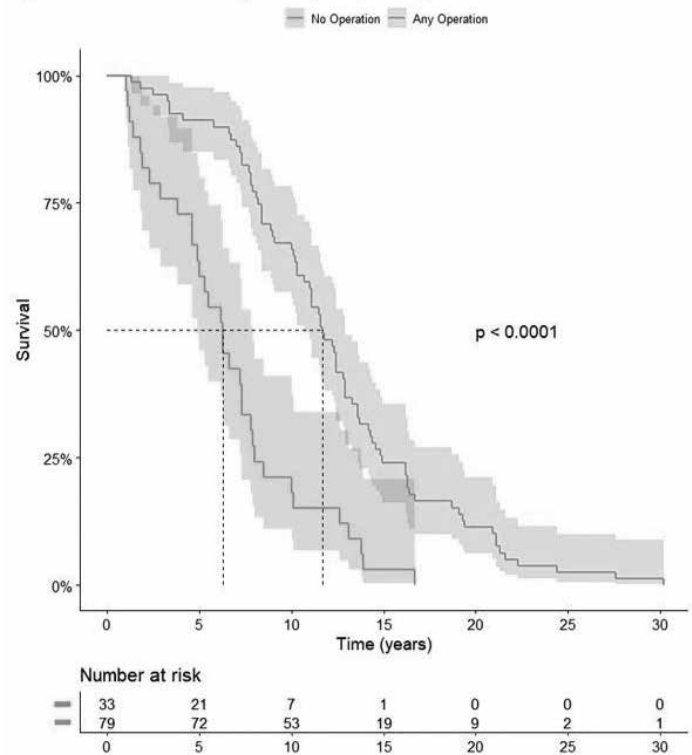


Figure: Kaplan-Meier curves by history of spine operation.

205. Three-Column Osteotomy at the Time of Growing Rod Graduation

Cem Cayli, MD; Gokay Dursun, MD; Riza Mert Cetik, MD; Rafik Ramazanov, MD; Gokhan H. Demirkiran, MD; Mehmet Ayvaz, MD; Muharrem Yazici, MD

Summary

This retrospective case series reports the clinical results of 8 patients who underwent three-column osteotomy (Schwab type 3,4 or 5) because of severe deformity, coronal/sagittal off-balance or crankshaft deformity at the time of growing rod graduation. Mean scoliosis angle of the major curve decreased from 72.5 to 42.3. Average operative time was 338 minutes (255-420) and blood loss was 1322 ml (950-1400). No neurologic complication occurred. We believe that 3CO is a reliable option in this patient population.

Hypothesis

Three-column osteotomy will provide substantial deformity correction with a low complication rate in the graduation of growing rod (GR) treatment.

Design

Retrospective case series.

Introduction

Treatment with GR is a common method in the management of early-onset scoliosis. Different methods have been investigated for graduation. When additional correction is desired, as in a rigid and severe residual curve, osteotomies may be required. A three-column osteotomy (3CO) is a powerful option which is less frequently applied in this patient population.

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Methods

Between 1996-2018, 185 patients treated with GR were evaluated. Patients that underwent 3COs (Schwab type 3,4 or 5) at the final fusion surgery and with ≥ 2 years of FU were included. The indications for a 3CO were: severe residual deformity, sagittal and/or coronal off-balance (Figure 1), or a severe crankshaft deformity. Radiographic measurements were made on the pre/post-index and pre/post-definitive radiographs. Complications were documented.

Results

Sixty-four of the 185 GR patients were graduated: 16 had acceptable alignment and weren't definitively fused. 27 were definitively instrumented without any osteotomy, 13 were managed with an osteotomy other than 3CO. Eight of the 185 patients had 3CO and were included (M/F = 2/6). Etiologies were: 3 syndromic, 3 idiopathic and 2 congenital. Average age at graduation was 13.6 years (11-16.6). Radiographic results are presented in Figure 1. Average operative time was 338 minutes (255-420) and blood loss was 1322 ml (950-1400). 1 superficial infection occurred postoperatively, and no neurologic complication was observed.

Conclusion

When GR treatment comes to an end with a severe deformity, in-situ fusion or observation alone are not viable options. Certain indications might call for a more demanding procedure such as the 3CO. Our study shows that the 3CO is a reliable option in this patient population, which achieves a balanced trunk with a low complication rate.

Take Home Message

Graduation after GR treatment may require an osteotomy if a severe residual deformity is present, and 3COs achieve substantial correction with a low complication rate.

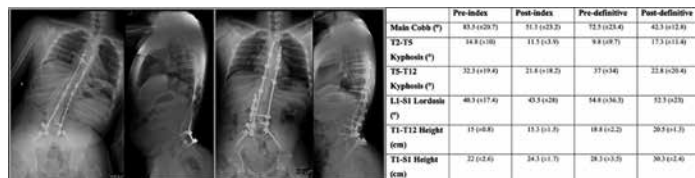


Figure 1. Patient with coronal off-balance, underwent 3CO at graduation. The table summarizes the radiographic measurements of the patient cohort.

206. Complications, Reoperations, and Mid-Term Outcomes Following Anterior Vertebral Body Tethering vs. Posterior Spinal Fusion: A Meta-Analysis

Gabriel R. Arquelles, BA; Max Shin, BA; Patrick J. Cahill, MD; John (Jack) M. Flynn, MD; Keith Baldwin, MD, MPH, MSPT; Jason B. Anari, MD

Summary

While AVBT is increasingly being viewed as a fusionless option to treat AIS, the technique is still in its infancy, and few studies have directly compared its outcomes to those of PSF. We performed a systematic review and meta-analysis of PSF and AVBT studies and found higher rates of complications and reoperation

in patients following AVBT. The disparity in reoperation rates was significantly greater in studies with longer term (3+ years) follow-up.

Hypothesis

We hypothesized that AVBT would demonstrate higher rates of complication & reoperation but better SRS-22 scores as compared to PSF.

Design

Systematic Review & Meta Analysis

Introduction

Anterior vertebral body tethering (AVBT) is a growth modulation technique theorized to correct AIS without the postoperative stiffness imposed by conventional fusions. However, clinical data are limited to small series examining short-term outcomes. To assess AVBT's potential as a viable alternative to PSF, a comprehensive comparison is warranted. The primary objective of this study was to compare postoperative complication and reoperation rates between patients with AIS undergoing PSF and AVBT.

Methods

We performed a systematic review for outcome studies following AVBT & PSF procedures. The inclusion criteria included the following: AVBT and/or PSF procedures; Lenke 1/2 patients; >90% of patient population were ages 10-18; <10% non-AIS scoliosis etiology; follow-up ≥ 1 year. A single-arm random effects meta-analysis was performed. Deformity corrections, complication and reoperation rates, and postoperative SRS scores were recorded.

Results

Ten (211 patients) AVBT studies and 14 PSF (1069 patients) were included. Mean follow-ups were similar for both groups. Pooled complication rates were 26% in AVBT vs. 2% in PSF and reoperation rates were 14.1% in AVBT vs. 0.6% in PSF and were associated with non-overlapping confidence intervals (CIs). The absolute difference in reoperation rates among studies with follow up times ≥ 36 months were 24.7% in AVBT vs. 1.8% in PSF. Deformity corrections, clinical outcomes, and mid-term SRS-22 scores were similar.

Conclusion

Our study showed greater rates of complications and reoperations with AVBT compared to PSF. Reoperation rates were significantly greater in studies with longer (36+ months) follow-up. Deformity correction, clinical outcomes, and mid-term SRS-22 scores were similar. While a potential fusionless treatment for AIS merits excitement, clinicians should consider AVBT with caution. Future long-term randomized prospective studies are needed.

Take Home Message

Patients and their families should be counseled about AVBT's higher complication and reoperation rates compared to the gold standard treatment and employ a shared decision-making model when considering AVBT.

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Outcome	Pooled Means [95% Confidence Interval]	
	AVBT	PSF
Complication Rate (%)	26.0 [12.0-40.0]	2.0 [0.0-4.0]
<36 months	11.8 [4.4-18.6]	1.0 [0.0-2.4]
36+ months	25.2 [19.1-31.7]	2.9 [0.5-5.3]
Re-Operation Rate (%)	14.1 [5.6-22.6]	0.6 [0.0-2.3]
<36 months	2.9 [0.0-8.4]	1.3 [0.0-0.7]
36+ months	24.7 [10.7-38.7]	1.8 [0.5-4]
Conversion to PSF (%)	1.4 [0-4.5]	<i>Not Applicable</i>
Main Thoracic Curve*		
Preoperative	46.0 [42.3-50.0]	53.3 [52.8-53.9]
First Erect	24.9 [20.1-29.8]	16.6 [12.8-20.3]
12-24 mo.	24.6 [17.8-31.4]	13.3 [8.7-17.8]
24-36 mo.	21.5 [8.3-34.7]	21.9 [17.4-26.4]
36+	22.5 [14.1-30.9]	22.7 [19.6-25.8]
Compensatory Lumbar Curve		
Preoperative	28.7 [25.6-32.0]	30.9 [29.2-32.5]
First Erect	19.3 [16.6-22.4]	9.9 [8.1-11.7]
12-24 mo.	16.5 [11.2-21.7]	<i>Insufficient Data</i>
24-36 mo.	13.2 [8.4-18.0]	10.7 [8.0-13.5]
36+	18.0 [3.5-32.5]	15.2 [13.3-17.1]
Thoracic Kyphosis		
Preoperative	24.3 [17.8-30.8]	23.0 [20.7-25.2]
First Erect	22.1 [16.5-27.7]	31.0 [27.93]
12-24 mo.	25.0 [13.4-36.6]	<i>Insufficient Data</i>
24-36 mo.	23.0 [19.6-26.4]	17.9 [15.1-20.7]
36+	22.5 [12.0-33.0]	24.5 [21.9-27.1]
Lumbar Lordosis		
Preoperative	52.0 [46.2-57.9]	47.2 [28.1-66.3]
First Erect	46.5 [40.1-52.8]	<i>Insufficient Data</i>
12-24 mo.	56.0 [47.2-64.9]	<i>Insufficient Data</i>
24-36 mo.	52.7 [48.6-56.8]	46.3 [42.3-50.3]
36+	55.1 [51.3-58.8]	46.1 [25.0-67.1]
Thoracic Rotation		
Preoperative	13.7 [12.1-15.2]	15.4 [12.4-18.4]
First Erect	10.0 [8.7-11.2]	6.0 [4.5-7.5]
12-24 mo.	8.1 [5.9-10.3]	<i>Insufficient Data</i>
24-36 mo.	6.9 [4.8-8.9]	8.07 [5.0-11.1]
36+	8.4 [1.0-15.7]	13.0 [3.3-22.6]
Post-Op SRS Self Image	4.27 [4.0-4.56]	4.23 [4.07-4.40]
Post-Op SRS Total	4.36 [4.06-4.65]	4.30 [4.17-4.43]

AVBT = Anterior Vertebral Body Tethering; PSF = Posterior Spinal Fusion
 *Complication rate reported as minimum number of patients with at least 1 complication
 Non-Overlapping confidence intervals are highlighted in bold

Aggregate Postoperative Outcomes in AVBT vs. PSF Studies

207. Screw Malalignment May Explain Cord Rupture in Vertebral Body Tethering: A Finite Element Analysis

Wanis Nafo, PhD; Kenny Y. Kwan, MD; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Kenneth MC Cheung, MD, MBBS, FRCS

Summary

VBT cords are made of very strong Polymer fibers and should be able to withstand correction tension forces. However, incidents of cord breakage have been reported near the vertebral screws. In this study, we investigated the effect of screw malalignment contact stresses and their effect on cord durability using finite element method. Our analysis showed that the larger the malalignment the proportionally higher the contact stresses, thus, the shorter the lifespan of the cord.

Hypothesis

Screw malalignment leads to increased contact stresses acting on the cord in vertebral body tethering (VBT) and therefore reduces the cord durability.

Design

Finite Element (FE) analysis.

Introduction

There is increasing interest in the use of VBT as a non-fusion

method of correcting scoliosis. Yet cord rupture is a recognized complication that could result in loss of correction. Its reason is unclear. We postulate that screw malalignment may generate contact stresses on the cord. In this study, we assessed, using an FE model, the effect of malalignment.

Methods

Numerical simulations of malalignment were performed using a 3D model that is composed of a cord and screw head. The geometries of the head and cord were defined based on a commercially available system. 3 simulations were performed, each consisted of 2 subsequent loading steps; the cord was first tensioned to 450N followed by an axial malalignment (head motion orthogonal to the cord) of 1mm, 2mm, and 4mm. Thereafter, the consequent stresses were analyzed to estimate the cord's durability across its cross-section.

Results

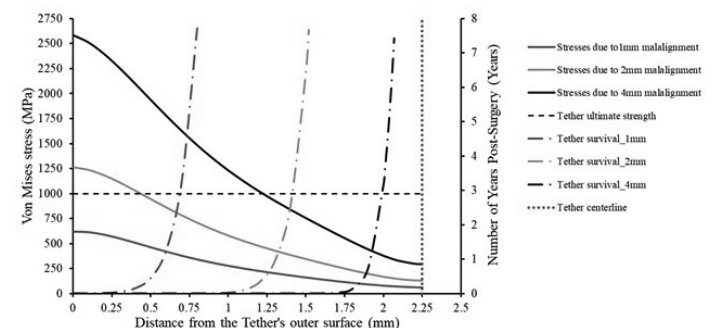
The tension stress resulted from the correction force was minimal (≈ 30 MPa, 3% of the cord's ultimate strength). The contact stresses generated from the three malalignments caused instantaneous (at zero-years) radial tears equivalent to 0.4mm, 1.1mm, and 1.8mm of the cord, respectively. The cord tore further by 0.65mm, 1.42mm, and 2mm, respectively, as time progressed (1-3 years). Thereafter, the cord was intact as represented by the asymptotic increase of time. Our analysis also indicated that the contact stresses increased proportionally to the malalignment; the stresses in 2mm and 4mm malalignments were 200% and 400% of the stresses calculated in 1mm malalignment, respectively.

Conclusion

Malalignment of screws during VBT surgeries can cause significant contact stresses. The higher the stresses the further the damage that can be reflected on the cord, which can prompt its early rupture. A study is on-going to assess the significance of this malalignment in the clinical setting.

Take Home Message

To avoid premature tether breakage, malalignment should be controlled and maintained within very low margins (≤ 1 mm). Higher malalignments generate proportionally higher stresses that will cause early cord breakage.



Stress distribution across the cord cross-section

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208. The Effect of Curve Location on The Prediction Rate of the Severity Index for AIS

Claudio Vergari, PhD; *Wafa Skalli, PhD*; Kariman Abelin Genevois, MD; Jean Claude Bernard, MD; Zongshan Hu, PhD; Jack Chun Yiu Cheng, MD, PhD; Winnie C. Chu, FRCR; Ayman Assi, PhD; Mohammad I. Karam, MS; Ismat Ghanem, MD; Tito Bassani, PhD; Fabio Galbusera, PhD; Luca Maria Sconfienza, MD, PhD; Isabelle Courtois, MD; Eric Ebermeyer, MD; Raphael Vialle, MD, PhD; Jean Dubousset, MD; Tristan Langlais, MD

Summary

A severity index to early detect progressive AIS from biplanar X-Rays and associated 3D reconstruction was recently presented. In the present work, the influence of curve location on the severity index was analyzed. 205 AIS patients were included at their first visit. After blind follow up, the S_index correctly classified 82 % of them as stable or progressive. Sensitivity in thoracic, thoracolumbar and lumbar curves were 93%, 74% and 89%, respectively. Specificity was similar across curves (78 % in average).

Hypothesis

Curve location could influence the predictive power of the severity index.

Design

Prospective and retrospective study.

Introduction

Early treatment of adolescent idiopathic scoliosis (AIS) is more effective than late; this requires determining early which patients will progress. A severity index was recently proposed to detect progressive AIS at the first exam. In the present work, a larger cohort was included to determine the effects of curve location on the severity index.

Methods

AIS patients with a Cobb angle between 10° and 25°, age > 10 years and Risser sign < 3 were included. They underwent biplanar radiography and 3D reconstruction of the spine, which allowed to compute the severity index. An index < 0.4 suggests a stable curve, while > 0.6 a progressive one; values in-between are undetermined. Patients were followed until decision of treatment (“progressive” patients) or until they reached skeletal maturity without progression (“stable patients”, with Risser ≥ 3, Cobb angle ≤ 25°). Patients were grouped by major curve location: thoracic (T, apex above T12), thoracolumbar (TL, apex in T12 or L1) or lumbar (L, apex below L2). Results are reported as average [95% confidence interval].

Results

205 patients were included (171 girls and 34 boys, 109 stable and 96 progressive). 88 patients had T curves, 52 were TL and 65 were L. At their first exam, 82% of patients were correctly classified as stable or progressive by the severity index, while 8 % were undetermined. Specificity and sensitivity were 87 [80-94] % and 78 [69-86] %, respectively. Percentage of correctly classified patients was not affected by curve location, nor specificity. Sensitivity was higher in T curves (93 [85-100] %) and L curves (89 [77-100] %) than TL curves (74 [56-92]).

Conclusion

This is a multicenter, multioperator and international study: data was included from six clinical centres in four countries (France, Hong Kong, Lebanon, Italy), and 3D reconstructions were performed by six operators. Results suggest that severity index is a good candidate for early detection of progressive scoliosis.

Take Home Message

The severity index for AIS correctly detected 82 % patients as progressive or stable, with better prediction in thoracic and lumbar curves.

Type of curvature	Total cases	Thoracic	Thoracolumbar	Lumbar
Sample size	205	88	52	65
Stable patients	109	46	27	36
Progressives patients	96	42	25	29
Correctly classified (%)	82	83	81	82
Sensitivity (%)	87	93	74	89
Specificity (%)	78	73	88	77

Table 1. Results of severity index in the cohort and by main curve location.

209. Influence of Different VBT Techniques on Spinal Range of Motion: A Biomechanical Cadaveric Study

Stephanie Da Paz, MD; Per D. Trobisch, MD; Luis Nicolini, M.Sc.; Johannes Greven, M.Sc.; Jana Seggewiß; Jörg Eschweiler, MD; Andreas Prescher, PhD; Marcus Stoffel, Dr.; Frank Hildebrand, MD; Philipp Kobbe, MD

Summary

This experimental study analyzed the range of motion (ROM) of thoracolumbar cadaveric spines instrumented with different VBT techniques (1 tether, 2 tethers, hybrid technique with a tether rod combination). The reduction of ROM was highest for side bending, but limited for axial or sagittal motion, even with a 2-cord-technique. The hybrid technique significantly reduced apical ROM but global ROM was reduced by less than 15 %.

Hypothesis

VBT will have limited effect on spinal ROM, irrespective of 1 or 2 cord-technique. A hybrid cord-rod-construct will lead to more but not full ROM reduction.

Design

Prospective in vitro study.

Introduction

Vertebral Body Tethering (VBT) is propagated as a growth modulating and motion preserving technique. However, there is only little data to be found on the influence of VBT on spinal motion. Technical modifications like a 2-cord-construct are increasingly being implemented. A hybrid cord-rod-construct may be of interest for patients with a rigid curve apex. The aim of this study was to analyze the ROM of thoracolumbar and lumbar segments for different VBT-constructs in human cadaveric spines.

Methods

Fresh frozen specimens (T10-L3) from 6 human donors were

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obtained for testing. The spines were tested in flexion-extension, lateral bending and axial rotation in 4 different conditions: 1) native, 2) instrumented with one tether from T10 to L3, 3) instrumented with a second tether from T11 to L3, and 4) instrumented with one tether and one titanium rod (hybrid) attached at T12, L1 and L2 vertebrae. The ROM of the whole spine (T10-L3) and at the L1/L2 segment was considered for statistical analysis with respect to the neutral position of the individual specimen.

Results

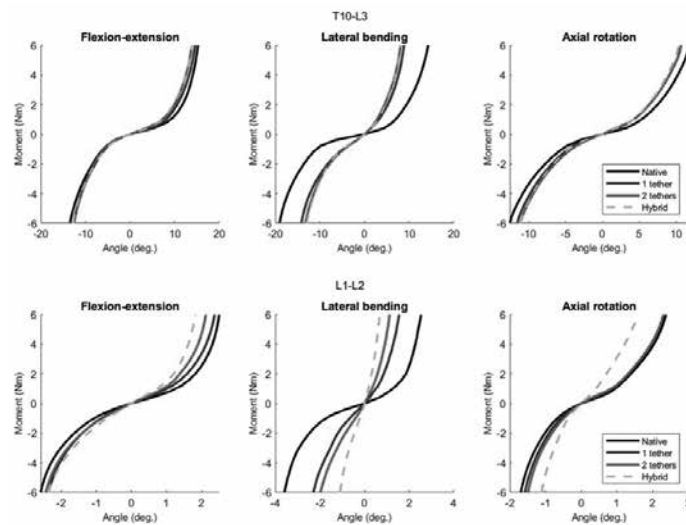
The median global ROM and median apical ROM (L1/2) stepwise reduced after implanting 1 tether, 2 tethers, and a hybrid construction. The global and apical ROM of the spine with 2 tethers slightly reduced in all loading directions compared to the 1 cord construct. The highest reduction of almost 50% was observed for lateral bending. Axial and sagittal planes showed a ROM reduction of less than 10% for 1- or 2-tether constructs. The hybrid technique showed an apical ROM reduction of up to 36% and a global ROM reduction of less than 15%.

Conclusion

Our study showed that VBT slightly restricts the motion of the native spine in the sagittal (<10%) and axial plane (<13%). We found that a 2-cord technique does not have an additional limiting effect on the kinematics of the spine. While a hybrid technique will reduce ROM at the fused level, it only has little restricting effect on the global ROM.

Take Home Message

VBT is a motion preserving technique whether it is performed with 1 or 2 cords. An apical rod reduces segmental ROM and leads to only 15% reduction for global ROM.



Median ROM

210. Marriage and Childbirth of Patients with Operatively and Nonoperatively Treated Adolescent Idiopathic Scoliosis at a Mean 26-Year Follow-Up

Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD

Summary

Because most patients with adolescent idiopathic scoliosis (AIS) are female, the impact of scoliosis on marriage and childbirth is particularly relevant. Therefore, we investigated marital status and childbirth of women with AIS at a mean follow-up of 26 years. Operatively and nonoperatively treated patients functioned well socially with respect to marital status (never married, 27.1% and 29.1%, respectively) and number of children (1.5 and 1.4 per married woman, respectively) compared to the data from the 2015 National Fertility Survey.

Hypothesis

Scoliosis and treatment for AIS do not negatively impact marital status and childbirth of women.

Design

Retrospective long-term follow-up study

Introduction

Several studies that investigated marital status and childbirth of patients with AIS had controversial results. Moreover, only one study compared controls with operatively and nonoperatively treated patients with AIS. Therefore, the impacts of scoliosis and treatment methods for AIS on marriage and childbirth remain unclear.

Methods

Inclusion criteria were: 1) female, 2) born in 1990 or earlier, 3) treated operatively or nonoperatively (brace or observation) for AIS, and 4) Cobb angle of major curve $\geq 30^\circ$ preoperatively or at skeletal maturity. At the final follow-up, marital status and the number of children were obtained. Patients were divided into operatively (Op) and nonoperatively (Nop) treated groups. As control values, we calculated age-matched predicted values using data from the 2015 National Fertility Survey.

Results

There were 55 women in the Op group (follow-up rate, 59.8%) and 85 in the Nop group (45.0%). Op group patients were significantly younger and had a greater curve at surgery and a smaller major curve at the final follow-up compared to the Nop group patients. There were no significant differences between the Op and Nop groups in the percentage of never-married women (29.1% vs. 27.1%) and nulliparity (18.9% vs. 16.4%), and in the number of children (1.5 vs. 1.4) of married women ($P > 0.75$). Results for both groups were similar to those expected according to the National Fertility Survey. In addition, to eliminate the effect of the curve magnitude, we analyzed patients with a major curve of 45° – 65° at surgery (Op group, $n = 24$) and at skeletal maturity (Nop group, $n = 27$) (52.8° vs. 51.1° , $P = 0.18$). Results showed no significant differences in marital status and childbirth between the two groups ($P > 0.3$).

Conclusion

Patients treated operatively or nonoperatively for AIS functioned well socially with respect to marital status and number of children, even compared to the values expected from the National Fertility Survey.

Take Home Message

Scoliosis per se and treatment methods for AIS had little or no

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impact on marital status and childbirth of women with AIS at a mean follow-up of 26-years.

	Patients with AIS			Control†
	Op group	Nop group	P	
Number of cases	55	85		
Age (years)				
At adolescence*	15.0 ± 2.4	14.9 ± 2.4	0.68	
Final	38.6 ± 10.0	42.1 ± 6.9	0.015	
Follow-up duration (years)	23.5 ± 9.7	28.2 ± 6.8	0.001	
Major curve				
Location				
Thoracic	67.3%	70.6%	0.9	
Lumbar	32.7%	29.4%		
Cobb angle (°)				
At adolescence*	63.7 ± 15.9	42.3 ± 8.6	<0.001	
Final	43.7 ± 15.1	55.0 ± 13.5	<0.001	
Never-married women (%)	29.1%	27.1%	0.95	25.3%
Nulliparity among married women (%)	18.9%	16.4%	0.96	14.9%
Number of children per married woman	1.5 ± 1.0	1.4 ± 1.0	0.76	1.6 ± 0.3
* At adolescence means at the time of surgery for the Op group and at skeletal maturity for the Nop group.				
†For control values, we calculated age-matched predicted values for this cohort using data from the 2015 National Fertility Survey.				

211. Neurologic Dysfunction in Adolescent Idiopathic Scoliosis Patients Treated with Thoracoabdominal Vertebral Body Tethering

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Summary

In adolescent idiopathic scoliosis (AIS) treatment, Vertebral body tethering (VBT) is an emerging technique which can be utilized for thoracolumbar curve correction through a thoracoabdominal approach. In investigating neurologic complications and the safety of neuromonitoring, 9% of patients experienced iliopsoas (IP) irritation and 43% experienced transient numbness. A change in the Adductor MEP from baseline during surgery was associated with transient numbness in the Obturator nerve distribution. All patients with numbness improved within 3 weeks of surgery without intervention.

Hypothesis

Neurologic monitoring, clinical and surgical characteristics can be used to predict transient sensory changes in the medial thigh following thoracoabdominal approach for VBT of AIS patients.

Design

Retrospective analysis of AIS patients who underwent thoracoabdominal approach for VBT at a single academic medical center from 2020 through 2021.

Introduction

VBT is a technique for correction of AIS while preserving motion and growth capability. To achieve tether placement in thoracolumbar curves, a retroperitoneal approach is utilized. Major neurologic complications are uncommon. Paresthesias and/or numbness on the medial aspect of the thigh are observed

more frequently. To date no description of the frequency or risk factors for these sensory changes has been published.

Methods

Demographic and clinical characteristics were obtained. Neurologic monitoring and clinical variables were assessed for all patients who underwent thoracoabdominal approach for VBT. Quantitative variables were assessed via T-test. Categorical variables were assessed via chi-square square statistic.

Results

Twenty-three patients were included in the case series. 9% of patients experienced IP irritation and 43% experienced transient numbness in the medial thigh. 90% of deficits occurred on the convex side of the lumbar curve. Sensory change was significantly associated with a change in Adductor MEP from baseline during surgery. No other factors were significant. No patients developed a motor deficit. All sensory changes resolved without intervention with full resolution of symptoms within 3 weeks.

Conclusion

Numbness and/or paresthesias are common complications following thoracoabdominal approach for VBT. A change in Adductor MEP may be associated with postoperative sensory deficit in the Obturator nerve distribution. Other neuromonitoring and clinical characteristics are not predictive in this study. Sensory changes commonly resolve without intervention within several weeks.

Take Home Message

Transient sensory changes following thoracolumbar VBT is common and resolves within 3 weeks without intervention. Change in Adductor MEP may be associated with these symptoms, but additional inquiry is needed.

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Table 1: Demographic, clinical and neuromonitoring data from 23 AIS patients following thoracolumbar VBT.

		No Post-op Paresthesia (n=13)	Post-op Paresthesia Present (n=10)	p value	
Demographics	Age	14.46±2.26	13.70±1.57	0.374	
	Gender (%F)	92.3%	90.0%	0.846	
	BMI	20.99±2.84	21.27±3.40	0.830	
	Risser	3.15±2.11	2.50±2.07	0.465	
	Sanders	5.80±2.25	4.33±2.83	0.226	
Charlson Comorbidity Index (CCI)		0.08±0.28	0	0.393	
Radiographic Parameters	Psoas Area (cm ²)	10.54±2.63	11.04±2.51	0.662	
	starting Lumbar Cobb Angle (°)	44.69±12.80	45.82±8.90	0.815	
	Post-op Lumbar Cobb Angle (°)	24.90±11.06	20.79±8.89	0.348	
	Change in Cobb Angle (°)	-19.79±8.37	-25.03±16.06	0.322	
Surgical Characteristics	Op time (min)	489.23±119.47	471.30±129.91	0.735	
	EBL (ml)	446.15±246.19	305.00±101.24	0.104	
	Fluoroscopy dose (mGy)	143.77±149.67	90.58±64.86	0.307	
	Levels Corrected	8.08±2.33	8.80±2.20	0.458	
	Double Staple at LIV	61.5%	90.0%	0.123	
	Double Curve	36.4%	33.3%	0.901	
	Left Retroperitoneal Approach	69.2%	90.0%	0.231	
	Retroperitoneal First Approach	36.4%	33.3%	0.901	
Sensory Evoked Potentials	Change in SEP Morphology	stable	46.2%	40.0%	0.768
		variable	46.2%	60.0%	0.510
		absent	7.7%	0.0%	0.370
	Loss of SEP	no loss	100.0%	90.0%	0.262
		partial loss	0.0%	10.0%	0.262
Motor Evoked Potentials	Baseline Iliopsoas MEP	present	87.5%	85.7%	0.919
		variable	0.0%	14.3%	0.268
		absent	12.5%	0.0%	0.333
	Change in Iliopsoas MEP	no change	57.1%	28.6%	0.280
		decreased	42.9%	71.4%	0.280
		absent	0.0%	0.0%	
	Baseline Adductor MEP	present	83.3%	77.8%	0.748
		variable	0.0%	11.1%	0.237
		absent	16.7%	11.1%	0.719
	Change in Adductor MEP	no change	75.0%	25.0%	0.046
		decreased	25.0%	62.5%	0.131
		absent	0.0%	12.5%	0.302
	Baseline Quadriceps MEP	present	100.0%	88.9%	0.257
		variable	0.0%	0.0%	
		absent	0.0%	11.1%	0.257
Change in Quadriceps MEP	no change	63.6%	50.0%	0.552	
	decreased	36.4%	50.0%	0.552	
	absent	0.0%	0.0%		

212. Is Thoracoscopic VBT a Pulmonary Function Declining or Improving Surgery?

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Summary

This study reports the effects of thoracic, thoracolumbar, and double-curve VBT on pulmonary function test results (PFT) for 54 consecutive patients with a mean follow-up of 31 months. All-thoracoscopic technique was used to approach thoracic vertebra, while retroperitoneal flank incision was used to access lumbar vertebra. Thoracic-only VBT improved FEV1% and FVC% at 1-year which was maintained at 2-years postop. On the other hand, thoracolumbar and double-curve VBT did not result in a decline nor an improvement in pulmonary function.

Hypothesis

Thoracoscopic VBT, as an anterior scoliosis surgery, may cause

deterioration in pulmonary function

Design

Retrospective analysis of prospectively collected data

Introduction

Previous studies have shown that anterior spinal fusion significantly decreased FVC% and FEV1% values after AIS surgery. There are no studies yet, which investigate the effects of anterior thoracoscopic VBT surgery on pulmonary function.

Methods

Data were collected preoperatively, at 6-weeks, 1-year, 2-years and latest follow-up. Demographic, clinical, radiographic data and complications were analyzed. Curve sizes at each follow-up were compared using repeated measures ANOVA. Preoperative, 1-year and 2-years postoperative FEV1% and FVC% were compared using paired sample t test in thoracic group and Wilcoxon test for thoracolumbar and double-curve groups.

Results

54 consecutive patients (51F, 3M; 12.4±1.5 years) with a mean follow-up of 31 (24-57) months were included. 78% were Lenke 1 (19 A, 6 Ar, 13 B and 4 C) and there were 1, 2, 6 and 2 patients with Lenke 2, 3, 5 and 6 curve patterns, respectively. Preoperatively, 30 (58.8%) patients were premenarchal (median Sanders: 3 (1-7), Risser: 0 (0-5)). A median of 7 (5-11) levels were tethered. Patients grew 7 cm on average; height measurements showing significant increase (p<0.001). 87% of the patients reached skeletal maturity at final follow-up. The mean preop MT curve magnitude of 48°±9.4° was corrected to 24.7°±7.2° at first erect, which was modulated to 16.1°±12.4° during follow-up, displaying a significant decrease. A total of 6 (11.1%) patients experienced pulmonary complications (2 ipsilateral and 1 contralateral atelectasis, 1 lobar atelectasis, 1 pleural effusion and 1 chylothorax). Thoracic VBT resulted in improved PFT at 1 year. No difference was observed between 1 and 2-years follow-up. Thoracolumbar and double-curve VBT; however, were similar between preop and 1-year follow-up (Figure).

Conclusion

Thoracic-only VBT surgery resulted in improved pulmonary function at 1-year, which was preserved at 2-years follow-up. Thoracolumbar and double-curve VBT surgeries did not cause worsening in pulmonary at 1-year. Further studies with longer follow-up are required.

Take Home Message

As an anterior approach, thoracoscopic VBT surgery did not have detrimental effects on pulmonary function in short-term follow-up. Thoracic-only-VBT resulted in improved FVC% and FEV1% at one and two-years postop.

	Pre-Operative			12 months			24 months				
	n	Mean ± SD	Median (Min-Max)	n	Mean ± SD	Median (Min-Max)	p	n	Mean ± SD	Median (Min-Max)	p
Thoracic VBT											
FVC% Predicted	38	79.6 ± 12.7	82 (53 - 115)	38	85.2 ± 15.5	85 (58 - 124)	0.014*	23	87.5 ± 12.0	90 (64 - 107)	0.340
FEV1% Predicted	38	80.1 ± 12.1	78 (60 - 110)	38	87.8 ± 15.5	86 (41 - 145)	0.001*	23	89.8 ± 11.7	92 (70 - 112)	0.144

	Pre-Operative			12 months		
	n	Mean ± SD	Median (Min-Max)	n	Mean ± SD	Median (Min-Max)
Thoracolumbar VBT						
FVC% Predicted	6	81.8 ± 14.9	85.5 (57 - 99)	6	85.7 ± 16.9	81.5 (60 - 112)
FEV1% Predicted	6	82.7 ± 15.0	84.5 (66 - 99)	6	86.5 ± 14.9	84.5 (67 - 113)

	Pre-Operative			12 months		
	n	Mean ± SD	Median (Min-Max)	n	Mean ± SD	Median (Min-Max)
Double-Curve VBT						
FVC% Predicted	9	82.7 ± 11.7	81 (61 - 97)	9	82.6 ± 12.5	83 (59 - 98)
FEV1% Predicted	9	82.4 ± 14.3	82 (59 - 107)	9	85.7 ± 17.6	87 (66 - 105)

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213. Does Upper Instrumented Vertebrae Selection Influence 2-Year Postoperative Cervical Sagittal Range of Motion Following Thoracolumbar Spinal Deformity Surgery Starting in the Upper Thoracic Region?

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Summary

Cervical spine flexibility allows the neck to maintain a horizontal gaze. The effect of the upper instrumented vertebrae (UIV) on the cervical sagittal range of motion (CSROM) following extensive adult thoracolumbar (TL) deformity surgery has not yet been explored. This study evaluates the effect of cephalad UIV selection on CSROM 2-years following TL correction.

Hypothesis

Following TL deformity surgery, a more cephalad UIV will lead to decreased CSROM.

Design

Retrospective Cohort

Introduction

Although the cervical spine is the most mobile segment, it is unclear to what extent, if any, the UIV after TL deformity surgery will affect CSROM. We aim to examine the relationship between various cephalad levels of UIV and CSROM at 2-years postoperative following adult TL deformity surgery.

Methods

We evaluated 44 consecutive postoperative TL deformity pts with 2-year postoperative cervical flexion and extension (F/E) xrays between 2016-18. No pts had a prior history of cervical fusion. UIV selection was divided into three groups: T1, T2 and T3/T4. CSROM was measured using the C1-7, C2-7 and O-C7 Cobb angles using maximum effort F/E xrays. Baseline clinical and radiographic parameters were reported. A one-way between subjects ANOVA was conducted to compare the effect of UIV on CSROM in all three groups.

Results

The breakdown of UIV in 44 TL deformity pts was:T1(9),T2(21), and T3/4(14). There were no significant differences in baseline demographics, pre/postoperative global alignment parameters at 2 years postop. ANOVA demonstrated a significant effect on postoperative O-C7 flexion ($F=8.98, p=0.0007$) between UIV groups. Post hoc comparisons using the Tukey HSD test indicated that there was a significant increase in O-C7 flexion between UIV T1 and UIV T2 (Mean Difference [MD] = 18.58°, 95%CI 6.3, 30.8) and UIV T1 and UIV T3/4 (MD= 21.92°, 95%CI 8.2, 30.8). However, no significant difference was seen in O-C7 flexion between UIV T1 and UIV T2 (MD=3.35°, 95%CI -8.1, 14.8). Although there was a trend for CSROM to increase with UIV T2 and UIV T3/4 selection when compared to UIV T1, the mean CSROM change between groups did not reach significance.

Conclusion

This is the first study of its kind evaluating CSROM following TL

deformity surgery starting in the upper thoracic spine. At 2 years postop, cervical flexion is significantly reduced with a UIV of T1 compared to UIV T2 or UIV T3/4, but cervical extension and total CSROM are no different.

Take Home Message

Patients can expect neck flexion to decrease with UIV T1 selection compared to UIV T3 or T4 selection following TL deformity surgery, without any difference in cervical extension or total CSROM.

Table 1: Mean change in patient demographics and radiographic parameters between groups.

	All Groups (mean)	T1 vs T2	T1 vs T3/4	T2 vs T3/4	P value ^a
Patient Demographics					
Age, y	59.4	4.778	7.111	2.333	0.4254
BMI, kg/m ²	27.68	3.478	2.361	-1.117	0.3756
Cervical Degeneration ^b	41	.038	3.2	3.3	0.90
Radiographic Parameters					
Global Alignment					
CVA Pre, cm	-2.47	-0.218	-3.999	-3.781	0.0778
CVA 2 Yr Post, cm	-2.01	0.3625	0.7367	0.3741	0.7774
SVA Pre, cm	4.37	-0.251	-5.301	-5.050	0.1220
SVA 2 Yr Post, cm	2.41	-1.181	-0.142	1.039	0.6715
Flexion					
C1-7 (°)	-6.32	13.228	19.788*	6.560	0.0140
C2-7 (°)	-19.14	4.422	6.867	2.445	0.6585
O-C7 (°)	-11.90	18.578*	21.924*	3.346	0.0007
Extension					
C1-7 (°)	71.66	5.191	6.450	1.259	0.7395
C2-7 (°)	32.70	9.226	11.710	2.485	0.1292
O-C7 (°)	74.44	4.917	8.114	3.197	0.5963
Total ROM					
C1-7 (°)	65.34	-3.443	-10.717	-7.274	0.411
C2-7 (°)	51.84	-0.473	-4.812	-4.339	0.773
O-C7 (°)	86.34	-4.049	-13.254	-9.205	0.4421

^a – Denotes a significant value of which $p < 0.05$

^b – Cervical Degeneration as measured by Gore et al

SD – Standard deviation; Pre – preoperative; Post – postoperatively; Yr – Year, CVA – coronal vertical axis; SVA – sagittal vertical axis; ROM – range of motion

214. Can Proximal Junctional Angles on Discharge Radiographs Predict Junctional Complications? A Decision Tree Analysis with 2-Year Minimum Followed-Up

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Summary

Retrospective cohort study of 117 patients evaluating whether pre-discharge standing radiographs can be used to predict the development of 2-year proximal junctional kyphosis (PJK) and proximal junctional failure (PJF) after surgery for adult spinal deformity (ASD). While discharge alignment, preoperative-discharge change, and offset from age-matched targets were similar between No PJK, PJK, and PJF cohorts, decision tree analysis showed that patients with a lower thoracic UIV and high proximal junctional angle may be at higher risk for PJK or PJF.

Hypothesis

Standing pre-discharge radiographs can be used to predict the development of PJK after correction of adult spinal deformity ASD

Design

Retrospective cohort study

Introduction

Proximal junctional complications often begin before the first

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surgical follow-up visit. Pre-discharge radiographs may be used to identify patients at risk for PJK before the “proximal junctional cascade” has begun.

Methods

Sample consisted of 117 ASD patients who underwent posterior-only fusion of the lumbar spine (≥ 5 levels, LIV pelvis) at one institution (2013-2020). All patients underwent full-length standing radiographs before hospital discharge. Outcomes of interests were 2-year radiographic PJK (Glattes’s criteria) and PJF (proximal junctional angle [PJA] $>28^\circ$ and Δ PJA $>22^\circ$ or revision for PJK before 2 years). Patients were stratified into 3 mutually exclusive groups: No PJK, PJK, or PJF. UIV was classified as upper or lower thoracic (UT above T8, LT T8 or below). Chi-square automatic interaction detection (CHAID) decision tree analysis was utilized to identify pre-discharge PJA thresholds associated with increased risk of PJK or PJF.

Results

The study cohort had a mean age 65.8 ± 8.5 , BMI 27.2 ± 4.9 , PI-LL 23.3 ± 17.4 , TPA 27.2 ± 11.5 . Mean preop-discharge change was $-24.5 \pm 15.2^\circ$ PI-LL and $-14.5 \pm 9.7^\circ$ TPA (all $p < 0.001$). Stratification of the sample by outcomes of interested revealed 64 (54.7%) No PJK, 39 (33.3%) PJK, 14 (12.0%) PJF. No differences were detected between cohorts in discharge alignment, preop-discharge change, or offset from age-adjusted alignment targets ($p > 0.005$). Decision tree analysis showed that 89.5% of LT patients with a Δ PJA $< 4.3^\circ$ should remain free of radiographic PJK and PJF. For patients with Δ PJA $\geq 4.3^\circ$ and PJA $> 15.5^\circ$, 57.1% of will develop PJF and 28.6% radiographic PJK (Figure 1).

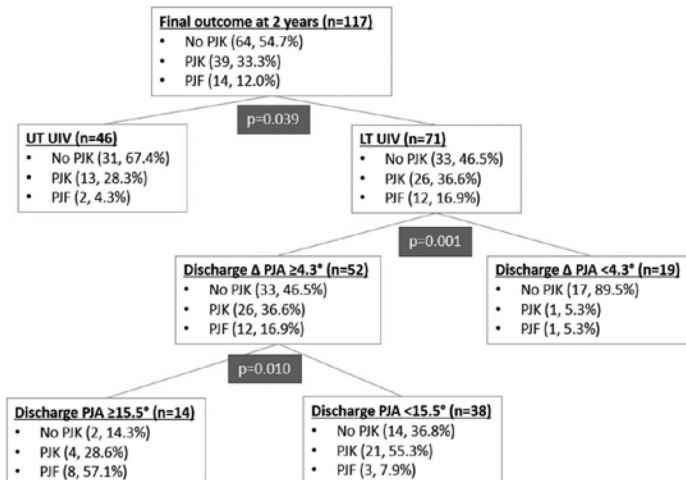
Conclusion

Most patients with a lower thoracic UIV, Δ PJA $\geq 4.3^\circ$, and PJA $> 15.5^\circ$ develop PJF. Considering that most proximal junctional complications occur before 6 weeks, bracing or earlier follow up may be warranted in this cohort.

Take Home Message

Most proximal junctional complications occur before the first post-discharge visit. Discharge radiographs may be used to anticipate impending PJK and PJF.

Decision tree analysis of factors predictive of proximal junctional complication



215. C2 Pelvic Angle (C2PA) is a Useful Radiographic Parameter that Correlates with Clinical Outcomes of Symptomatic Proximal Junctional Kyphosis

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Summary

Proximal junctional kyphosis (PJK) after spine deformity surgery is a radiographic phenomenon defined based on the proximal junctional angle (PJA). Currently, there is minimal literature demonstrating correlation between clinical outcome scores and PJA. The lack of correlation may be due to the inadequate assessment of global spinal alignment from the PJA. The C2PA is a novel radiographic angle that portrays the mismatch between the global spinal alignment and alignment proximal to the spine that corresponds with ODI and SRS scores.

Hypothesis

C2PA is a better clinical predictor of PJK than PJA based on patient reported outcome scores.

Design

Prospectively collected cohort

Introduction

The definition of PJK after spine deformity surgery is based on the PJA. Despite the growing amount of literature on PJK, minimal correlation exists between PJK and clinical outcome scores. PJA poorly represents, and is difficult to measure, PJK for global spinal alignment after deformity surgery. C2PA is a novel radiographic angle that demonstrates the difference between global spinal alignment and alignment proximal to the spinal construct.

Methods

A radiographic review was performed on 98 deformity patients from July 2015-July 2018. The angle between the posterior superior sacrum, C2 centroid and upper instrumented vertebrae (UIV) centroid in the pre and postop setting (2 year or prior to return to OR) were measured and labeled as C2PA. The patients were divided into PJK and non-PJK groups based on a) PJK defined as PJA $> 20^\circ$ and b) PJK defined as C2PA $> 20^\circ$. Logistic regression and Chi-square analyses were performed to study the relationship between the postop PJA and C2PA with ODI/SRS scores.

Results

Of the 98 patients, there were 20 patients with PJK when it was defined as PJA $> 20^\circ$. There were no statistically significant correlation between ODI and SRS scores in the Non-PJK and PJK group when it was defined as PJA. There were minimal differences between the ODI scores (8.0 vs. 7.0, $p=0.66$) and the SRS total scores (71.3 vs. 70.6, $p=0.85$) in the Non-PJK and PJK group when it was defined as PJA $> 20^\circ$. When PJK was defined as C2PA $> 20^\circ$, there were 31 patients with PJK. There were statistically significant differences between the Non-PJK and PJK group for both

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ODI (8.0 vs. 16.0, $p=0.015$) and SRS total scores (97.0 vs. 88.0, $p=0.010$) when PJK was defined as C2PA > 20°

Conclusion

This is the first study demonstrating that C2PA is a superior radiographic representation of PJK, and directly correlates with patient reported outcomes. C2PA > 20° is the critical angle that corresponds with clinical PJK.

Take Home Message

C2PA is a novel parameter that radiographically represents PJK and clinically correlates with patient reported outcome scores.



Same patient without PJK based on PJA (right) and with PJK based on C2PA (left)

216. Understanding Energy Conservation and Whole-Body Shifts in Healthy Adults Across Ages – The Multi-Ethnic Alignment Normative Study (MEANS)

Hwee Weng Dennis Hey, MD; Hee-Kit Wong, FRCS; Gabriel KP Liu, MD; Hui-Wen Tay; Zeeshan M. Sardar, MD; Kazuhiro Hasegawa, MD, PhD; Michael P. Kelly, MD; Hend Riahi, MD; Stephane Bourret, PhD; Jean-Charles Le Huec, MD; Lawrence G. Lenke, MD

Summary

Whole-body sagittal balancing is achieved through the complex interplay of angular changes and body shifts. This large, multi-centre, cross-sectional radiographic comparison study of 456 adult subjects identified anterior pelvic shift phenomenon up to 86.2%, which reverses at age ≥ 60 years. Multivariate analysis found larger T9-tilt and larger TPA to be predictors of anterior pelvic shift, while greater knee flexion, larger CAM-HAa, older

age and being male were predictors of posterior pelvic shift. These findings may refine spinal realignment strategies.

Hypothesis

To describe patterns of whole-body sagittal alignment in standing, associated body shifts across ages, and identify predictors of pelvic shifts.

Design

A large, multi-centre, cross-sectional radiographic comparison study, comprising 456 healthy, asymptomatic subjects aged 18-80 years from five countries (181 males, 275 females; mean age 40.4 ± 15.0 years).

Introduction

Whole-body sagittal balancing is achieved through the complex interplay of angular changes and body shifts. The phenomenon of anterior pelvic shift (hips anterior to knees) has been observed, but understanding remains limited.

Methods

Subjects underwent whole-body low-dose stereoradiographs, and were stratified into anterior versus posterior pelvic shift, with subsequent comparison of their radiographic parameters including cervical, thoracic, lumbar, pelvic and lower limb alignment. Uni- and multivariate analyses were conducted to identify predictors of anterior versus posterior pelvic shifts. Age-stratified analysis of radiographic parameters was also performed.

Results

Of the 456 subjects, 86.2% demonstrated anterior pelvic shift. Nationality and gender, larger T1-tilt, T9-tilt, medial auditory canals (CAM)-knee distance and C2C7 angle, and smaller T1-pelvis angle (TPA), global sagittal axis (GSA), CAM-hip axis angle (HAa), odontoid (OD)-HAa, sagittal vertical axis (SVA), CAM-HA distance (HAd), OD-HAd, cervical SVA, T1-slope and L4S1 angle were associated with anterior as opposed to posterior pelvic shift. Subjects age ≥ 60 years demonstrated less anterior pelvic shift with shorter hip-knee and hip-ankle distances, smaller T1-tilt, and larger SVA, TPA, GSA, CAM/OD-HAd, CAN/OD-HAa and T9-tilt, as compared to subjects age < 60 years. Multivariate analysis found larger T9-tilt and larger TPA to be predictors of anterior pelvic shift, while greater knee flexion, larger CAM-HAa, older age and being male were predictors of posterior pelvic shift.

Conclusion

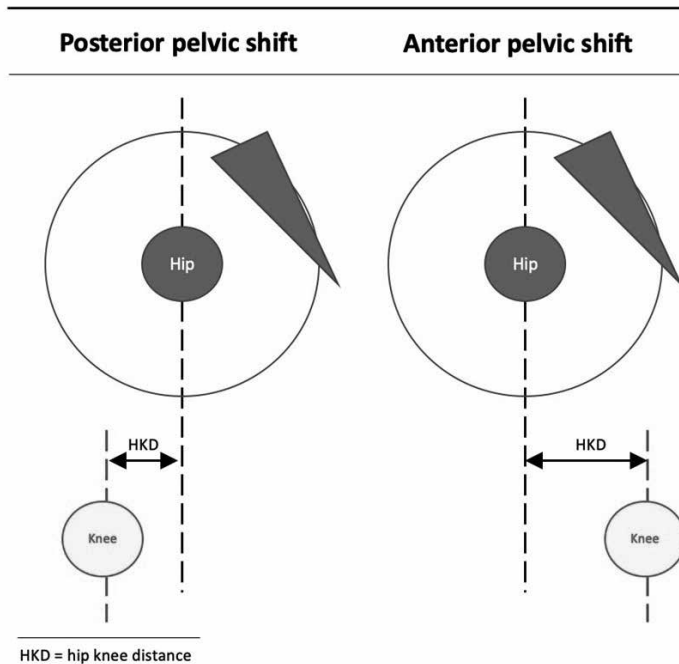
Anterior pelvic shift is a common, naturally-occurring phenomenon and reverses at age ≥ 60 years. Combined understanding of angular changes and body shifts may refine spinal realignment strategies.

Take Home Message

Anterior pelvic shift is a common, naturally-occurring phenomenon in adult asymptomatic subjects. Identified predictors of anterior and posterior pelvic shift may refine spinal realignment strategies.

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All subjects



Pelvic shifts

217. A Prospective Multicenter Evaluation of the Relationship Between Standing and Recumbent Spinopelvic Alignment in Supine, Lateral or Prone Position

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Summary

403 patients undergoing spinal fusion had intraoperative images taken after recumbent positioning on the OR table compared against preoperative standing x-rays. Mean change in lumbar lordosis (LL) was small and there was no significant change in the proportion of aligned patients, regardless of position. Use of a Wilson frame in prone positioning led to significantly worsened alignment due to decrease in LL.

Hypothesis

Intraoperative recumbent positioning (supine, lateral or prone) may alter the proportion of aligned spines among lumbar fusion patients.

Design

Prospective observational multicenter

Introduction

Spinopelvic alignment, important for successful surgical outcomes, is traditionally measured on standing x-rays. We assessed change in alignment brought about by intraoperative recumbent positioning, and differences between supine, lateral and prone positions.

Methods

We performed a prospective multicenter study on lumbar spinal

fusion patients. Sagittal parameters (lumbar lordosis [LL] and pelvic incidence [PI]) were measured on preop standing and intraop recumbent images. Images were deemed as aligned or malaligned, based on whether LL was within 10 degrees of PI or of ideal LL (ILL), defined by the equation $0.5PI + 28$. The prone group was sub-analyzed depending on whether Wilson frame was used.

Results

403 patients (53% female) underwent spinal fusion in the following positions: supine (41), lateral (167) and prone (195). Standing to recumbent LL change (mean, median): supine (4.6, 3.0); lateral (-1.6, 0); prone (-1.2, -1.0). Standing to recumbent PI-LL mismatch change (mean, median): supine (-4.6, -4.0); lateral (1.9, 1.0); prone (-0.7, 0). Standing to recumbent ILL-LL mismatch change (mean, median): supine (-3.6, -2.0); lateral (1.7, 1.0); prone (0.2, 0.5). Using the PI-LL method, proportion of aligned patients (standing vs. recumbent): supine (46.3% vs. 63.4%, $p=0.07$); lateral (59.3% vs. 59.3%, $p=1.0$); prone (57.9% vs. 63.6%, $p=0.17$). Using the ILL-LL method, proportion of aligned patients (standing vs. recumbent): supine (53.7% vs. 65.9%, $p=0.10$); lateral (58.1% vs. 61.1%, $p=0.45$); prone (59.0% vs. 64.6%, $p=0.15$). In the prone position, Wilson frame worsened PI-LL mismatch (6.8 vs. -3.3, $p<0.0001$) and ILL-LL mismatch (9.4 vs. -2.9, $p<0.0001$).

Conclusion

Spinopelvic alignment change brought about by recumbent positioning is small, whether in supine, lateral or prone position, and the proportion of aligned patients is unchanged. In the prone position, use of a Wilson frame is associated with significantly worsened sagittal alignment.

Take Home Message

Recumbent positioning (supine, lateral or prone) generally did not change the proportion of aligned vs. malaligned patients. Wilson frame use was associated with worsened sagittal alignment.

219. The Effect of Scoliosis on Audio-Visual and Socio-Emotional Processing and the Use of Adaptive Communicative Equipment in Children with Severely Involved Cerebral Palsy

Amanda T. Whitaker, MD; Stephanie Burkhardt, BS; Kaleigh Hague, PT; Lindsay Pietruszewsk, PT

Summary

Children with severe cerebral palsy (CP) often develop scoliosis. There lacks objective evidence on the benefits of spine fusion compared to other children who are similarly affected with cerebral palsy. After spine surgery, children who did not undergo spine fusion had a decrease in their CP CHILd outcome measures, sitting balance, ability to use an eye gaze communication device, socioemotional processing, and picture-word identification measured by event-related potentials compared with those that underwent spine fusion.

Hypothesis

Changing seated position by correcting scoliosis will improve the ability for children to interact with their surroundings and use adaptive communication devices.

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Design

Prospective case-control study

Introduction

Children with severe cerebral palsy (CP) often develop scoliosis. Many of them are also non-verbal and unable to communicate their needs and demonstrate an interaction with their surroundings. Non-invasive event-related potentials (ERPs) can assess cognitive and neural processing in children who cannot communicate and assess changes in the way children view their surroundings

Methods

Children (9-18 years) with GMFCS IV/V CP were included with audio-visual and socio-emotional event related potentials (ERP), adaptive communication and postural assessments, and CP-CHILD outcome scores at baseline, 6 months and 1 year. We performed an ANCOVA for effect size of the intervention at one year of age, controlling for baseline EEG.

Results

8 children underwent spine fusion and 16 controls. After fusion, there was an increased level of sitting balance in all the domains, with loss in the control group. The quality of the eye gaze calibration improved in the surgical group (29-52%), but not in the controls (39-39%). For the ERP, children had more usable trials after fusion, and 3 controls lost the ability to participate ($p=0.02$). There was a significant effect of the intervention on both brain-based recognition of human face (social-emotional) and receptive language (recognition of matched picture-word vs. non-matched sets) at one year, that was NOT explained by time alone. (Table 1) CP CHILD scored increased significantly for the fusion group in total score with no improvement in the controls (10.8 vs. 0.6).

Conclusion

Children with GMFCS IV/V CP after spine fusion have improved sitting balance, ability to use a communication device, picture-word identification, socioemotional processing, and health-related quality of life outcomes, personal care/ADLs, positioning/transfers/mobility and communication/social interaction compared to a similar group of children during the same time period.

Take Home Message

Spine fusion in CO objectively improves sitting balance, social-emotional processing, receptive language, adaptive communication device usage and quality of life outcomes compared with an age and GMFCS-matched control group.

ERP Paradigm	6 month (adjusted R-squared; ANCOVA p value)	1 year (adjusted R-squared; ANCOVA p value)
Human Face Recognition	0.100; $p=0.491$	0.277; $p<0.001$
Picture-Word Matching	0.334; $p=0.007$	0.144; $p<0.001$

220. Management of Progressive Late Onset Scoliosis with Magnetic Growth Rod Insertion Leading to Improvement of Neural Anomalies - A Case Report

Valerio Pace, MBBS; Amit Zaveri, MBBS; *Dimpu Bhagawati, MBBS, FRCS*; Hilali Noordeen, MBBS

Summary

This is a unique case of progressive late onset idiopathic scoliosis with associated Chiari malformation and syringomyelia, showing an improvement in these neural anomalies after gradual and protracted distractive lengthening of the spine with Magnetic Growing Rods (MGR).

Hypothesis

What are the consequences of the surgical treatment with MGR for Adolescent Idiopathic Scoliosis in patients with Chiari type I malformation? Could the surgical treatment and the following distraction procedures help improving the neural anomalies?

Design

Case report. Multidisciplinary team.

Introduction

The Authors would like to present the first known reported case of late onset idiopathic scoliosis with concomitant neural anomalies, treated with sequential distraction using magnetic growth rod, had significant improvement in both cranio-cervical and intraspinal anomaly. It is unclear whether the surgical treatment with MGR and the following distraction procedures help improving the neural anomalies of Chiari type I malformation or may even cause harm.

Methods

A caucasian, growing female child (at the age of ten) presented with moderately progressive late onset right thoracic scoliosis. She was found to have Chiari type I malformation and a cervicothoracic syrinx on routine pre-operative MRI scanning. We treated this child by inserting magnetic growing rod (MGR) system. After 48 months of follow up with serial distractions, the metalwork (MGR) was removed due to aseptic wound breakdown and granuloma formation. Subsequently due to the progression of deformity, a definitive posterior instrumented spinal fusion was done. A repeat MRI Scan of the Spine was done prior to this definitive procedure to assess for any residual neural anomalies.

Results

The Chiari type I malformation appeared to have completely resolved, with no cerebellar tonsillar herniation seen, and a significant improvement in the size of the cervicothoracic syringomyelia effectively downgrading it to a prominent central canal.

Conclusion

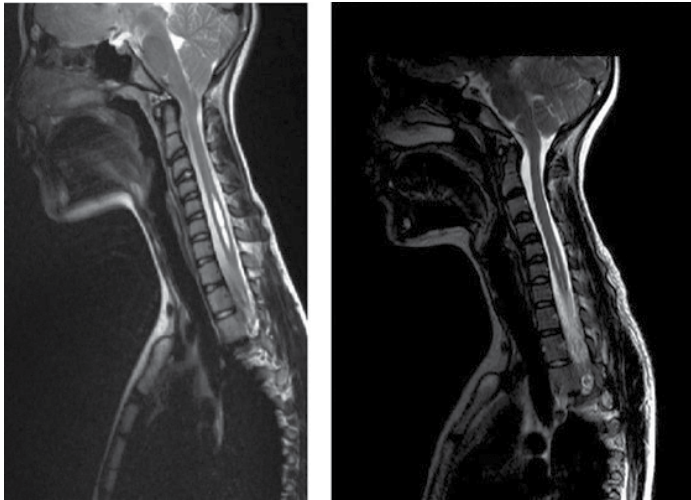
This is a unique case of progressive late onset idiopathic scoliosis with associated Chiari malformation and syringomyelia, showing an improvement in these neural anomalies after gradual and protracted distractive lengthening of the spine with MGR.

Take Home Message

Neural anomalies of Chiari type I malformation could be re-

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solved with MGR surgery and following distraction procedures. However higher level of evidence and an appropriately sized cohort are needed.



MRI

221. The Effect of Scoliosis Support Orthosis Bracing on Adult Spinal Deformity Patients: Evaluation of Gait and Dynamic Balance

Ram Haddas, PhD; Alexander M. Satin, MD; *Isador H. Lieberman, MD*; Damon Mar, PhD

Summary

This study demonstrated significant immediate and long-term improvements in patient outcomes, spatiotemporal gait parameters, and functional balance measures from the use of a custom-fitted, off-the-shelf scoliosis support orthosis (SSO) in symptomatic adult spinal deformity (ASD) patients. Given these results, it is reasonable to consider SSO treatment for certain patients who have not yet progressed to meet surgical indications or who choose not to undergo surgery.

Hypothesis

To investigate the impact of scoliosis support orthosis (SSO) on pain, gait parameters, and functional balance measures in symptomatic adult spinal deformity (ASD) patients.

Design

Prospective cohort study

Introduction

Non-operative treatment is regarded as the first-line therapy for patients with ASD without neurologic deficits or significant impairment. While there is high-level evidence supporting the use of rigid bracing in adolescent idiopathic scoliosis, there is a paucity of literature pertaining to the use of scoliosis support orthosis (SSO) in ASD patients.

Methods

Thirty ASD patients (26 Females, Age: 72.7, Cobb Angle: 47.1°) were evaluated on 3 different occasions: first day of bracing: baseline (Pre), and 45-min post fitting (Post45m), and after 8-weeks of bracing for 4 hours a day (Post8w). Each patient performed a 6-minute walk (over-ground gait), a dynamic balance

test, and completed VAS, ODI, and SRS22r.

Results

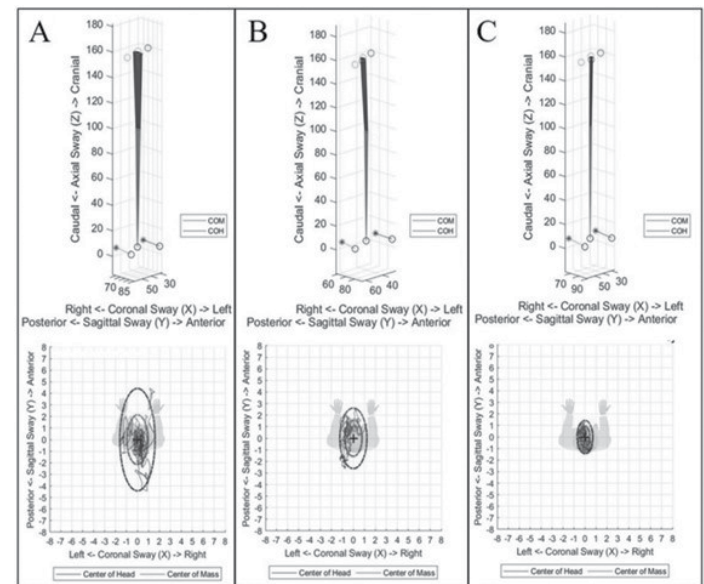
Significant short- and long-term improvements using SSO were found in the 6-minute walk (Pre: 278.6; Post45m: 322.2; Post8w: 338.8 m, $p < 0.001$), walking speed (Pre: 0.88; Post45m: 0.97; Post8w: 0.97 m/s, $p < 0.001$), head total sway distance during the balance test (Pre: 81.33; Post45m: 68.63; Post8w: 60.72 cm, $p = 0.048$), low-back pain (VAS: Pre: 5.5; Post45m: 3.5; Post8w: 3.3, $p < 0.001$), and for the ODI (Pre: 41.9; Post45m: 32.9; Post8w: 30.1, $p = 0.005$).

Conclusion

This study demonstrated clinically significant improvements in PROMs, spatiotemporal gait measures, and functional balance measures after continuous use of a SSO. These improvements were observed immediately following brace-fitting and maintained at 8-week follow-up. In addition, this is the first SSO study for ASD to examine gait parameters and functional balance measures. Given these results, it is reasonable to consider a SSO for conservative management of patients with mild symptoms of pain and deformity, and who have not yet progressed to meet surgical indications.

Take Home Message

The results of this study demonstrated clinically significant improvements in PROMs, spatiotemporal gait parameters and functional balance measures with the use of a SSO for patients with ASD.



Cone of Economy Measurements of Baseline (A), Post 45-Minutes (B), and Post 8-Weeks (C) Fitting of Scoliosis Support Orthosis Bracing

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The Scoliosis Research Society gratefully
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About SRS

SRS OVERVIEW

Founded in 1966, the Scoliosis Research Society is an organization of medical professionals and researchers dedicated to improving care for patients with spinal deformities. Over the years, it has grown from a group of 37 orthopaedic surgeons to an international organization of more than 1,400 health care professionals.

MISSION STATEMENT

The purpose of the Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

MEMBERSHIP

SRS is open to orthopaedic surgeons, neurosurgeons, researchers, and allied health professionals who have a practice that focuses on spinal deformity. Visit www.srs.org/professionals/membership for more information and to apply online.

Active Fellowship requires the applicant to have fulfilled a minimum three 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 is open to orthopaedic surgeons, neurosurgeons and researchers who are willing to commit to a clinical practice, which includes at least 20% spinal deformity. This candidacy is a path to SRS Active Fellowship. Candidate Fellows stay in this category for a minimum of three years, during which time they must demonstrate their interest in spinal deformity and in the goals of SRS. Candidate Fellows may not vote or hold office, but may serve on committees.

Associate Fellowship is for distinguished members of the medical profession including nurses, physician assistants, as well as orthopaedic surgeons, neurosurgeons, scientists, engineers and specialists who have made a significant contribution to scoliosis or related spinal deformities who do not wish to assume the full responsibilities of Active Fellowship. Associate Fellows may not vote or hold office, but may serve on committees.

Senior Candidate Fellowship is limited to senior surgeons, neurosurgeons and to non-physicians members of allied specialties. This candidacy is an accelerated path to Active Fellowship for those who have 20 years of experience, are a full professor, head of spine unit or chief of spine division, and have a clinical practice that includes 20% spinal deformity. After two years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Senior Candidate Fellowship does not include the right to vote or hold office.

PROGRAMS AND ACTIVITIES

SRS is focused primarily on education and research that include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Courses, a Global Outreach Program, the Research Education Outreach (REO) Fund which provides grants for spine deformity research, and development of patient education materials.

WEBSITE

For the latest information on SRS meetings, activities, and membership visit www.srs.org. The SRS Website Committee works to ensure that the website information is accurate, accessible, and tailored for target audiences. Content categories include information for medical professionals, patients/public, and SRS members.

SOCIAL MEDIA

Join the conversation surrounding the Annual Meeting by including #SRSAM21 in your social media posts.



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Save the Date

29TH IMAST

INTERNATIONAL MEETING ON ADVANCED SPINE TECHNIQUES

April 6-9, 2022 | Miami, Florida, USA



SAVE the DATE

SCOLIOSIS RESEARCH SOCIETY 57th ANNUAL MEETING

SEPTEMBER 20-23, 2022 • SYDNEY • AUSTRALIA



SRS
Scoliosis Research Society

Meeting Outline

*Denotes Non-CME Session

MONDAY, SEPTEMBER 20, 2021		
8:00-14:00	SRS Board of Directors Meeting*	Sterling 9
TUESDAY, SEPTEMBER 21, 2021		
8:00-11:00	SRS Board of Directors Meeting*	Sterling 9
11:00-12:00	Council Meeting Lunch*	Foyer Outside of Sterling 3, 6, 7, 8
11:30-13:00	Council Meetings*	Sterling 3, 6, 7, 8
12:00-17:00	Registration Open*	Grand Foyer
12:00-18:00	Speaker Ready Room Open*	Mills 3
13:00-17:00	Hibbs Society Meeting	Regency DEF
18:30-21:30	SRS Leadership Dinner* (by invitation only)	<i>Offsite</i>
WEDNESDAY, SEPTEMBER 22, 2021		
6:00-20:00	Speaker Ready Room Open*	Mills 3
6:00-19:00	Registration Open*	Grand Foyer
7:30-12:00	Pre-Meeting Course	Grand Ballroom
12:30-13:30	Lunchtime Symposia (3 Concurrent Sessions)	Grand Ballroom, Regency ABC, Regency DEF
14:00-15:30	Abstract Session 1	Grand Ballroom
16:00-17:00	Case Discussions (3 Concurrent Sessions)	Grand Ballroom, Regency ABC, Regency DEF
17:30-19:45	Opening Ceremonies*	Grand Ballroom
19:45-20:45	Welcome Reception*	Grand & Regency Foyers
THURSDAY, SEPTEMBER 23, 2021		
6:30-19:00	Speaker Ready Room Open*	Mills 3
7:00-19:00	Registration Open*	Grand Foyer
8:00-9:55	Abstract Session 2	Grand Ballroom
10:25-12:45	Abstract Session 3 and Harrington Lecture	Grand Ballroom
13:30-15:00	Industry Workshops* (5 Concurrent Sessions)	Grand Ballroom ABCD, Grand Ballroom EFGH, Regency ABC, Regency DEF, Park View
15:30-17:30	Half-Day Courses (2 Concurrent Sessions)	Regency ABC, Regency DEF
17:35-19:05	Early Career Surgeon Session	Park View
19:05-20:30	Early Career Surgeon Social, Hosted By Medtronic	Park View
FRIDAY, SEPTEMBER 24, 2021		
6:30-18:00	Speaker Ready Room Open*	Mills 3
7:00-17:00	Registration Open*	Grand Foyer
8:00-9:50	Abstract Session 4: Hibbs Award-Nominated Papers	Grand Ballroom
10:20-12:00	Abstract Session 5 and Presidential Address	Grand Ballroom
12:30-14:15	Member Business Meeting and Lunch*	Grand Ballroom
12:30-14:00	Lunchtime Symposium: A SRS-AANS Collaboration	Regency DEF
14:45-16:10	Abstract Sessions 6 and 7 (2 Concurrent Sessions)	Grand Ballroom, Regency DEF
16:40-18:05	Abstract Sessions 8 and 9 (2 Concurrent Sessions)	Grand Ballroom, Regency DEF
SATURDAY, SEPTEMBER 25, 2021		
7:00-8:00	SRS Board of Directors Meeting*	Park View
7:30-12:30	Speaker Ready Room Open*	Mills 3
7:30-10:00	Registration Open*	Grand Foyer
8:00-10:05	Abstract Session 10	Grand Ballroom
10:35-12:35	Abstract Session 11	Grand Ballroom

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Network: SRS2021 | Password: AM2021

Wireless Internet is supported, in part, by Medtronic.