48TH

FORTY-EIGHTH ANNUAL MEETING

OF THE

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

Live Sessions:
December 9-12, 2020

On-Demand Content Available:
December 7, 2020-January 15, 2021

Rick Sasso, MD, *President*
Michael D. Daubs, MD and Andrew Dailey, MD, FAANS, *Scientific Program Chairs*

www.csrs.org

Hands On Surgical Techniques Course

July 15-17, 2021 Indiana Spine Group, Indianapolis, Indiana

Future Instructional Courses

Dec. 1, 2021	Marriott Marquis, Atlanta, GA
Nov. 16, 2022	Manchester Grand Hyatt, San Diego, CA
Nov. 30, 2023	The Cosmopolitan of Las Vegas, NV

Future Annual Meetings

Dec. 2-4, 2021	Marriott Marquis, Atlanta, GA
Nov. 17-19, 2022	Manchester Grand Hyatt, San Diego, CA
Dec 1-3, 2023	The Cosmopolitan of Las Vegas, NV

The material presented at this Annual Meeting has been made available by the Cervical Spine Research Society for educational purposes only. This 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 Author(s), which may be helpful to others who face similar situations.

Continuing Education Credit

Accreditation Statement

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Credit Claiming and Certificates of Attendance

Physicians can claim credit and certificates of attendance for the 2020 Annual Meeting or Instructional Course through the CME tab of the Annual Meeting Virtual Platform.

A legacy CME generator may be used to claim credit for meetings from 2015-2019. Visit https://www.csrs.org/education/claim-cme.

Electronic devices of any kind may not be used to record any portion of the Annual Meeting Scientific Program, E-Posters or Industry Workshops.

Administrative Staff:
Denise Lemke, Executive Director
Lindsey Groves Sausser, Meetings and Membership Manager

Cervical Spine Research Society
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CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

Cervical Spine Research Society
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Phone: 414-918-9834
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FOUNDED 1973

Origins of the Society

The Cervical Spine Research Society is an organization of individuals interested in clinical and research problems of the cervical spine. Its purpose is the exchange and development of ideas and philosophy regarding the diagnosis and treatment of cervical spine injury and disease.

The concept of a sub-specialty group devoted to the cervical spine was first considered in 1966. As interest in this area grew, a preliminary meeting to consider the formation of such an organization was held in Las Vegas, Nevada, in February, 1973, during the annual meeting of the American Academy of Orthopaedic Surgeons.

Present at the meeting were Edward H. Simmons and Ian McNab of Toronto; Richard Rothman and Henry H. Sherk of Philadelphia; Lee H. Riley, Jr. of Baltimore; Alice L. Garrett of West Haverstraw, New York; and Bernard Jacobs and J. William Fielding of New York City.

The name "Cervical Spine Research Society" was agreed upon and annual meetings were planned. The first such meeting was held in New York City in November, 1973. Since that time, yearly meetings have taken place at various locations within the North American continent.

Since the primary purpose of the organization is to carry out research and develop and exchange information on the cervical spine, international participation has been encouraged.

To provide a wide range of interest, it was felt that the composition of the membership should reflect the varying specialties and disciplines dealing with the cervical spine; biomechanical engineering, neurology, neurosurgery, radiology, orthopaedic surgery, and others. Qualifications for membership were to include demonstration of continued interest in the cervical spine and its related structures.

The organization has developed projects and has continued to grow. Current members are encouraged to seek out individuals, with appropriate interests, for membership to ensure the Society's future.

J. William Fielding, MD

Mission Statement

The Cervical Spine Research Society is a multidisciplinary organization that provides a forum for the exchange of ideas and promotes clinical and basic science research of the cervical spine. The organization values collegial interaction and strong scientific principles.

Officers

Rick C. Sasso, MD*	President
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Andrew C. Hecht, MD	Member
Han-Jo Kim, MD	Member
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Themistocles Protopsaltis, MD	Member
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Jason W. Savage, MD	Member
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Safdar N. Khan, MD	Member
R. Alden Milam	Member

Seed Starter Grant Subcommittee

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W. Ryan Spiker, MD	Member

2020 CSRS Committees

Resident Fellow Grant Subcommittee

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Samuel K. Cho, MD	Member
Carlo Santaguida, MD	Member
Frank Phillips, MD	Member
Michael P. Stauff, MD	Member

Cervical Spine Registry Subcommittee

Zoher Ghogawala, MD*	Sub-committee co-chair
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Samuel K. Cho, MD	Member
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Ryan Snowden, MD	Member
Barrett I. Woods, MD	Member
Neill M. Wright, MD	Member
Jim A. Youssef, MD	Member

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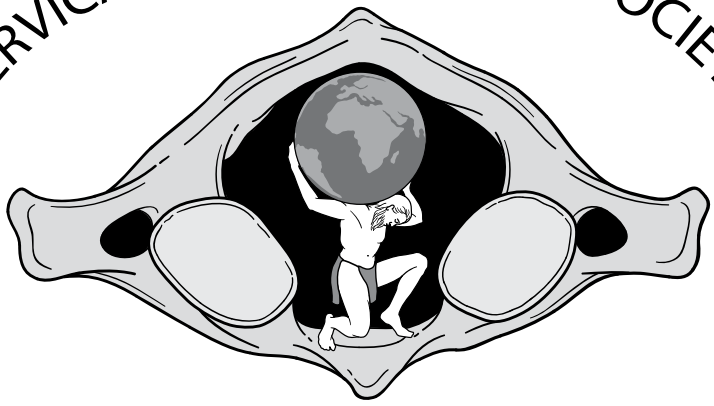
John G. Heller, MD	Member
Addisu Mesfin, MD	Member
Thomas E. Mroz, MD	Member
Themistocles S. Protopsaltis, MD	Member

CERVICAL SPINE RESEARCH SOCIETY



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Scientific Program

2020 Instructional Course Schedule for *Live* Programming

Tuesday, December 1

4:00pm-6:35pm PST / 7:00pm-9:35pm EST	Scientific Program - Instructional Course

Wednesday, December 2

4:00pm-6:35pm PST / 7:00pm-9:35pm EST	Scientific Program - Instructional Course

Thursday, December 3

4:00pm-6:35pm PST / 7:00pm-9:35pm EST	Scientific Program - Instructional Course

2020 Annual Meeting Schedule for *Live* Programming

Wednesday, December 9

3:00pm-4:00pm PST / 6:00pm-7:00pm EST	DePuy Synthes Industry Workshop*
4:00pm-6:42pm PST / 7:00pm-9:42pm EST	Scientific Program - Annual Meeting

Thursday, December 10

6:00am-8:00am PST / 9:00am-11:00am EST	Scientific Program - Annual Meeting
3:30pm-4:00pm PST / 6:30pm-7:00pm EST	Members' Business Meeting
4:00pm-5:15pm PST / 7:00pm-8:15pm EST	Henry H. Bohlman Presidential Guest Lecture Peyton Manning*
5:20pm-6:20pm PST / 8:20pm-9:20pm EST	Scientific Program - Annual Meeting

Friday, December 11

3:00pm-4:00pm PST / 6:00pm-7:00pm EST	Medtronic Industry Workshop*
4:00pm-5:20pm PST / 7:00pm-8:20pm EST	Scientific Program - Annual Meeting
5:20pm-5:35pm PST / 8:20pm-8:35pm EST	CSRS Awards Session

Saturday, December 12

6:00am-8:35am PST / 9:00am-11:35am EST	Scientific Program - Annual Meeting

**Denotes Non-CME Session*

CSRS *On-Demand* Sessions Available Dec. 7, 2020-Jan. 15, 2021

Reference the Abstract Book to see full On-Demand Abstract Presentations. These presentations will not be offered live, but are still available for CME on the Virtual Meeting Platform.

- CSRS Research Grants
- Complications - Avoidance and Management
- Deformity Diagnostics/Imaging
- Other
- Focused Abstracts
- Basic Science
- Cost Effectiveness/Health Policy
- Epidemiology/Etiology/Natural History
- Outcomes
- E-Posters

On-Demand content for the Instructional Course will be available Dec. 7, 2020-Jan. 15, 2021. On-Demand content for the Annual Meeting will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

All times are listed in Pacific Standard Time (PST).

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Live Sessions: December 9-12, 2020

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Scientific Program Chairs Michael D. Daubs, MD • Andrew Dailey, MD, FAANS

Program Committee Samuel K. Cho, MD • Matthew W. Colman, MD
William F. Donaldson, III, MD • Ben J. Garrido, MD;Regis W. Haid, MD • Andrew C. Hecht, MD
Han-Jo Kim, MD • Craig A. Kuhns, MD • Brian K. Kwon, MD, PhD • Ronald A. Lehman, MD
Steven C. Ludwig, MD • Sergio A. Mendoza-Lattes, MD • Justin W. Miller, MD
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Jeffrey A. Rihn, MD • Carlo Santaguida, MD • Jason W. Savage, MD • Brian W. Su, MD
Eeric Truumees, MD • Barrett I. Woods, MD

Scientific Meeting Objectives

- Present the results of current cervical spine research data.
- Promote discussion of new developments and techniques.
- Foster research concerning the diagnosis and treatment of cervical spine injury and disease.

No electronic devices of any kind may be used to record any portion of the Instrucional Course, Annual Meeting Scientific Program, E-Posters, Industry Workshops, or Technical Exhibits.

48th Annual Meeting Virtual *Live* Schedule

Live Session Dates and Times

Annual Meeting *Live* Sessions are broadcasting via our Virtual Annual Meeting Platform December 9-12, 2020. To gain access, register by November 30, 2020 for the Annual Meeting.

On-Demand content for the Annual Meeting will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

All times are listed in Pacific Standard Time (PST).

Wednesday, December 9

🕐 *Live* Session Time: 3:00pm-4:00pm PST / 6:00pm-7:00pm EST

DePuy Synthes Industry Workshop

Complex Cervical Case Based Round Table Discussion

Faculty: Christopher Ames, MD; John Shin, MD; Justin Smith, MD

🕐 *Live* Session Time: 4:00pm-4:10pm PST / 7:00pm-7:10pm EST

CSRS Annual Meeting Welcome

Moderator(s): Rick C. Sasso, MD; Michael Daubs, MD; Andrew Dailey, MD, FAANS

🕐 *Live* Session Time: 4:10pm-5:27pm PST / 7:10pm-8:27pm EST

Symposia I: Using Big Data for Cervical Spine Magement

Moderator(s): Daniel Sciubba, MD

4:10pm-4:12pm	**Introduction** *Daniel Sciubba, MD*
4:12pm-4:27pm	**Case Presentation** *Daniel Sciubba, MD*
4:27pm-4:42pm	**Prospective, Multi-Center Studies: What Can We Collect And What Can We Conclude?** *Zoher Ghogawala, MD, FACS*
4:42pm-4:57pm	**Predictive Alytics: We Cannot Tell The Future, But We Can Predict Better Than** *Christopher Ames, MD*
4:57pm-5:12pm	**Machine Learning And Spine: Is It Here Or Is It Hype?** *Joseph Schwab, MD*
5:12pm-5:27pm	**Discussion and *Live* Q&A**

Wednesday, December 9

Live Session Time: 5:30pm-6:42pm PST / 8:30pm-9:42pm EST

Highlighted Abstracts I

Moderator(s): Michael Daubs, MD; Andrew Dailey, MD, FAANS

5:30pm-5:32pm **Welcome**
Michael Daubs, MD; Andrew Dailey, MD, FAANS

5:32pm-5:37pm **FIRST PLACE - RESIDENT/FELLOW AWARD**

Presentation #1. **Early versus (<24 hrs) Late (>=24 hrs) Surgical Decom Presentationsion for Central Cord Syndrome: A Propensity Score-Matched Alysis**
Michael G. Fehlings, MD, PhD, FRCSC; ***Jetan H. Badhiwala, MD;*** *Jefferson R. Wilson, MD PhD; Christopher D. Witiw, MD, MS*

5:37pm-5:42pm **FIRST PLACE - CLINICAL RESEARCH AWARD**

Presentation #2. **A randomized controlled multi-center trial comparing ventral and dorsal surgery for CSM: 2-year results**
Edward C. Benzel, MD; ***Zoher Ghogawala, MD, FACS;*** *Adam S. Kanter, MD; Praveen V. Mummaneni, MD; Erica F. Bisson, MD; James S. Harrop, MD, FAANS; Robert F. Heary, MD; Michael P. Steinmetz, MD; Michael G. Fehlings, MD, PhD, FRCSC; Todd J. Albert, MD; Paul M. Arnold, MD; K. Daniel D. Riew, MD; Marjorie C. Wang, MD; John G. Heller, MD; Fred G. Barker, II, MD*

5:42pm-5:47pm **SECOND PLACE - RESIDENT/FELLOW AWARD**

Presentation #3. **Does Screw Length for Primary Two-level ACDF Influence Pseudarthrosis Risk?**
Nathan J. Lee, MD; *Paul Park, MD; Jun S. Kim, MD; Venkat Boddapati, MD; Justin Mathew, MD; Megha M. Vulapalli, BS; Louis F. Amorosa, MD; Zeeshan M. Sardar, MD; Rold A. Lehman, Jr., MD; K. Daniel Riew, MD*

5:47pm-5:52pm **THIRD PLACE - BASIC SCIENCE AWARD**

Presentation #4. **Characterization of Basal and Cytokine Stimulated Biomarker Profiles of Degenerative Cervical and Lumbar Fusion Explants ex-vivo**
Jacob S. Kramer, BS; ***Don K. Moore, MD;*** *Naomi N. Lee, DVM, MS; Aaron M. Stoker, PhD, MS; Theodore J. Choma, MD; Muhammad Mirza, MD*

5:52pm-5:57pm **THIRD PLACE - CLINICAL RESEARCH AWARD**

Presentation #5. **Cervical disc arthroplasty versus anterior cervical discectomy and fusion: 10-year outcomes of a prospective, randomized clinical trial at three sites.**
Pierce D. Nunley, MD; *Michael Hisey, MD; Micah Smith, MD; Marcus B. Stone, PhD*

Individual Disclosures can be found in the Disclosure Index pages 41-69.

Wednesday, December 9

5:57pm-6:02pm Presentation #6. **Impact of Pre-operative Kyphosis on Outcomes of Cervical Disc Replacement**
*Sheeraz Qureshi, MD, MBA; **Avani Vaishnav, MBBS;** Chirag Chaudhary, MBBS; Hikari Urakawa, MD; Kosuke Sato, MD; Ryan Lee, MBA; Jung Kee Mok, BS; Darren A. Chen, BS; Sravisht Iyer, MD; Steven McAny, MD; Todd J. Albert, MD*

6:02pm-6:07pm Presentation #7. **Comparing Outcomes and Mortality of Upper Cervical and Subaxial Cervical Spine Trauma in Elderly Patients**
***Catherine R. Carlile, MD;** Andrew B. Rees, BS; Jacob D. Schultz, BS; Byron F. Stephens, II, MD*

6:07pm-6:12pm Presentation #8. **Perioperative Outcomes of Concomitant Shoulder Diagnoses for Patients Undergoing Cervical Spine Procedures**
*Peter G. Passias, MD; Waleed Ahmad, MS; Sara Naessig, BS; Katherine E. Pierce, BS; Frank A. Segreto, BS; **Shaleen Vira, MD;** Bassel Diebo, MD*

6:12pm-6:17pm **FIRST PLACE - BASIC SCIENCE AWARD**
Presentation #9. **Efficacy of clinical hiPSC-OPC-enriched NS/PCs for transplantation in the subacute phase of spil cord injury**
***Yasuhiro Kamata, MD;** Miho Isoda, Ms.; Shuhei Ito, PhD; Morio Matsumoto, MD; Hideyuki Okano, MD; Masaya Nakamura, MD; Jun Kohyama, PhD; Narihito Nagoshi, MD*

6:17pm-6:22pm Presentation #10. **Is it Safe to Stop at C7 During Multi-Level Posterior Cervical DecomPresentation sion and Fusion? - Multi-Center alysis**
***Eeric Truumees, MD;** Devender Singh, PhD; Devender Singh, PhD; William F. Lavelle, MD; Ron Riesenburger, MD; Matthew Geck, MD; Swamy Kurra, MD; Anthony J. Yu, MS; Daniel Grits, BS; Robert Winkelman, BS; Thomas Mroz, MD; John Stokes, MD*

6:22pm-6:42pm **Discussion and *Live* Q&A**

On-Demand content for the Annual Meeting will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

Thursday, December 10

Live Session Time: 6:00am-7:00am PST / 9:00am-10:00am EST

CSRS Asia Pacific Session: Surgical strategies for the myeolpathy caused by OPLL
Moderator(s): Kyung-Soo Suk, MD

6:00am-6:12am	**K-line (+) myelopathy: Anterior vs. Posterior Decompression** *Gabriel Liu, MD*
6:12am-6:24am	**K-line (-) myelopathy: Anterior decompression** *Dong-Ho Lee, MD*
6:24am-6:36am	**K-line (-) myelopathy: Posterior decompression + PF** *Masashi Koda, MD*
6:36am-6:48am	**K-line (-) myelopathy: Circumferential surgery** *Yu Sun, MD*
6:48am-6:59am	**Discussion**

Live Session Time: 7:00am-8:00am PST / 9:00am-10:00am EST

CSRS Europe Session: The Cervical Cases That Influenced my Concepts and Strategy
Moderator: Heiko Koller, MD

7:00am-7:05am	**Introduction** *Heiko Koller, MD*
7:05am-7:13am	**Case 1** *David Choi, MD*
7:13am-7:21am	**Case 2** *Deszoe Jeszensky, MD*
7:21am-7:29am	**Case 3** *Carmen L.A. Vleggeert-Lankamp, MD*
7:29am-7:37am	**Case 4** *Jorg Klekamp, MD*
7:37am-7:45am	**Case 5** *Petr Vachata, MD*
7:45am-8:00am	**Discussion and Live Q&A**

Live Session Time: 4:00pm-4:10pm PST / 7:00pm-7:10pm EST

Welcome
Moderator(s): Rick C. Sasso, MD; Michael Daubs, MD; Andrew Dailey, MD, FAANS

Individual Disclosures can be found in the Disclosure Index pages 41-69.

Thursday, December 10

Live Session Time: 4:10pm-5:20pm PST / 7:10pm-8:20pm EST

Symposia II: Safety In Cervical Spine Surgery

Moderator(s): Todd Albert, MD

4:10pm-4:15pm	**Introduction** *Todd Albert, MD*
4:15pm-4:30pm	**Prevention of Complications** *Steven Ludwig, MD*
4:30pm-4:45pm	**Safety in an Outpatient Setting: Which Cases and Nuances** *Sheeraz Qureshi, MD, MBA*
4:45pm-5:00pm	**Safety in Deformity and Myelopathy Surgery** *Han Jo Kim, MD*
5:00pm-5:20pm	**Discussion and Live Q&A**

On-Demand content for the Annual Meeting, aside from the Awards Session which will be live only, will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

Live Session Time: 5:20pm-5:35pm PST / 8:20pm-8:35pm EST

Awards Session: Frank J. Eismont, Lifetime Achievement Award Recipient; CSRS Research Grant Awards; and CSRS Abstract Awards

Moderator(s): Rick C. Sasso, MD

This session will only be offered live.

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

Friday, December 11

Live Session Time: 3:00pm-4:00pm PST / 6:00pm-7:00pm EST

Medtronic Industry Workshop

Prestige LP™ Cervical Disc System – Design, Data, Differentiation

Faculty: Ron Lehman, MD and Rick Chua, MD

Live Session Time: 4:00pm-5:00pm PST / 7:00pm-8:00pm EST

Henry H. Bohlman Presidential Guest Lecture - Peyton Manning

Moderator(s): Rick C. Sasso, MD

This session will only be offered live.

Live Session Time: 5:00pm-6:15pm PST / 8:00pm-9:15pm EST

Symposia III: Why We Can't All Agree: Sports-Related Debates of the Cervical Spine

Moderator(s): Wellington Hsu, MD

5:00pm-5:05pm	**Introduction** *Wellington Hsu, MD*
5:05pm-5:10pm	**Return to Play: 1-Level Cervical Pseudarthrosis, Yes** *Alexander Vaccaro, MD, PhD, MBA*
5:10pm-5:15pm	**Return to Play: 1-Level Cervical Pseudarthrosis, No** *Alpesh Patel, MD, FACS*
5:15pm-5:22pm	**Discussion and Live Q&A**
5:22pm-5:27pm	**RTP: 2-Level ACDF, Yes** *John Heller, MD*
5:27pm-5:32pm	**RTP: 2-Level ACDF, No** *Robert Watkins, III, MD*
5:32pm-5:39pm	**Discussion and Live Q&A**
5:39pm-5:44pm	**RTP: C1 Ring Anomaly, Yes** *Thomas Zdeblick, MD*
5:44pm-5:49pm	**RTP: C1 Ring Anomaly, No** *K. Daniel Riew, MD*
5:49pm-5:56pm	**Discussion and Live Q&A**
5:56pm-6:01pm	**RTP: Congenital Cervical Stenosis, No** *Andrew Hecht, MD*
6:01pm-6:06pm	**RTP: Congenital Cervical Stenosis, Yes** *Wellington Hsu, MD*
6:06pm-6:15pm	**Discussion and Live Q&A**

On-Demand content for the Annual Meeting will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

Individual Disclosures can be found in the Disclosure Index pages 41-69.

Saturday, December 12

Live Session Time: 6:00am-7:12am PST / 9:00am-10:12am EST

Highlighted Abstracts II

Moderator(s): Michael Daubs, MD; Andrew Dailey, MD, FAANS

6:00am-6:02am **Welcome**
Michael Daubs, MD; Andrew Dailey, MD, FAANS

6:02am-6:07am **THIRD PLACE - RESIDENT/FELLOW AWARD**

Presentation #11. **Publicly Available Online Resources for ACDF are not Easily Read or Understood by the Average Patient**
Christopher Lindsay, MD; *Mary K. Skalitzky, BA; Alan G. Shamrock, MD; Burke Gao, MD; Trevor R. Gulbrandsen, MD; Joshua Eisenberg, MD; Andrew Pugely, MD*

6:07am-6:12am **SECOND PLACE - BASIC SCIENCE AWARD**

Presentation #12. **ExPresentation sion alysis of susceptibility genes for ossification of the posterior longitudil ligament**
Shuji Watabe, MD, PhD; *Hideaki Nakajima, MD, PhD; Kazuya KH. Honjoh, MD, PhD; Arisa Kubota, MD; Ai Takahashi, MD, PhD; Akihiko Matsumine, MD, PhD*

6:12am-6:17am Presentation #13. **Complex cervical spine surgery improves quality of life in the extremely elderly age group; results from an ambispective study of 582 patients over 75 years old from a single institution.**
Jamie RF. Wilson, MD, FRCS; *Jetan H. Badhiwala, MD; Hetshree Joshi, BA; Ali Moghaddamjou, MD; Raja Rampersaud, MD; Stephen J. Lewis, MD; Eric M. Massicotte, MD, FRCSC; Michael G. Fehlings, MD, PhD, FRCSC*

6:17am-6:22am Presentation #14. **Concomitant foraminotomy for radiculomyelopathy is directly involved in postoperative upper limb palsy in cervical laminoplasty**
Hiroyuki Ishiguro, MD, PhD; *Shota Takeka, MD, DMSc; Masafumi Kashii, MD, PhD; Yuichiro YU. Ukon, MD; Yukitaka Nagamoto, MD, PhD; Masayuki Furuya, MD, PhD; Takahiro TM. Makino, MD, DMSc; Yusuke Sakai, MD; Takashi Kaito, MD, PhD*

6:22am-6:27am **SECOND PLACE - CLINICAL RESEARCH AWARD**

Presentation #15. **Intrathecal administration of recombint human hepatocyte growth factor for acute traumatic cervical spil cord injury: double-blinded, placebo-controlled and randomized phase I/II study.**
Masaya Nakamura, MD; ***Kazuya Kitamura, MD, PhD;*** *Narihito Nagoshi, MD; Osahiko Tsuji, MD; Kota Suda, MD, PhD; Takeshi Maeda, MD, PhD; Yoshiyuki Yato, MD, PhD; Daichika Hayata, PhD; Morio Matsumoto, MD; Hideyuki Okano, MD*

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

Saturday, December 12

6:27am-6:32am Presentation #16. **Pain catastrophizing impacts outcome scores but not recovery kinetics after 1-2 level anterior cervical surgery**
Sheeraz Qureshi, MD, MBA; ***Sohrab Virk, MD;*** *Avani Vaishv, MBBS; Chirag Chaudhary, MBBS; Ryan Lee, MBA; Hikari Urakawa, MD; Kosuke Sato, MD; Jung Mok, BS; Darren A. Chen, BS; Steven McAny, MD; Sravisht Iyer, MD; Todd J. Albert, MD; Catherine Gang, MPH;*

6:32am-6:37am Presentation #17. **A Novel Method to Classify Cervical Incomplete Spil Cord Injury based on Potential for Recovery: A Group-Based Trajectory Alysis**
Michael G. Fehlings, MD, PhD, FRCSC; ***Jetan H. Badhiwala, MD;*** *Jefferson R. Wilson, MD PhD; Christopher D. Witiw, MD, MS*

6:37am-6:42am Presentation #18. **Does the Lowest Instrumented Vertebra (LIV) Level Predict Mechanical Failure in Posterior Cervical Fusion?**
Byron F. Stephens, II, MD; ***Joseph T. Labrum IV, IV, MD;*** *Imullah Khan, MBBS; Kristin R. Archer, PhD; Amir M. Abtahi, MD*

6:42am-6:47am Presentation #19. **Outcomes of Neurologic Complication and Utility of Intraoperative Neuromonitoring for Lower Cervical and Upper Thoracic Posterior Based Three Column Osteotomies for Cervical Deformity**
Christopher Ames, MD; ***Darryl Lau, MD;*** *Alexander F. Haddad, BS; Vedat Deviren, MD*

6:47am-6:52am Presentation #20. **Patient Specific Cervical Deformity Corrections with Consideration of Associated Risk: Establishment of Risk Benefit Thresholds for Invasiveness Based on Deformity and Frailty Severity**
Peter G. Passias, MD; *Katherine E. Pierce, BS; Reud Lafage, MS; Virginie Lafage, PhD; Eric O. Klineberg, MD; Alan H. Daniels, MD; Themistocles Protopsaltis, MD; Richard Hostin, MD; Breton Line, BS; Douglas Burton, MD; Shay Bess, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD; Christopher Ames, MD*

6:52am-7:12am **Discussion and *Live* Q&A**

Individual Disclosures can be found in the Disclosure Index pages 41-69.

Saturday, December 12

Live Session Time: 7:15am-8:35am PST / 10:15am-11:30am EST

Symposia IV: The Race to the Bottom: Why Governmental Bundled Payments/Risk Based Care has Failed for Cervical Spine Surgery

Moderator(s): Alexander Vaccaro, MD, PhD, MBA; Paul Slosar, MD

7:15am-7:17am	**Introduction** *Alexander Vaccaro, MD, PhD, MBA; Paul Slosar, MD*
7:17am-7:37am	**Overview of CMS and Bundled Payment Program related to Spine Surgery: BPCI, BPCI-A** *Vadim Goz, MD*
7:37am-7:52am	**BPCI/BPCI-A: A Private Practice Success Story** *Paul Slosar, MD*
7:52am-8:07am	**Rothman Experience- Why BPCI/BPCI-A Doesn't Work for Spine Surgery** *Kartik Shenoy, MD*
8:07am-8:30am	**Discussion and Live Q&A**
8:30am-8:35am	**Close of Meeting** *Rick C. Sasso, MD*

On-Demand content for the Annual Meeting will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

CSRS On-Demand Sessions Available Dec. 7, 2020-Jan. 15, 2021

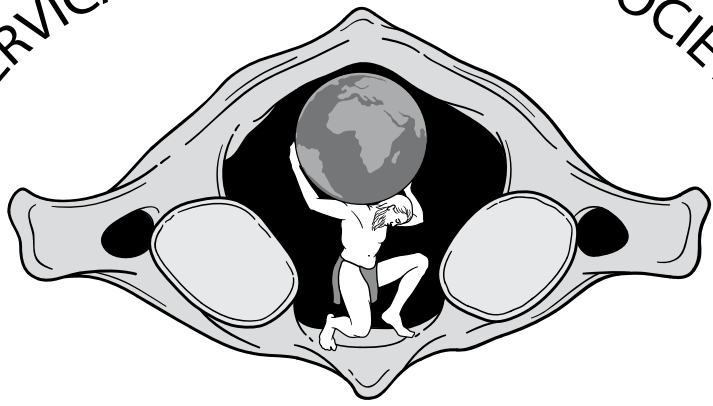
Reference the Abstract Book to see full On-Demand Abstract Presentations. These presentations will not be offered live, but are still available for CME on the Virtual Meeting Platform.

CSRS Research Grants	Basic Science
Complications - Avoidance and Management	Cost Effectiveness/Health Policy
Deformity Diagnostics/Imaging	Epidemiology/Etiology/Natural History
Other	Outcomes
Focused Abstracts	E-Posters

On-Demand content for the Instructional Course will be available Dec. 7, 2020-Jan. 15, 2021. On-Demand content for the Annual Meeting will be available on the Virtual Meeting Platform the day after it airs live through Jan. 15, 2021.

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

CERVICAL SPINE RESEARCH SOCIETY



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Alphabetical Participant Disclosure List

Alphabetical Participant Disclosure List

Name	AM2020 Disclosure
Abtahi, Amir (MD)	No Relevant Financial Relationships
Ahuja, Christopher (MD)	CEO/CMO relationship with Inteligex Inc.
Akbar, Muhammad Ali	No Relevant Financial Relationships
Albert, Todd (MD)	Treasurer relationship with Americal Orthopaedic Association; Stock Shareholder relationship with Bonovo Orthopedics, Inc.; Stock Shareholder relationship with Paradigm Spine, LLC; Treasurer relationship with American Orthopaedic Association; Ownership Interest relationship with Augmedics; Stock Shareholder relationship with Bonovo Orthopedics, Inc.; Ownership Interest relationship with CytoDyn Inc.; Patent Holder relationship with DePuy Synthes Spine; Author relationship with Elsevier, Inc.; Ownership Interest relationship with Innovative Surgical Designs, Inc.; Stock Options relationship with InVivo Therapeutics; Author relationship with JP Medical Publishers; Ownership Interest relationship with Morphogenesis; Consultant relationship with NuVasive, Inc.; Stock Shareholder relationship with Paradigm Spine, LLC; Ownership Interest relationship with Physician Recommended Nutriceuticals; Ownership Interest relationship with Precision Orthopedics; Ownership Interest relationship with Pulse Equity; Board of Directors relationship with Scoliosis Research Society; Editorial Board relationship with Spine Universe; Ownership Interest relationship with Spinicity; Author relationship with Springer; Ownership Interest relationship with Strathspey Crown; Ownership Interest relationship with Surg.IO LLC; Author relationship with Thieme Medical Publishers; Patent Holder relationship with Zimmer Biomet; Board of Directors relationship with Back Story, LLC
Ames, Christopher (MD)	Consultant relationship with DePuy Synthes; Consultant relationship with Medtronic; Research Grant relationship with Titan Spine; Research Grant relationship with DePuy Synthes; Editorial Board relationship with Operative Neurosurgery; Executive Committee relationship with ISSG; Director relationship with Global Spinal Analytics; Research Grant relationship with International Spine Study Group (ISSG); Royalties relationship with DePuy Synthes; Royalties relationship with Stryker; Royalties relationship with Biomet Zimmer Spine; Royalties relationship with Nuvasive; Royalties relationship with Next Orthosurgical; Royalties relationship with K2M; Royalties relationship with Medicrea; Consultant relationship with Medicrea; Consultant relationship with K2M; Research relationship with Titan Spine; Research relationship with DePuy Synthes; Research relationship with ISSG; Editorial Board relationship with Operative Neurosurgery; Grant relationship with Scoliosis Research Society; Executive Committee relationship with ISSG; Director relationship with Global Spinal Analytics

Name ROLE	AM2020 Disclosure
Anderson, Paul (MD)	Consultant relationship with Medtronic; Stock Shareholder relationship with Titan Spine; Consultant relationship with Amgen; Scientific/Medical Advisory Board Member relationship with Radius Medical; Royalties relationship with Regeneration technologies
Anderst, William (PhD)	No Relevant Financial Relationships
Arnold, Paul (MD, FAANS, FACS)	No Relevant Financial Relationships
Badhiwala, Jetan (MD)	No Relevant Financial Relationships
Bell, Joshua (MD)	No Relevant Financial Relationships
Bellabarba, Carlo (MD)	No Relevant Financial Relationships
Berman, Daniel (MD)	No Relevant Financial Relationships
Bhatia, Nitin (MD)	Royalties relationship with Alphatec; Royalties relationship with Zimmer Biomet; Royalties relationship with Spineart; Royalties relationship with Seaspine; Royalties relationship with Stryker
Bible, Jesse (MD)	No Relevant Financial Relationships
Bisson, Erica (MD, MPH)	No Relevant Financial Relationships
Buchowski, Jacob (MD, MS)	Royalties relationship with K2M; Royalties relationship with Wolters Kluwer; Royalties relationship with Globus
Buser, Zorica (PhD)	No Relevant Financial Relationships
Byun, Chan-Woong (MD)	No Relevant Financial Relationships
Canseco, Jose (MD)	No Relevant Financial Relationships
Carlile, Catherine (MD)	No Relevant Financial Relationships
Cha, Elliot (MS)	No Relevant Financial Relationships
Cha, Thomas (MD)	No Relevant Financial Relationships
Changoor, Stuart (MD)	No Relevant Financial Relationships
Chaput, Chris (MD)	Consultant relationship with Globus
Chee, Ana	No Relevant Financial Relationships
Cheng, Wayne (MD)	No Relevant Financial Relationships
Cho, Samuel (MD)	Consultant relationship with Globus; Consultant relationship with Globus; Consultant relationship with Zimmer Biomet
Choi, David (MD)	No Relevant Financial Relationships
Coe, Jeffrey (MD)	Consultant relationship with NuVasive; Consultant relationship with Benvenue; Stock Shareholder relationship with Alphatec; Consultant relationship with Providence Medical Technologies; Stock Shareholder relationship with ClearView Medical; Scientific/Medical Advisory Board Member relationship with ClearView Medical; Consultant relationship with Mirus
Colman, Matthew (MD)	No Relevant Financial Relationships
Couch, Brandon (MD)	No Relevant Financial Relationships

Alphabetical Participant Disclosure List

Name	AM2020 Disclosure
Crawford, Charles (MD)	Product Development relationship with Alphatec; Consultant relationship with Depuy-Synthes; Consultant relationship with Medtronic; and Product Development relationship with Nuvasive
Daffner, Scott (MD)	Consultant relationship with Bioventus; Research Grant Overall Principal Investigator relationship with Bioventus; Research Grant Site Principal Investigator relationship with Pfizer; Research Grant Site Principal Investigator relationship with Spinal Kinetics; Fellowship Support relationship with AO Spine
Dailey, Andrew (MD, FAANS)	Consultant relationship with Zimmer Biomet; Research Grant Site Principal Investigator relationship with K2M/Stryker
Darden, Bruce (MD)	Scientific/Medical Advisory Board Member relationship with Cutting Edge Spine; Stock Shareholder relationship with BioMedFlex; Fellowship support relationship with Nuvasive
Daubs, Michael (MD)	No Relevant Financial Relationships
Diebo, Bassel (MD)	No Relevant Financial Relationships
Divi, Srikanth	No Relevant Financial Relationships
Donaldson, William (MD)	No Relevant Financial Relationships
Elmi-Terander, Adrian (MD, PhD)	No Relevant Financial Relationships
Elysee, Jonathan (BS)	No Relevant Financial Relationships
Fatima, Nida (MD)	No Relevant Financial Relationships
Fehlings, Michael (MD, PhD, FRCSC, FACS)	No Relevant Financial Relationships
France, John (MD)	No Relevant Financial Relationships
Furlan, Julio (MD, MBA, PhD, MSc, FRCPC)	No Relevant Financial Relationships
Garrido, Ben (MD)	Consultant relationship with ATEC
Gerling, Michael (MD)	No Relevant Financial Relationships
Ghanayem, Alexander (MD)	No Relevant Financial Relationships
Ghogawala, Zoher (MD, FACS)	No Relevant Financial Relationships
Goh, Brian (MD, PhD)	No Relevant Financial Relationships
Goldstein, Jeffrey (MD)	No Relevant Financial Relationships
Goz, Vadim (MD)	No Relevant Financial Relationships
Groves Sausser, Lindsey	No Relevant Financial Relationships

Name ROLE	AM2020 Disclosure
Gum, Jeffrey (MD)	Consultant relationship with Medtronic; Consultant relationship with Acuity; Consultant relationship with K2M/ Stryker; Consultant relationship with NuVasive; Consultant relationship with Mazor; Employee relationship with Norton Healthcare; Scientific/Medical Advisory Board Member relationship with K2M/ Stryker; Scientific/ Medical Advisory Board Member relationship with Medtronic; Royalties relationship with Acuity; Speakers Bureau relationship with Dupuy; Research Grant Site Principal Investigator relationship with NuVasive; Research Grant Site Principal Investigator relationship with Integra & Intellirod Spine Inc; Stock relationship with Cingulate Therapeutics; Rayalties relationship with NuVasive; Research Grant Site Principal Investigator relationship with Norton Healthcare; Research Grant Site Principal Investigator relationship with Pfizer; Research Grant Site Principal Investigator relationship with International Spine Study Group; Scientific/Medical Advisory Board Member relationship with National Spine Health Foundation
Gupta, Munish (MD)	No Relevant Financial Relationships
Haid, Regis (MD, FAANS)	No Relevant Financial Relationships
Harrop, James (MD, FAANS)	Scientific/Medical Advisory Board Member relationship with Depuy Spine; Speakers Bureau relationship with Globus spine; Speakers Bureau relationship with Stryker
Hecht, Andrew (MD)	No Relevant Financial Relationships
Heller, John (MD)	Royalties and stock ownership relationship with Medtronic
Holly, Langston (MD, FAANS)	No Relevant Financial Relationships
Holtzman, Ari (MD)	No Relevant Financial Relationships
Hong, James (PhD)	No Relevant Financial Relationships
Hsu, Wellington (MD)	Scientific/Medical Advisory Board Member relationship with Stryker; Scientific/Medical Advisory Board Member relationship with Medtronic; Scientific/Medical Advisory Board Member relationship with Asahi; Scientific/Medical Advisory Board Member relationship with Bioventus; Scientific/Medical Advisory Board Member relationship with Agnovos; Scientific/Medical Advisory Board Member relationship with Wright Medical
Hughes, Steven (MD)	No Relevant Financial Relationships
Ishiguro, Hiroyuki (MD, PhD)	No Relevant Financial Relationships
Jack, Andrew	No Relevant Financial Relationships
Jain, Deeptee (MD)	Advisor relationship with Kaia Health; Consultant relationship with Kaia Health
Jeszensky, Deszoe (MD)	Royalty,Stock Shareholder, Patent Holder relationship with DePuySynthesSpine, Medacta Spine, INNO4Spine
Kalsi-Ryan, Sukhvinder (PhD)	No Relevant Financial Relationships
Kamata, Yasuhiro (MD)	No Relevant Financial Relationships

Alphabetical Participant Disclosure List

Name	AM2020 Disclosure
Kang, Kyung-Chung (MD)	No Relevant Financial Relationships
Kaye, Ian (MD)	Research Grant Overall Principal Investigator relationship with Camber Spine; Stock Shareholder relationship with J and J; Stock Shareholder relationship with Nuvasive
Khan, Safdar (MD)	No Relevant Financial Relationships
Khazaei, Mohammad (MD)	No Relevant Financial Relationships
Kim, Han Jo (MD)	Consultant relationship with Zimmerbiomet; Consultant relationship with K2M- Styrker; Consultant relationship with Alphatec
Kim, Jun (MD)	No Relevant Financial Relationships
Kitamura, Kazuya (MD, PhD)	No Relevant Financial Relationships
Klekamp, Jorg (MD)	No Relevant Financial Relationships
Koda, Masao (MD, PhD)	No Relevant Financial Relationships
Koller, Heiko (MD)	Consultant relationship with DepuySynthes; Scientific/Medical Advisory Board Member relationship with DSS
Kontakis, Michail (MD)	No Relevant Financial Relationships
Kuhns, Craig (MD)	No Relevant Financial Relationships
Kwon, Brian (MD, PhD, FRCSC)	No Relevant Financial Relationships
Kwon, Woo-Keun (MD, PhD)	No Relevant Financial Relationships
Labrum IV, Joseph (MD)	No Relevant Financial Relationships
Lafage, Renaud (MS)	Stock Shareholder relationship with Nemaris
Lau, Darryl (MD)	No Relevant Financial Relationships
Lawrence, Brandon (MD)	No Relevant Financial Relationships
Lee, Dong-Ho (PhD)	No Relevant Financial Relationships
Lee, Ho Jin (MD, PhD.)	No Relevant Financial Relationships
Lee, HyungRae (MD)	No Relevant Financial Relationships
Lee, Jong Beom (MD, PhD)	No Relevant Financial Relationships
Lee, Nathan (MD)	No Relevant Financial Relationships
Lee, Ryan (MBA)	No Relevant Financial Relationships
Lehman, Ronald (MD)	Consultant relationship with Medtronic; Consultant relationship with Stryker; Royalty relationship with Medtronic; Royalty relationship with Stryker; Research Grant Site Principal Investigator relationship with Department of Defense
Lemke, Denise	No Relevant Financial Relationships
Li, Quan (MD)	No Relevant Financial Relationships
Lindsay, Christopher (MD)	No Relevant Financial Relationships
Liu, Gabriel (MBBCh (Ire), MSc (Ire), FRCS (Ire), FRCSEd (Orth))	No Relevant Financial Relationships
Lombardi, Joseph (MD)	No Relevant Financial Relationships

Name ROLE	AM2020 Disclosure
Lopez, Wylie (MD)	No Relevant Financial Relationships
Louie, Philip (MD)	No Relevant Financial Relationships
Ludwig, Steven (MD)	Patent Holder relationship with Depuy-Synthes Spine; Scientific/ Medical Advisory Board Member relationship with Nuvasive Spine; Patent Holder relationship with Stryker-K2M; Owner relationship with Maryland Development Corporation; Patent Holder relationship with Atlas Spine; Owner relationship with ASIP
Lundgren, Mary (DO, PhD)	No Relevant Financial Relationships
Lynch, Conor (MS)	No Relevant Financial Relationships
Lyu, Feizhou (MD)	No Relevant Financial Relationships
Maki, Satoshi (MD, PhD)	No Relevant Financial Relationships
Martin, Allan (MD, PhD, FRCSC)	No Relevant Financial Relationships
Mendoza-Lattes, Sergio (MD)	Consultant relationship with Globus Medical; Consultant relationship with DePuy Synthes
Merali, Zamir (MD)	No Relevant Financial Relationships
Merchan, Nelson (MD)	No Relevant Financial Relationships
Milam, R. Alden (MD)	Fellowship Funding relationship with Nuvasive; Fellowship Funding relationship with AO Spine; Consultant relationship with Depuy Synthes; Patent Holder relationship with Cutting Edge Spine; Research Grant Site Principal Investigator relationship with Bioventus; Research Grant Site Principal Investigator relationship with Orthofix; Scientific/Medical Advisory Board Member relationship with Bioventus
Miller, Justin (MD)	No Relevant Financial Relationships
Moghaddamjou, Ali (MD)	No Relevant Financial Relationships
Mohanty, Sarthak (B.S.)	No Relevant Financial Relationships
Moore, Don (MD)	No Relevant Financial Relationships
Moore, Timothy (MD)	No Relevant Financial Relationships
Mroz, Thomas (MD)	royalties relationship with stryker
Murphy, Rory (MD)	No Relevant Financial Relationships
Naessig, Sara (BS)	No Relevant Financial Relationships
Nagoshi, Narihito (MD)	No Relevant Financial Relationships
Nakajima, Hideaki (MD, PhD)	No Relevant Financial Relationships
Nassr, Ahmad (MD)	No Relevant Financial Relationships
Nottmeier, Eric (MD)	Royalties relationship with Globus Spine; Stock Shareholder relationship with Mirus Spine; Stock Shareholder relationship with TrackX
Nunley, Pierce (MD)	Research Grant Site Principal Investigator relationship with Zimmer Biomet; Speakers Bureau relationship with Zimmer Biomet; Consultant relationship with Zimmer Biomet

Alphabetical Participant Disclosure List

Name	AM2020 Disclosure
Odum, Susan (PhD)	No Relevant Financial Relationships
Orndorff, Douglas (MD)	Consultant relationship with SeaSpine; Royalty/License relationship with SeaSpine; Consultant relationship with Stryker; Consultant relationship with NuVasive
Ozaki, Masahiro (MD, PhD)	No Relevant Financial Relationships
Park, Sehan (MD)	No Relevant Financial Relationships
Passias, Peter (MD)	Other financial or material support relationship with Allosource; Consultant relationship with Medicrea; Consultant relationship with SpineWave; Consultant relationship with Zimmer; Research Grant Overall Principal Investigator relationship with CSRS; Other Financial or Material Support relationship with Allosource; Speakers Bureau relationship with Globus Medical; Consultant relationship with Medicrea; Consultant relationship with SpineWave; Consultant relationship with Terumo
Patel, Alpesh (MD, FACS)	Consultant relationship with Amedica; Consultant relationship with NuVasive; Consultant relationship with Zimmer Biomet; Consultant relationship with Alphatec; Fellowship relationship with NuVasive; Scientific/Medical Advisory Board Member relationship with nView; Stock Shareholder relationship with TDI, LLC; Stock Shareholder relationship with Nocimed; Scientific/Medical Advisory Board Member relationship with Kuros Biosciences; Stock Shareholder relationship with Cytonics; Consultant relationship with Johnson and Johnson
Petersen-Fitts, Graysen (MD)	No Relevant Financial Relationships
Phillips, Frank (MD)	Royalties relationship with Nuvasive, Medtronic; Consultant relationship with Nuvasive, Stryker, Medtronic, Spinal Kinetics,Globus, SIBone; Medical Advisory Board relationship with Nuvasive,Theracell,Surgio, Edge, SIBone, Vertiflex, Augmedic
Piche, Joshua (MD)	No Relevant Financial Relationships
Pinter, Zachariah (MD)	No Relevant Financial Relationships
Presciutti, Steven	No Relevant Financial Relationships
Protopsaltis, Themistocles (MD)	Consultant relationship with Globus; Consultant relationship with Stryker K2; Consultant relationship with Medicrea; Consultant relationship with Innovasis; Consultant relationship with Altus; Consultant relationship with Altus; Consultant relationship with Styker K2; Consultant relationship with Altus; Consultant relationship with Globus; Consultant relationship with Stryker K2; Consultant relationship with NuVasive; Consultant relationship with Medicrea; Consultant relationship with Innovasis

Name ROLE	AM2020 Disclosure
Qureshi, Sheeraz (MD, MBA)	Professional Society member relationship with The American Orthopaedic Association; Clinical Experience Program relationship with AMOpportunities; Editorial board member relationship with Annals of Translational Medicine; 1) Program Committee member 2) Professional Society member relationship with Association of Bone and Joint Surgeons; Ownership Interest relationship with Avaz Surgical; Other: 1) Publications Committee member 2) Professional Soc relationship with Cervical Spine Research; Editorial board member relationship with Contemporary Spine Surgery; Royalties, Speakers' Bureau, Consultant relationship with Globus Medical, Inc.; Scientific/Medical Advisory Board Member relationship with Healthgrades; 1) Program Committee member 2) Professional Society member relationship with International Society for the Advancement of Spine Surgery; Scientific/Medical Advisory Board Member relationship with LifeLink.com Inc.; Treasurer relationship with Minimally Invasive Spine Study Group; 1) Value Committee member 2) MIS Committee member 3) Advoca relationship with North American Spine Society; Consultant relationship with Paradigm Spine; Speaker address relationship with RTI Surgical Inc.; Clinical Events Committee member relationship with Simplify Medical, Inc.; 1) Program Committee member 2) Professional Society member 3 relationship with Society of Lateral Access Surgery; 1) Program Committee member 2) Professional Society member 3 relationship with Society of Minimally Invasive Spine Surgery; Scientific/Medical Advisory Board Member relationship with Spinal Simplicity, LLC; Ownership Interest relationship with Vital 5 (past relationship)
Raad, Micheal (MD)	No Relevant Financial Relationships
Radcliff, Kristen (MD)	No Relevant Financial Relationships
Reisener, Marie-Jacqueline (MD)	No Relevant Financial Relationships
Rhee, John (MD)	Product Development relationship with Stryker Spine; Product Development relationship with Zimmer Biomet; Speakers Bureau relationship with Medtronic; Writing Textbooks relationship with Wolters Kluwer
Rider, Sean (MD)	No Relevant Financial Relationships
Riew, K. Daniel (MD)	No Relevant Financial Relationships
Rihn, Jeffrey (MD)	Stock Shareholder relationship with Xtant Medical; Consultant relationship with Globus Medical; Corporate Board Member relationship with Deputy Editor,The Spine Journal
Samuel, Andre (MD)	No Relevant Financial Relationships
Santaguida, Carlo (MD, FRCSC)	No Relevant Financial Relationships
Sasso, Rick (MD)	Patent Holder relationship with Medtronic; Consultant relationship with NuVasive

Alphabetical Participant Disclosure List

Name	AM2020 Disclosure
Savage, Jason (MD)	Consultant relationship with Stryker Spine
Schroeder, Gregory (MD)	Consultant relationship with Stryker, Zimmer, Medtronic, ISD, Bioventus, Teledoc, AOSpine; Consultant relationship with Astute, Wolters klewer, csrs
Schwab, Joseph (MD)	No Relevant Financial Relationships
Sciubba, Daniel (MD)	Consultant relationship with Depuy-Synthes; Consultant relationship with Medtronic; Consultant relationship with Stryker; Consultant relationship with Baxter
Seok, Sangyun (MD)	No Relevant Financial Relationships
Shaffrey, Christopher (MD)	Patent Holder, relationship with NuVasive; Consultant relationship with SI Bone; Research Grant Overall Principal Investigator relationship with ISSG Foundation; Consultant relationship with Medtronic; Consultant relationship with Medtronic; Patent Holder relationship with Medtronic; Patent Holder relationship with NuVasive; Consultant relationship with SI Bone; Patent holder, royalties relationship with Medtronic; Consultant relationship with NuVasive; Research Grant Site Principal Investigator relationship with ISSG Foundation; Research Grant Site Principal Investigator relationship with Department of Defense; Consultant relationship with SI Bone
Sheikh Alshabab, Basel (MD)	No Relevant Financial Relationships
Shenoy, Kartik (MD)	No Relevant Financial Relationships
Sherrod, Brandon (MD)	No Relevant Financial Relationships
Shibata, Reo (MD)	No Relevant Financial Relationships
Shimizu, Takayoshi (MD)	No Relevant Financial Relationships
Shin, Jae-Won (MD, PhD)	No Relevant Financial Relationships
Singh, Hardeep (MD)	No Relevant Financial Relationships
Slosar, Paul (MD)	Consultant relationship with Episode Solutions
Smith, Justin (MD, PhD)	Consultant relationship with Cerapedics; Consultant relationship with Zimmer Biomet; Consultant relationship with Nuvasive; Consultant relationship with DePuy Synthes; Consultant relationship with Stryker; Stock Shareholder relationship with Alphatec; Consultant relationship with Zimmer Biomet; Consultant, Research Grants relationship with Nuvasive; Consultant relationship with Carlsmed; Consultant relationship with Cerapedics; book editor relationship with Thieme; Consultant relationship with DePuy Synthes; Research Grant Site Principal Investigator relationship with ISSGF; Stock Shareholder relationship with Alphatec
Song, Se-Jin (MD)	No Relevant Financial Relationships
Spiker, W. Ryan (MD)	No Relevant Financial Relationships
Stauff, Michael (MD)	No Relevant Financial Relationships

Name ROLE	AM2020 Disclosure
Steinhaus, Michael (MD)	No Relevant Financial Relationships
Stephens, Byron (MD)	Consultant relationship with Stryker Spine; Consultant relationship with Depuy Synthes Spine; Consultant relationship with DePuy Synthes
Streufert, Benjamin (MD)	No Relevant Financial Relationships
Su, Brian (MD)	No Relevant Financial Relationships
Suk, Kyung-Soo (MD, PhD)	No Relevant Financial Relationships
Sun, Yu (MD)	No Relevant Financial Relationships
Suzuki, Satoshi (MD)	No Relevant Financial Relationships
Tamai, Koji (MD)	No Relevant Financial Relationships
Taylor, Adam (MD)	No Relevant Financial Relationships
Tribus, Clifford (MD)	Consultant relationship with Stryker; Consultant relationship with Zimmer; Patent Holder relationship with Spineology; Patent Holder relationship with Amedica
Truumees, Eeric (MD)	No Relevant Financial Relationships
Vaccaro, Alexander (MD, PhD, MBA)	Stock Shareholder relationship with Advanced Spinal Intellectual Properties; Royalties relationship with Avaz Surgical; Stock Shareholder relationship with Bonovo Orthopaedics; Stock Shareholder relationship with Computational Biodynamics; Stock Shareholder relationship with Cytonics; Stock Shareholder relationship with Deep Health; Stock Shareholder relationship with Dimension Orthotics LLC; Stock Shareholder relationship with Electrocore; Stock Shareholder relationship with Flagship Surgical; Stock Shareholder relationship with FlowPharma; Stock Shareholder relationship with Franklin Bioscience; Stock Shareholder relationship with Globus; Stock Shareholder relationship with Innovative Surgical Design; Stock Shareholder relationship with Insight Therapeutics; Stock Shareholder relationship with Nuvasive; Stock Shareholder relationship with Orthobullets; Stock Shareholder relationship with Paradigm Spine; Stock Shareholder relationship with Parvizi Surgical Innovation; Stock Shareholder relationship with Progressive Spinal Technologies; Stock Shareholder relationship with Replication Medica; Stock Shareholder relationship with Spine Medica; Stock Shareholder relationship with Spinology; Stock Shareholder relationship with Stout Medical; Stock Shareholder relationship with Vertiflex
Vachata, Petr	No Relevant Financial Relationships
Vaishnav, Avani (MBBS)	No Relevant Financial Relationships
Vira, Shaleen (MD)	No Relevant Financial Relationships
Virk, Sohrab (MD)	No Relevant Financial Relationships

Alphabetical Participant Disclosure List

Name	AM2020 Disclosure
Vleggeert-Lankamp, Carmen L.A. (MD)	No Relevant Financial Relationships
Wagner, Scott (MD)	No Relevant Financial Relationships
Wahlmeier, Steven (MD)	No Relevant Financial Relationships
Wang, Jeffrey (MD)	royalties relationship with Depuy Synthes; royalties relationship with Amedica; royalties relationship with seaspine; royalties relationship with zimmer biomet; investment relationship with electrocore; investment relationship with bone biologics; investment relationship with surgitech; options relationship with Pearldiver
Wanner, John (MD)	No Relevant Financial Relationships
Watanabe, Shuji (MD, PhD)	No Relevant Financial Relationships
Watkins, III, Robert (MD)	No Relevant Financial Relationships
Weinberg, Douglas (MD)	No Relevant Financial Relationships
Wilson, Jamie (MD, FRCS)	No Relevant Financial Relationships
Wilson, Jefferson (MD PhD)	Consultant relationship with Stryker; Scientific/Medical Advisory Board Member relationship with Bioventus
Woods, Barrett (MD)	No Relevant Financial Relationships
Wright, Neill (MD)	Royalties relationship with Nuvasive; Scientific/Medical Advisory Board Member relationship with Ulrich medical USA; Speakers Bureau relationship with Zimmer Biomet; Scientific/Medical Advisory Board Member relationship with Cerapedics
Xia, Tian (MD)	No Relevant Financial Relationships
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Yang, Daniel (BS)	No Relevant Financial Relationships
Yang, Jun-Song (MD)	No Relevant Financial Relationships
Yao, Yu Cheng (MD)	No Relevant Financial Relationships
Yolcu, Yagiz (MD)	No Relevant Financial Relationships
Zaragoza, Emanuel (MD)	No Relevant Financial Relationships
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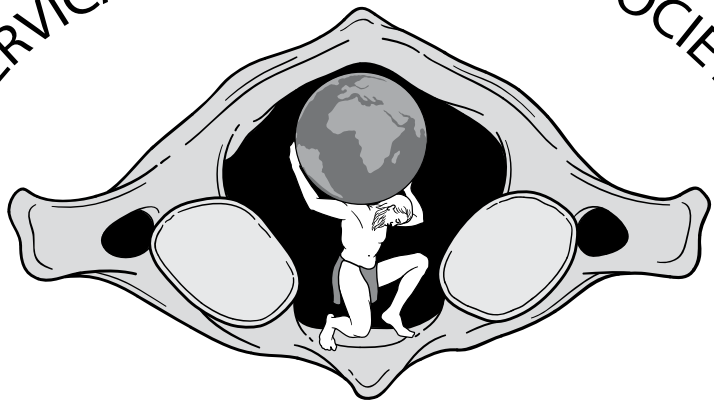

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Podium and E-Poster Presentations

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Presentation #1 ***Resident/Fellow Research Award***

Early versus (<24 hrs) Late (≥24 hrs) Surgical Decompression for Central Cord Syndrome: A Propensity Score-Matched Analysis

Jetan Badhiwala, MD, *Jefferson Wilson, MD, PhD, Christopher Witiw, MD, MS, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: The optimal clinical management of central cord syndrome (CCS) remains unclear; yet this is becoming an increasingly relevant public health problem in the face of the global aging population. This study provides a head-to-head comparison of the neurological and functional outcomes of early (< 24 hrs) versus late (= 24 hrs) surgical decompression for CCS.

Materials and Methods: Patients who underwent surgery for CCS (LEMS – UEMS = 5; ASIA Impairment Scale [AIS] grade C or D) were identified from three prospective, multi-center spinal cord injury (SCI) datasets (NACTN; STASCIS; NASCIS III). Propensity scores were calculated as the probability of undergoing early (< 24 hrs) compared to late (= 24 hrs) surgery using the logit method and adjusting for data source, age, injury mechanism, and baseline ASIA motor score (AMS), AIS grade, and neurological level. Propensity score matching was performed in a one-to-one ratio by an 'optimal matching' technique. The primary endpoint was motor recovery (upper extremity motor score [UEMS]; lower extremity motor score [LEMS]; AMS) at 1 year. Secondary endpoints were Functional Independence Measure (FIM) motor score and complete independence in each FIM motor domain at 1 year. Effect sizes for outcomes were summarized by mean differences (MDs) or odds ratios (ORs) and associated 95% confidence intervals.

Results: The final study cohort consisted of 186 patients with CCS. Baseline characteristics were balanced between propensity score-matched early (N=93) and late (N=93) surgery groups (Table 1). Early surgical decompression resulted in significantly improved recovery in upper limb (MD 2.3, P=0.047), but not lower limb (MD 1.1, P=0.256), motor function, as compared with late surgery (Table 2). More patients in the early surgery group appeared to achieve complete independence in various functional activities, particularly those involving upper limb function; however, these associations did not reach statistical significance, and there was no difference in 1-year FIM motor score (MD 4.4, P=0.182). On subgroup analysis, outcomes were comparable with early or late decompressive surgery in AIS grade D patients. However, in patients with AIS grade C injury, early surgery resulted in significantly greater recovery in overall motor score (MD 9.5, P=0.038), owing to gains in both upper and lower limb motor function (Table 3).

Conclusion: This study found early (< 24 hrs) compared to late (= 24 hrs) surgical decompression to result in improved recovery in upper limb motor function at 1 year in patients with central cord syndrome. The benefit of early surgery was especially realized in patients with AIS grade C injury. Treatment paradigms for central cord syndrome should be redefined to encompass early surgical decompression as a neuroprotective therapy.

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Table 1: Baseline characteristics

Variable	Early surgery	Late surgery	P Value
Age—mean ± SD	47.8 ± 16.8	48.0 ± 15.5	0.935
Female sex—no. (%)	27 (29.0)	18 (19.4)	0.123
Mechanism of injury—no. (%)			0.762
Fall	37 (39.8)	40 (43.0)	
Motor vehicle accident	41 (44.1)	43 (46.2)	
Sports accident	6 (6.5)	4 (4.3)	
Other	9 (9.7)	6 (6.5)	
AIS grade C—no. (%)	20 (21.5)	24 (25.8)	0.490
Neurological level—median (IQR)	C5 (C4-C5)	C5 (C4-C5)	0.863
UEMS—mean ± SD	25.2 ± 12.5	25.0 ± 14.0	0.895
LEMS—mean ± SD	39.5 ± 11.2	38.1 ± 12.2	0.400
AMS—mean ± SD	64.8 ± 22.2	63.0 ± 25.1	0.623
Light touch score—mean ± SD	91.9 ± 24.3	90.2 ± 27.1	0.666
Pin prick score—mean ± SD	86.1 ± 28.9	86.2 ± 28.9	0.986
Administration of steroids—no. (%)	58 (62.4)	53 (57.0)	0.455

Table 2: Motor and functional recovery at 1 year

	Mean score			
Variable	Early surgery	Late surgery	MD (95% CI)†	P Value
UEMS	43.6	41.2	2.3 (0.03 to 4.5)	0.047*
LEMS	47.6	46.2	1.1 (-0.8 to 3.0)	0.256
AMS	91.2	87.4	3.2 (-0.2 to 6.6)	0.065
FIM motor score	82.7	78.2	4.4 (-2.1 to 11.0)	0.182

†Comparing early surgery to late surgery
*Statistically significant difference (P<0.05)

Table 3: Motor and functional recovery at 1 year stratified by baseline AIS grade

	AIS grade C		AIS grade D	
Variable	MD (95% CI)†	P Value	MD (95% CI)†	P Value
UEMS	4.8 (-1.3 to 11.0)	0.119	1.3 (-1.1 to 3.8)	0.280
LEMS	4.2 (0.1 to 8.4)	0.046*	0.2 (-2.1 to 2.3)	0.914
AMS	9.5 (0.5 to 18.4)	0.038*	1.4 (-2.4 to 5.1)	0.465
FIM motor score	11.1 (-4.1 to 26.3)	0.145	1.2 (-5.4 to 7.9)	0.708

†Comparing early surgery to late surgery
*Statistically significant difference (P<0.05)

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Presentation #2 ***Clinical Research Award***

A randomized controlled multi-center trial comparing ventral and dorsal surgery for CSM: 2-year results

Zoher Ghogawala, MD, FACS, *Adam Kanter, MD, Praveen Mummaneni, MD, Erica Bisson, MD, MPH, James Harrop, MD, FAANS, Robert Heary, MD, Michael Steinmetz, MD, Michael Fehlings, MD, PhD, FRCSC, FACS, Todd Albert, MD, Paul Arnold, MD, FAANS, FACS, K. Daniel Riew, MD, Marjorie Wang, MD, John Heller, MD, Fred Barker, MD, Edward Benzel, MD*

Introduction: The Cervical Spondylotic Myelopathy-Surgical study is a randomized prospective study conducted to compare the effectiveness of ventral versus dorsal (fusion or laminoplasty) surgery for patients with multi-level CSM. Outcomes were compared at 2 years after surgery.

Materials and Methods: A multi-center prospective, randomized clinical trial was conducted on patients aged 45-80 years with multi-level CSM (1). The CSM-S study was supported by NIH (R13AR065834-01) & PCORI (CE 1304-6173). Study rationale, design, and protocol were published in 2014 (2). Patients were screened and enrolled over a 4 year period (2014-2018) from 15 sites. Patients were randomized to ventral or dorsal surgery (2:3 randomization). Dorsal surgical approach (dorsal fusion or laminoplasty) was at the discretion of surgeon and patient. Outcome assessments (SF-36, NDI, mJOA, and EQ-5D) along with patient work status were obtained pre-operatively, 3 months, 6 months, and at 1 and 2 years post-operatively. Complications were assessed by an independent study coordinator at 1 month and 1 year post-operatively.

Results: A total of 15 sites randomized 163 patients. 63 (38.7%) were randomized to ventral surgery and 100 (61.3%) to dorsal. Average age was 62.2 years and 49% were male. Baseline characteristics were comparable between ventral and dorsal groups. After randomization there was a 3% crossover rate. A total of 124 (76%) patients provided 2 year follow-up. Analysis as randomized demonstrated no difference in improvement in SF-36 PCS at 2 years between ventral and dorsal surgery (5.1 Ventral vs. 6.1 Dorsal; P=0.55). Ventral surgery had less EBL (80 ml) versus dorsal surgery (257 ml) (P=0.0002) and more complications (43% vs. 23%; P=0.0074). We conducted a pre-specified analysis of patients as treated. 66 patients ultimately underwent ventral fusion (VF) and 97 (69 dorsal fusion (DF) and 28 dorsal laminoplasty (DL)) underwent dorsal surgery. Patients, regardless of strategy, demonstrated significant improvements in NDI, mJOA, and EQ-5D over a two year period post-operatively (P<0.001). DL had superior primary outcome SF-36 PCS (9.72) when compared with VF (5.2; P=0.04) and DF (4.53; P=0.05) (Figure 1). DL had a lower major complication rate (7% versus VF [15%] versus DF [20%]; P=0.04) (Figure 2). Monitoring was done in 84% of cases. Neurological monitoring did not affect the rate of major complications (monitoring [16%] versus no monitoring [16%]; P=.94). DF patients were delayed in returning to work compared with VF and DL P<0.003) although overall return to work was not different at 1 and 2 years (Figure 3).

Conclusion: Patients undergoing surgery for CSM demonstrate improved overall quality of life. Not all CSM patients are candidates for laminoplasty; however, dorsal laminoplasty (when selected by surgeon) for CSM is associated fewer complications and with greater improvements

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in health-related quality of life for 2 years after surgery.

Figure 1. SF-36 PCS score from baseline through 2 years follow-up. Dorsal laminoplasty shows sustained improvement at 2 years compared to ventral fusion and dorsal fusion.

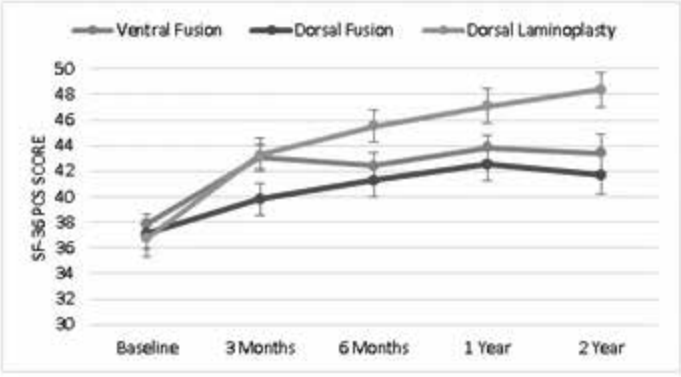

Figure 2. Rate of major complication in dorsal laminoplasty is significantly lower than in ventral fusion and dorsal fusion. Major complications included deep venous thrombosis (1 case), new post-operative deficit (2 cases), 30-day hospital readmission (6 cases), and other complications that did not resolve within 3 months including dysphagia (9 cases), infection (1 case), or C5 paresis (7 cases).

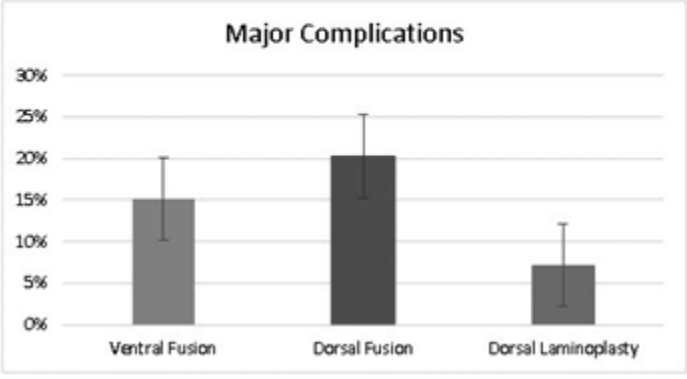

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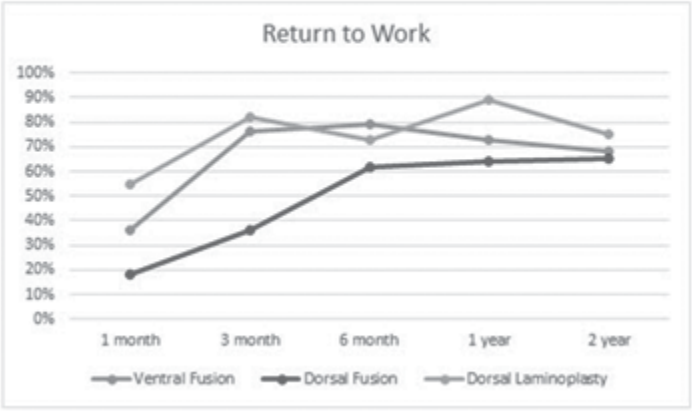
Figure 3. Return-to-work by surgical approach over 2 years. At baseline, 68/163 were working. At 3 months, return-to-work is worse for dorsal fusion patients (P=0.003).



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Presentation #3 ***Resident/Fellow Research Award***

Does Screw Length for Primary Two-level ACDF Influence Pseudarthrosis Risk?

Nathan Lee, MD, *Paul Park, MD, Jun Kim, MD, Venkat Boddapati, MD, Justin Mathew, MD, Meghana Vulapalli, BS, Louis Amorosa, MD, Zeeshan Sardar, MD, Ronald Lehman, MD, K. Daniel Riew, MD*

Introduction: Pseudarthrosis remains a major complication for patients undergoing ACDF (0%-15% at 1-year follow-up)[1]. Potential modifiable risk factors are known in literature, such as smoking and osteoporosis[2-5]. Biomechanical studies suggest that plates with locking screws can enhance the fixation rigidity to support bony fusion[6-8]. Although longer screws are known to be correlated with increased pull-out strength[9-11], deeper screw depths can increase the risk for intraoperative complications. An important factor that has yet to be studied is the minimum screw length relative to the diameter of the vertebral body necessary to achieve successful fusion. In this study, we hypothesize that screws with shorter depths relative to the vertebral body will increase the risk for radiographic pseudarthrosis and result in poor patient reported outcomes (PROs).

Materials and Methods: We reviewed a prospectively collected database (2015-2018) of adult (≥18 years-old) patients who underwent a primary two-level ACDF with or without corpectomy. All ACDF constructs involved fixed angle screws. The minimum follow-up period was 1 year. For each ACDF level, the screw length and vertebral body (VB) % (screw length divided by the anterior-posterior vertebral body diameter) were measured. Radiographic pseudarthrosis (interspinous motion (ISM) ≥1mm) was recorded at 6-weeks, 6-months, and 1-year for each patient (Figure 1). The positive and negative predictive values (PPV, NPV) for ISM ≥ 1mm were measured for different VB% thresholds. A VB% of <75% was found to have the highest PPV (93%) and NPV (70%) for radiographic pseudarthrosis. This threshold of <75% was then assessed in our bivariate and multivariate analyses. The neck disability index (NDI) was used to assess PROs up to 2-years after surgery.

Results: A total of 85 patients were included in this study. The mean age±standard deviation was 58.9±10.3 and 42.4% of patients were female. The mean follow-up was 21.6±8.3 months. By 1-year, overall fusion success was achieved in 92.9% of patients. The 1-year revision rate was 4.7%. Patients with any screw VB% <75% had substantially worse fusion success (64.3%) than those who did not (98.6%) at 1-year. The VB%<75% increased the risk for radiographic pseudarthrosis at every follow up period(Table A). In comparison to other time-points, patients with radiographic pseudarthrosis at 6-weeks had significantly worse NDI scores by 2-years (p=0.016). The independent risk factors for radiographic pseudarthrosis at 6-weeks included any screw VB%<75% (OR 77, p<0.001), prior/current smoker (OR 6.8, p=0.024), and corpectomy (OR 0.1, p=0.010)(Table B). Patients with ISM≥1 mm had a higher rate of revision surgery at 1-year (5.9% vs. 3.9%), but this was not statistically significant (p=0.656).

Conclusion: In primary two-level ACDF, early radiographic pseudarthrosis is significantly associated with poor PROs at 2-years. As an intraoperative guide, spine surgeons can use the screw VB% threshold of <75% to avoid unnecessarily short screws. This threshold can be

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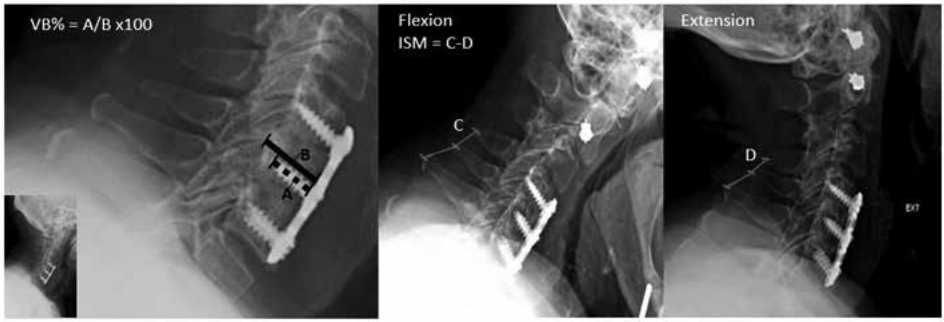
easily measured pre- and intra-operatively, and has been found to be strongly correlated to radiographic pseudarthrosis in the early postoperative period. To our knowledge, this is the first study to demonstrate that longer screws can support better fusion after ACDF surgery.



The Interspinous Motion (≥1mm) at Different Follow-up Periods by Screw Length (mm) and Vertebral Body %

		6 Week			6 Month			1 Year			Any		
		No	Yes	P-value	No	Yes	P-value	No	Yes	P-value	No	Yes	P-value
Top Screw	Length, Mean (Standard Deviation)	17.7 (2.4)	17.6 (2.4)	0.933	17.6 (2.3)	17.9 (2.8)	0.739	17.6 (2.4)	18.7 (2.4)	0.288	17.7 (2.4)	17.6 (2.4)	0.949
	Vertebral Body%	92.5 (7.5)	90.8 (12.0)	0.454	93.1 (8.7)	86.5 (11.1)	***0.019***	91.7 (9.6)	93.1 (7.5)	0.730	92.5 (7.5)	90.7 (11.8)	0.420
	Vertebral Body% < 75%	0.0	13.3	***0.011***	1.6	21.4	***0.003***	5.6	0.0	0.550	0.0	12.9	***0.023***
Middle Screw	Length, Mean (Standard Deviation)	16.7 (2.1)	16.7 (2.4)	1	16.8 (2.2)	16.6 (2.4)	0.763	16.8 (2.2)	16.0 (13.3)	0.404	16.7 (2.1)	16.7 (2.3)	0.964
	Vertebral Body%	87.1 (7.7)	82.1 (10.2)	***0.018***	86.9 (7.8)	77.4 (10.2)	***<0.001***	85.8 (8.7)	74.5 (7.1)	***0.003***	87.1 (7.7)	81.8 (10.1)	***0.012***
	Vertebral Body% < 75%	2.3	30	***<0.001***	5.0	50.0	***<0.001***	10.8	66.7	***0.004***	2.3	32.3	***<0.001***
Bottom Screw	Length, Mean (Standard Deviation)	17.4 (2.1)	17.7 (2.6)	0.579	17.5 (2.1)	17.6 (3.3)	0.833	17.4 (2.2)	18.6 (3.7)	0.283	17.4 (2.1)	17.8 (2.5)	0.477
	Vertebral Body%	92.7 (21.0)	86.3 (10.0)	0.106	92.4 (18.4)	81.1 (11.1)	***0.038***	91.2 (17.7)	77.2 (7.9)	***0.011***	92.7 (21.0)	86.5 (9.8)	0.112
	Vertebral Body% < 75%	0.0	23.1	***0.003***	0.0	46.2	***<0.001***	3.2	80.0	***<0.001***	0.0	22.2	***0.003***
	Any Screw Vertebral Body% <75%	1.9	37.5	***<0.001***	5.7	60.0	***<0.001***	11.3	83.3	***<0.001***	1.8	39.4	***<0.001***

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Step-Wise Multivariate Logistic Regression for Interspinous Motion (>1mm)					
	Independent Risk Factors	**Odds Ratio**	**95% Confidence Interval**		**P-value**
6-Week	Any Screw Vertebral Body% <75%	76.8	5.9	981	***<0.001***
	Smoker	6.8	1.3	45.4	***0.024***
	Corpectomy	0.1	0.02	0.58	***0.010***
	Osteoporosis	1.1	0.2	5.5	0.980
	BMP Use	0.4	0.09	1.7	0.210
6-Month	Any Screw Vertebral Body% <75%	24.9	5.6	111	***<0.001***
	Smoker	4.9	0.73	33.6	0.100
	Osteoporosis	2.7	0.4	18.2	0.310
	BMP Use	0.7	0.1	4.8	0.709
	Corpectomy	0.6	0.12	3.1	0.567
1-Year	Any Screw Vertebral Body% <75%	38	3.2	450	***0.004***
	Osteoporosis	5.7	0.4	88	0.214
	Corpectomy	1.4	0.13	15.6	0.780
Any-Time	Any Screw Vertebral Body% <75%	79	6.2	>999	***<0.001***
	Smoker	6.8	1.1	45.7	***0.049***
	Corpectomy	0.11	0.02	0.63	***0.014***
	Osteoporosis	1.1	0.19	5.5	0.982
	BMP Use	0.4	0.1	1.7	0.215

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Presentation #4 *Basic Science Award*

Characterization of Basal and Cytokine Stimulated Biomarker Profiles of Degenerative Cervical and Lumbar Fusion Explants ex-vivo

Don Moore, MD, *Jacob Kramer, BS, Naomi Lee, DVM, MS, Aaron Stoker, PhD, MS, Theodore Choma, MD, Muhammad Mirza, MD*

Introduction: Intervertebral disc (IVD) degeneration occurs from a combination of many biological and patient factors, including local and systemic inflammatory and degradative processes. This study was designed to investigate the differences in pro-inflammatory and pro-degradative metabolism observed IVD from lumbar and cervical specimens retrieved from patients undergoing fusion procedures.

Materials and Methods: With IRB approval (IRB#2010692) and informed patient consent, IVD excised during lumbar (n=35) or cervical (n=20) fusion (n=55) was obtained from patients (mean age 55.8, 38 females). Biopsy explants (6 mm) were created from nucleus pulposus and annulus fibrosus. Tissues were cultured for 3 days in either basal or cytokine stimulated (10 ng/mL IL-1ß) media, after which media were collected for biomarker evaluation. Media were tested for MMP-1, MMP-2, MMP-3, MMP-7, MMP-8, MMP-9, MMP-13, TIMP-1, TIMP-2, TIMP-3, TIMP-4, GRO-a, MCP-3, PDGF-AA, PDGF-AB/BB, IL-2, IL-4, IL-6, IL-8, MCP-1, MIP-1a, MIP-1ß, RANTES, TNF-a, and VEGF using commercially available assays according to the manufacturer's protocol. Significant differences between groups were determined by Mann-Whitney U-Test with significance set at P=0.05.

Results: Fig 1: Inflammatory Cytokines and ChemokinesIn basal media, lumbar explants produced significantly greater levels of GRO-a, MCP-3, IL-6, IL-8, MIP-1a, MIP-1ß, RANTES, TNF-a and significantly reduced levels of IL-2 compared to cervical explants. After cytokine stimulation, lumbar explants produced significantly greater levels of RANTES and significantly reduced levels of IL-2 compared to cervical explants. Cytokine stimulation significantly increased production of GRO-a, MCP-3, IL-2, IL-6, IL-8, MIP-1a, MIP-1ß, and TNF-a by both lumbar and cervical explants, and IL-4 by lumbar explants.Fig 2: Degradative Enzymes and InhibitorsIn basal media, lumbar explants produced significantly greater levels of MMP-1, MMP-8, MMP-9, and significantly reduced levels of MMP-7 and TIMP-3 compared to cervical explants. After cytokine stimulation, lumbar explants produced significantly greater levels of MMP-8 and MMP-9 compared to cervical explants. Cytokine stimulation significantly increased production of MMP-1 and MMP-3 by both lumbar and cervical explants. Further, lumbar explants significantly increased MMP-13 and decreased TIMP-2 production with cytokine simulation.

Conclusion: Lumbar discs produced a generally higher pro-inflammatory phenotype compared to cervical discs. In general, cytokine stimulation caused similar significant increases in biomarker production in both cervical and lumbar tissues, indicating tissues from both sites are still responsive to stimulation, and there are conserved responses between regions. However, there were differential effects with inflammatory stimulation between sites, indicating there may be unique inflammatory responses by cervical and lumbar tissues. While cervical and lumbar explants each produced degradative enzymes and their inhibitors in both basal

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and cytokine stimulated conditions, their differential production may indicate unique matrix metabolism regulation in each region that is modulated by further inflammatory signaling. Further study is required to determine the factors driving these differences in cervical and lumbar IVD pathophysiology, and how these differences relate to the development of the disease at these specific sites. If these mechanisms can be identified, it is possible that novel site-specific treatment modalities could be developed for the treatment of lumbar and cervical IVD degeneration.

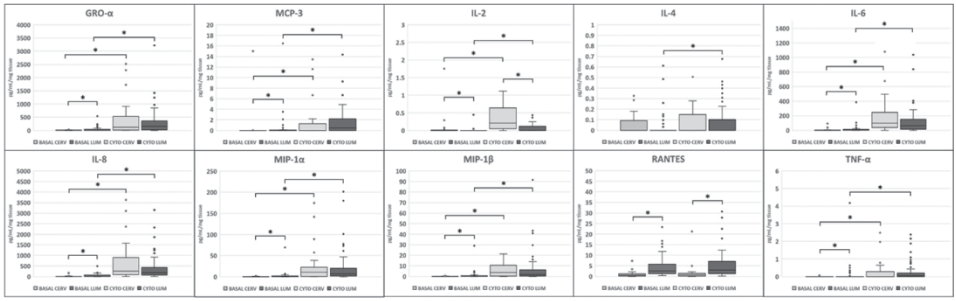

Figure 1: **Graphs depicting values for inflammatory cytokines and chemokines in basal and cytokine stimulated explants harvested from cervical and lumbar fusion procedures**

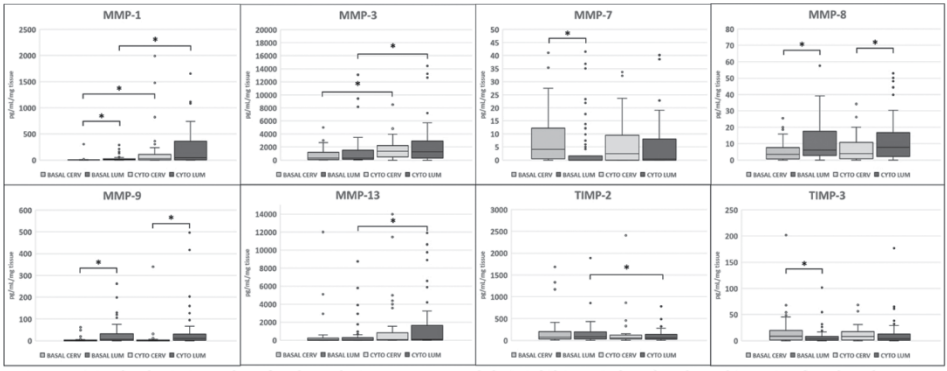

Figure 2: **Graphs depicting values for degradative enzymes and their inhibitors in basal and cytokine stimulated explants harvested from cervical and lumbar fusion procedures**

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Presentation #5 ***Clinical Research Award***

Cervical disc arthroplasty versus anterior cervical discectomy and fusion: 10-year outcomes of a prospective, randomized clinical trial at three sites.

Pierce Nunley, MD, *Michael Hisey, MD, Micah Smith, MD, Marcus Stone, PhD*

Introduction: Short- and mid-term studies have shown the safety and effectiveness of cervical disc arthroplasty (CDA) to treat cervical disc degeneration. The purpose of this study is to assess the 10-year safety and effectiveness of cervical disc arthroplasty (CDA) compared to anterior cervical discectomy and fusion (ACDF).

Materials and Methods: This was a multicenter, prospective, randomized study of patients treated with CDA or ACDF at one- or two contiguous levels. The primary inclusion criteria were cervical degenerative disc at one or two contiguous levels and no prior cervical operations. Following completion of the 7-year FDA post approval study, follow-up continued at 10 years for consenting patients from three high-enrolling centers. Outcomes included NDI, VAS neck and arm pain, SF12, patient satisfaction, secondary surgical procedures (removals, revisions, reoperations, or additional fixation) and adverse events. Radiographic adjacent segment pathology (rASP) was defined with the Kellgren-Lawrence scale. Independent radiologists conducted all radiographic evaluations. From the original enrollment of 155 patients (105 CDA; 50 ACDF), 10-year follow-up was obtained from 106 patients. The longest follow-up was 13.1 years. There were no significant differences in preoperative characteristics between these patients and the original FDA cohort.

Conclusion: Ten years after surgery, CDA has significantly lower rates of subsequent surgery and minimal progression of rASP from 7 years. Our results through 10 years demonstrate that CDA continues to be a safe and effective surgical alternative to fusion. The significantly lower risk of subsequent surgery after CDA greatly reduces the overall burden to the patient and health care system.

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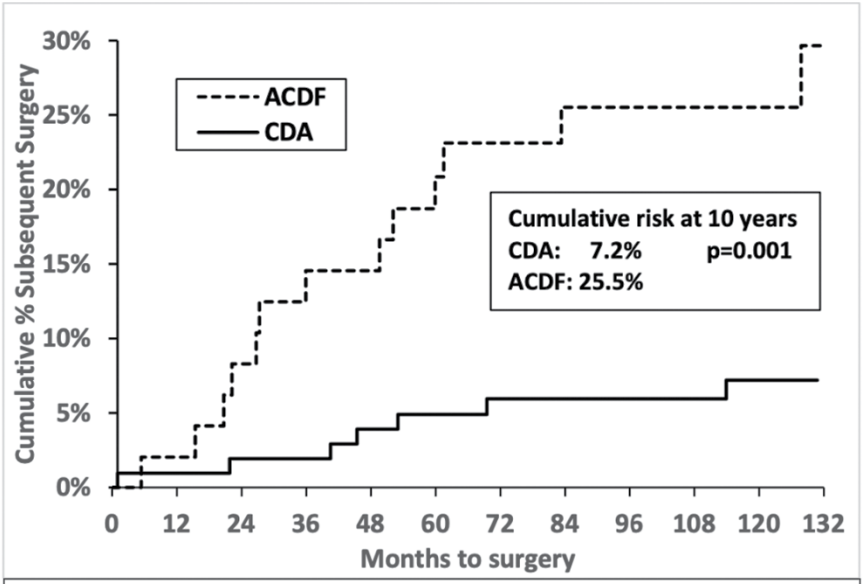

Patients at risk												
CDA	105	102	100	100	97	94	90	82	75	75	50	-
ACDF	50	47	44	41	41	37	34	24	20	20	20	12

Figure 1. Cumulative risk of subsequent surgery after CDA and ACDF.

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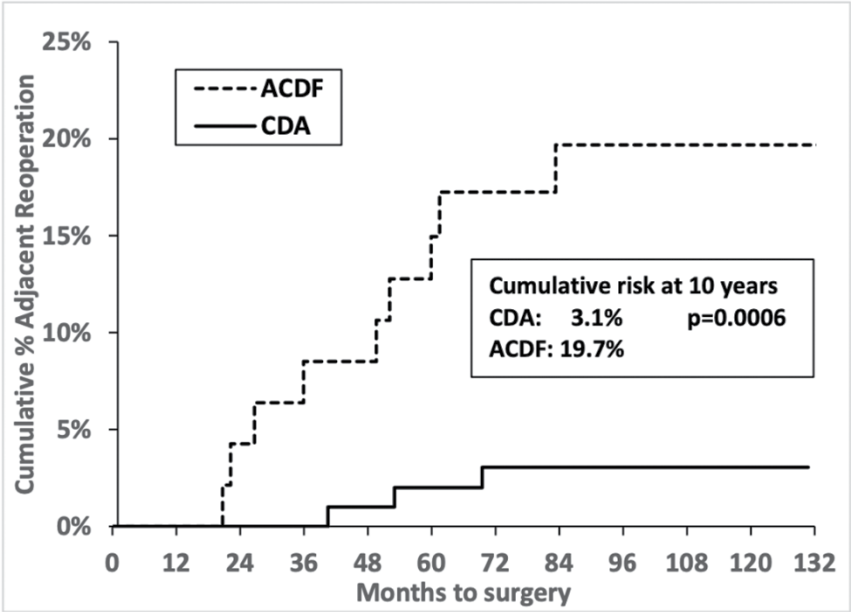

Patients at risk												
CDA	105	103	101	101	99	96	92	84	77	77	51	-
ACDF	50	47	45	43	43	39	36	26	22	22	22	15

Figure 2. Cumulative risk of adjacent level subsequent surgery after CDA and ACDF.

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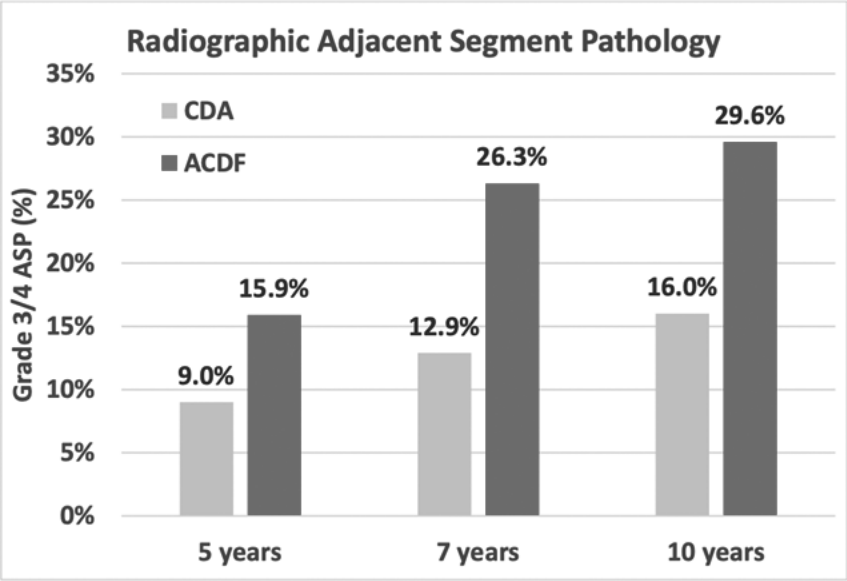

Figure 3. Progression of grade 3/4 adjacent segment pathology in CDA vs. ACDF at 3 centers (CDA vs. ACDF at 10 years; p=0.058).

Presentation #6

Impact of Pre-operative Kyphosis on Outcomes of Cervical Disc Replacement

Avani Vaishnav, MBBS, *Chirag Chaudhary, MBBS, Hikari Urakawa, MD, Kosuke Sato, MD, Ryan Lee, MBA, Jung Kee Mok, BS, Darren Chen, BS, Sravisht Iyer, MD, Steven McAnany, MD, Todd Albert, MD, Sheeraz Qureshi, MD, MBA*

Introduction: Cervical disc replacement (CDR) is a commonly used surgical technique for degenerative pathology. Although CDR has demonstrated efficacy in relieving symptoms while preserving range of motion, there is concern regarding the use of this technique in patients with pre-operative kyphosis due to the risk of worsening of kyphosis post-operatively, and its impact on clinical outcomes. Thus, the purpose of this study was to evaluate the impact of pre-operative kyphosis on clinical and radiographic outcomes following CDR.

Materials and Methods: A retrospectively review of prospectively collected data of 40 who underwent CDR for degenerative conditions was performed. Patient-reported outcome measures(PROMs) including NDI, VAS arm & neck pain, SF12 physical (PHS) and mental health(MHS), and PROMIS physical function were collected pre-operatively and at follow-up. Radiographic measurements (segmental cobb angle, C2-C7 cobb angle, cervical SVA, cranial tilt and T1 slope) were measured at each timepoint.Patients were divided into two groups (Kyphosis and No Kyphosis) based on the presence of segmental or regional kyphosis pre-operatively. Groups were compared using Chi-square or Fisher's exact test for categorical variables, and Independent Samples t-test or Mann-Whitney u-test for continuous variables. Change in PROMs within each group was evaluated using paired samples t-test or Wilcoxon Signed-Ranks Test. Change over time between groups was compared using mixed ANOVA.

Results: Of the 40 patients included, 14 (35%) did not have kyphosis and 26 (65%) had kyphosis – segmental, regional (C2-C7), or both (Table 1). There were no significant differences in demographics (age, gender, BMI, Charlson Comorbidity Index and ASA; $p>0.0.5$), number of levels ($p=0.316$) or level of surgery ($p=0.646$).A significant difference was seen in the segmental cobb angle, C2-C7 cobb angle and T1 slope at all time-points ($p<0.05$), with the No Kyphosis cohort having greater lordosis and a greater T1 slope. Both cohorts showed a statistically significant improvement in segmental lordosis from pre-operatively to each follow-up, with no difference between groups in the amount of change. The segmental cobb angle in the Kyphosis cohort improved from a kyphotic angle pre-operatively (2.76+4.63 degrees) to a lordotic angle post-operatively (-3.45+6.26 degrees), which was maintained up to 12 weeks (-4.58+5.10). There no other differences in radiographic parameters. (Fig.1)There were no significant difference in pre- or post-operative PROMs, or change in PROMs between the two groups ($p>0.05$), and both groups showed statistically significant improvements in VAS arm and neck during the early follow-up, which were maintained till 3 months ($p<0.05$), and both groups showed improvement in SF12-MHS at 3 months ($p<0.05$). The Kyphosis group also demonstrated significant improvements in NDI, SF12-PHS and PROMIS. (Fig.2)

Conclusion: The results of our study suggest that CDR resulted in an improvement in the segmental cobb angle and was able to provide lordosis even in those patients who were kyphotic pre-operatively, although this did not impact the C2-C7 cobb angle or other radiographic param-

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eters. In addition, patients with kyphosis had equivalent improvements in PROMs compared to their non-kyphotic counterparts. Thus, our results suggest that CDR results in favorable clinical and radiographic outcomes even in patients with pre-operative kyphosis.

Table 1: Number of patients with kyphosis

No Kyphosis	14 (35%)
Segmental Kyphosis, No Cervical Kyphosis	7 (17.5%)
Cervical Kyphosis, No Segmental Kyphosis	4 (10%)
Segmental and Cervical Kyphosis	15 (37.5%)

Figure 1. Radiographic Outcomes

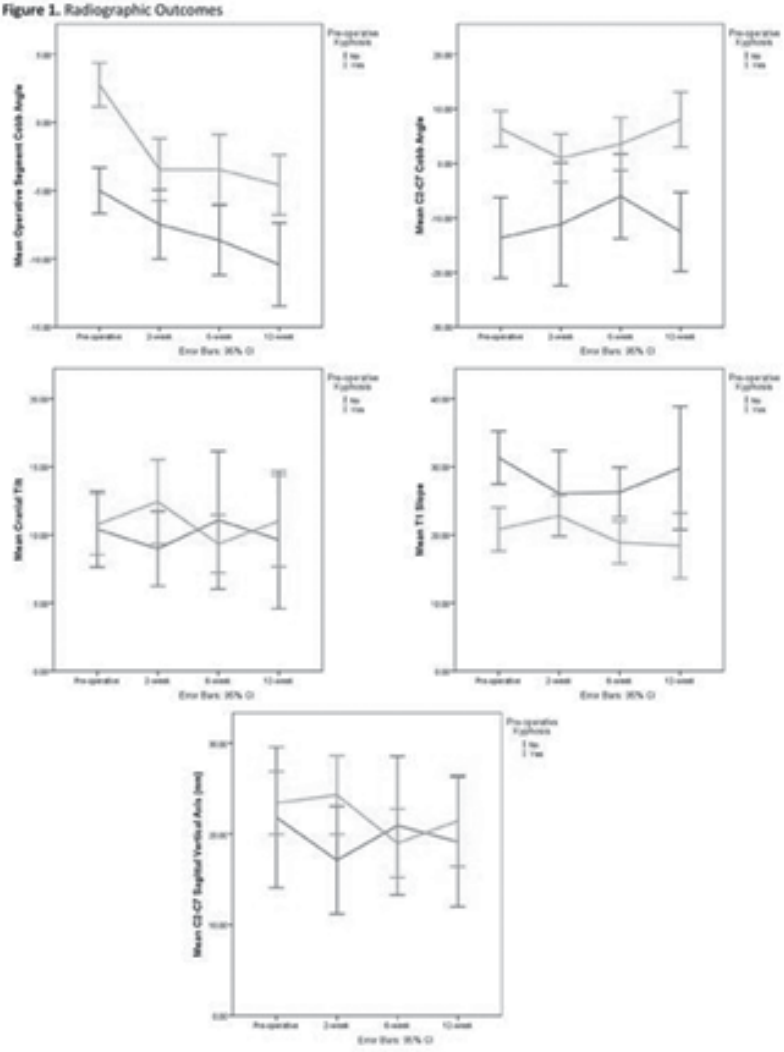

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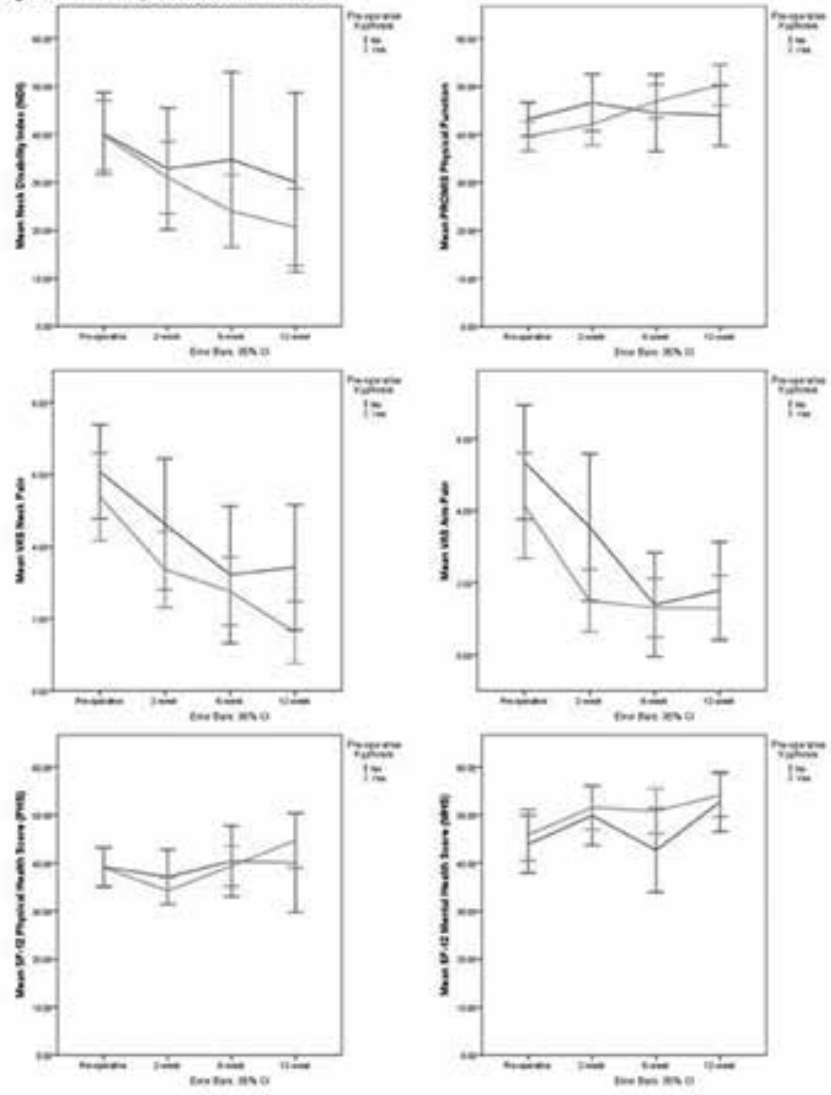
Figure 2. Patient Reported Outcome Measures



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Presentation #7

Comparing Outcomes and Mortality of Upper Cervical and Subaxial Cervical Spine Trauma in Elderly Patients

Catherine Carlile, MD, *Andrew Rees, BS, Jacob Schultz, BS, Byron Stephens, MD*

Introduction: In contrast to younger patients, the elderly are more likely to sustain severe cervical spine trauma from relatively low-energy mechanisms. The presence of preexisting pathology such as osteoporosis, cervical stenosis, ankylosis, and degenerative changes can predispose elderly patients to fractures and neurologic injury in both the upper and subaxial cervical spine. To date, there has been little research comparing outcomes and mortality rates of patients with upper cervical (occiput-C2) versus subaxial (C3-C7) injuries. Given this paucity of data on this subject, we sought to compare mortality rates and outcomes between elderly patients with upper cervical and subaxial cervical spine injuries.

Materials and Methods: All elderly trauma patients (65+) with cervical spine injuries who presented to a single, high-volume, level I trauma center between 2010-2019 were identified via an institutional trauma database. Retrospective chart review was performed to assess treatment rendered, complication, and outcome measures and then stored in a deidentified database. Imaging characteristics of patients including psoas index (a marker for sarcopenia) and L3 Hounsfield Unit (an indicator of osteoporosis) were calculated using standard technique and recorded into the database. Patients were sorted into upper cervical (occipital condyle, C1, and C2 vertebral fractures and ligamentous injuries) and subaxial (C3-7) cohorts and by treatment (operative vs non-operative management). Surgical and medical morbidity variables recorded include surgical site infection, pneumonia, STEMI, DVT/PE and stroke. Pearson's Chi-squared tests were used to compare rates of mortality and complications.

Results: A total of 922 patients were identified, with 545 upper cervical (59%), and 377 subaxial (41%) trauma patients. Patients with upper cervical spine trauma were significantly older (P<.001), more sarcopenic (P=.002), osteoporotic (P=.002), and had higher rates of dementia (P=.003). There was no significant difference in cardiac or pulmonary comorbidities between the two groups (P=.7). Patients with subaxial injuries had a higher injury burden, with significantly higher Injury Severity Scale (ISS) scores (P=.008), non-continguous spine injuries (P=.016), closed head injury (P=.04), and pelvic fractures (P=.04). Comparing operative cohorts, there was a higher proportion of medical and surgical complications in the upper cervical group (P=.006), and specifically higher incidence of pneumonia (P=.009). There was also found to be higher overall mortality in all upper cervical injuries both operative and nonoperatively managed as compared to the subaxial cohort (P=.015). There was no significant difference in in-hospital mortality (P=.25).

Conclusion: Although patients with subaxial injuries were found to be more severely traumatized with higher energy mechanisms and more severe associated injuries, our data demonstrates that patients with upper cervical trauma are at higher risk for medical and surgical complication and mortality, regardless of need for operative intervention. This is likely secondary to poor reserve given their older age, advanced sarcopenia, and increased morbidity associated with

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both operative management and nonoperative immobilization of patients with upper cervical trauma. In conclusion, we have demonstrated in the largest study to date that patients with upper cervical injuries, although less severely traumatized, should be more critically evaluated given their increased risk for morbidity and mortality, especially during discussions with the patient and family about expected outcomes.

Table 1. Subaxial Spine Trauma Patient Characteristics

	Atlantoaxial Trauma (n=545)	Subaxial Trauma (n=377)		
	n (%), X̄ ± SD	*n (%), X̄ ± SD*	*P-Value*	
Demographics				
Age	79.2 ± 8.5	75.5 ± 8.0	<0.001b	***
Sex (Male)	253 (46.4%)	233 (61.8%)	<0.001a	***
BMI	26.9 ± 6.3	26.9 ± 5.5	0.937b	
Psoas Index	0.082 ± 0.027	0.092 ± 0.032	0.032b	*
L3 Vertebral Body HU	113.4 ± 56.1	130.6 ± 127.0	0.020b	*
Comorbidities				
Pulmonary Disease	89 (16.3%)	58 (15.4%)	0.700a	
Cardiac Disease	174 (31.9%)	108 (28.6%)	0.288a	
Dementia	91 (16.7%)	37 (9.8%)	0.002a	*
Alcohol Use Disorder	18 (3.3%)	13 (3.4%)	0.904a	
Bleeding Disorder	16 (2.9%)	3 (0.8%)	0.025a	*
Anemia	9 (1.7%)	9 (2.4%)	0.427a	
On Anticoagulation	73 (13.4%)	55 (14.6%)	0.606a	
Injury Severity				
ISS	16.9 ± 10.5	18.8 ± 10.5	0.007b	*
MFI	1.6 ± 1.1	1.4 ± 1.1	0.119b	
Noncontiguous Spine Fractures	158 (29.0%)	138 (36.6%)	0.016a	*
Closed Head Injury	105 (19.3%)	94 (24.9%)	0.040a	*
Appendicular Fracture	149 (27.3%)	119 (31.6%)	0.176a	
Pelvic Fracture	41 (7.5%)	43 (11.4%)	0.042a	*
Hypotension on Admission	31 (5.7%)	24 (6.4%)	0.669a	
Presenting Laboratory Values				
WBC	13.0 ± 6.5	13.4 ± 6.1	0.319b	
HCT	37.2 ± 5.4	37.1 ± 5.6	0.798b	
Platelets	219.1 ± 72.6	207.2 ± 79.3	0.02b	*
Lactate	2.4 ± 2.0	2.7 ± 2.2	0.376b	
Operation Performed	62 (11.4%)	120 (31.8%)	<0.001a	***
Length of Hospital Stay (Days)	6.2 ± 5.7	7.8 ± 7.6	<0.001b	***
Mortality and Morbidity				
Pneumonia	29 (5.4%)	20 (5.3%)	0.991a	
NSTEMI	11 (2.0%)	6 (1.6%)	0.636a	
DVT/PE	4 (0.7%)	4 (1.1%)	0.599a	
Stroke	4 (0.7%)	1 (0.3%)	0.341a	
Other Hospital-Acquired Infection	22 (4.0%)	16 (4.2%)	0.876a	
In-Hospital Mortality	61 (11.2%)	33 (8.8%)	0.229a	
Overall Mortality	233 (42.8%)	131 (3.5%)	0.015a	*

*,p<0.05; ***,p<0.001; aPearson Test; bt-test

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Presentation #8

Perioperative Outcomes of Concomitant Shoulder Diagnoses for Patients Undergoing Cervical Spine Procedures

Peter Passias, MD, Waleed Ahmad, MS, Sara Naessig, BS, Katherine Pierce, BS, Frank Segreto, BS, ***Shaleen Vira, MD,*** *Bassel Diebo, MD*

Introduction: For patients undergoing a cervical spine procedure, the effect of a shoulder injury on perioperative outcomes is not well understood. Our study aimed to investigate the impact shoulder injuries have on perioperative outcomes for elective cervical spine surgery patients.

Materials and Methods: Patients undergoing elective cervical spine surgery were isolated with ICD-9 diagnosis codes. Cervical procedure(CP) patients with concurrent shoulder diagnosis(S-Dx) were further isolated. Means comparison tests compared differences in demographics, surgical, and perioperative outcomes between those who had a cervical procedure and a concurrent shoulder diagnosis(CP/S-Dx) and those who had a cervical procedure with no shoulder diagnosis(CP). Logistic regression analysis assessed the odds of complication associated with a shoulder diagnosis, controlling for age and surgical invasiveness.

Results: 1,482,311 elective cervical spine surgery patients were included. Overall, 17,873(1.2%) patients underwent a CP and had a concurrent S-Dx. CP and S-Dx patients compared to only CP patients were significantly younger and male(both $p<0.05$). CP/ S-Dx patients presented with higher rates of alcohol abuse, anemia, rheumatoid arthritis, congestive heart failure, chronic pulmonary disease, drug abuse, hypertension, and liver disease (all $p<0.05$). CP/S-Dx patients underwent more invasive procedures ($p<0.001$) including spinal fusions and osteotomies (both $p<0.05$) but less decompressions ($p<0.001$). CP/S-Dx patients had higher overall perioperative complication rates, including higher rates of anemia, cardiac, respiratory, DVT and experienced a longer LOS(5.97 days vs. 3.71 days) (all $p<0.05$). CP/S-Dx patients had higher rates of non-home discharge(36.7% vs. 25.8%) and incurred greater total hospital charges($101,899 vs. $73,572; both $p<0.001$). Adjusting for age and invasiveness, patients undergoing a cervical procedure with a shoulder diagnosis were associated with increased odds of any complication(OR:1.3[1.3-1.4]; $p<0.001$).

Conclusion: Patients with a concurrent shoulder diagnosis undergoing a cervical spine procedure were 30% more likely to experience a perioperative complication compared to those without a shoulder injury. Prior to proceeding with surgery, providers should consider the effect of shoulder injuries on outcomes of cervical spine procedures.

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Presentation #9 ***Basic Science Award***

Efficacy of clinical hiPSC-OPC-enriched NS/PCs for transplantation in the subacute phase of spinal cord injury

Yasuhiro Kamata, MD, *Miho Isoda, Ms, Shuhei Ito, PhD, Morio Matsumoto, MD, Hideyuki Okano, MD, Masaya Nakamura, MD, Jun Kohyama, PhD, Narihito Nagoshi, MD*

Introduction: Spinal cord injury (SCI) is a devastating event with sudden onset of motor and sensory dysfunction [1]. One of the main pathology in SCI is demyelination of neuronal axons, thus remyelination of host axons by grafting oligodendrocyte progenitor cells (OPCs) is considered an effective strategy to restore function[2]. Indeed, several studies have reported enhancement of remyelination by transplanting human induced pluripotent stem cell-derived OPC-enriched neural stem/progenitor cells (hiPSCs-OPC-enriched NS/PCs) [3, 4, 5, 6], but it is unrealistic to use conventional procedure to induce the cells in actual clinical setting because they are cultured on feeder condition which contains animal derivatives. Recently, we have established and optimized a robust protocol to produce OPC-enriched NS/PCs from feeder-free hiPSCs (ffhiPSCs). Therefore, the aim of the present study is to investigate the efficacy and safety of the NS/PCs when transplanted in a rodent model of SCI.

Materials and Methods: ffhiPSC-OPC-enriched NS/PCs were generated from clinically-relevant feeder-free iPSCs provided by the Center for iPS Cell Research and Application (CiRA) at Kyoto University [7, 8]. First, single cell RNA-sequencing of ffhiPSC-OPC-enriched NS/PCs were performed. Second, contusive SCI was induced at the Th10 level in NOD-SCID mice, and the ffhiPSC-OPC-enriched NS/PCs were transplanted into the lesion epicenter 9 days after the injury. An equal volume of phosphate buffered saline was injected for the control groups. Motor function of injured mice was assessed by the Basso Mouse Scale score, Rota-rod test, DigiGait analysis and kinematics. Histological analyses were performed to examine the survival and differentiation of the grafted cells.

Results: Single cell RNA-sequencing revealed a definitive transcriptome signature of ffhiPSC-OPC-enriched NS/PCs that was distinguished by the expression of several transcription factors related to oligogenesis. Histological analyses in vivo revealed that the transplanted cells well survived and migrated far into the host spinal cord without any tumor formation. The transplanted cells differentiated into three neural lineages including neurons, astrocytes and oligodendrocytes. In particular, the differentiation rate of oligodendrocyte was 36.6±2.8% (fig1). The active remyelination on damaged axon in injured spinal cord was observed in the transplanted group by immunoelectron microscopy (fig2). Importantly, hindlimb motor function was significantly improved in the transplanted group one week following transplantation and thereafter (fig3). Both Digigait and rotarod tests revealed a significant motor functional improvement in the transplanted group at 12 weeks after transplantation. In addition, kinematic indicated that the transplantation group had a smoother step and a more consistent step cycle than the control group.

Conclusion: We established an efficient protocol to generate OPC-enriched NS/PCs from feeder-free iPSCs despite harsh environment under xeno-free condition. Notably, the transplanted cells contributed to the improvement of motor function with robust remyelination for the demyelinated

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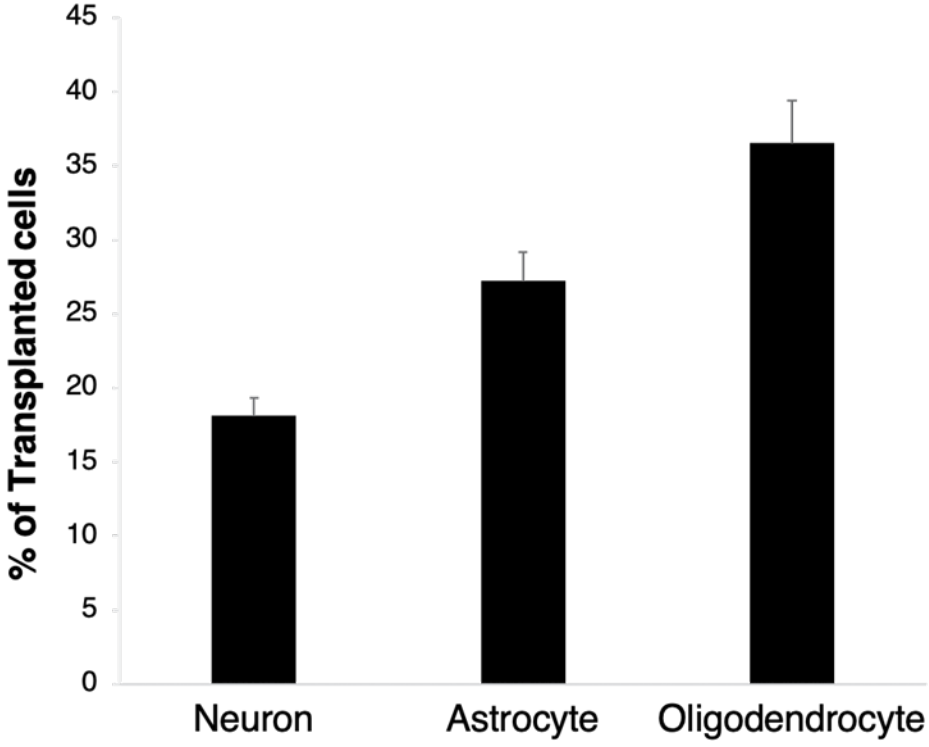
axon. Based on these favorable results, we have proceeded to the next step for the preparation of clinical trial using the OPC-enriched NS/PCs.



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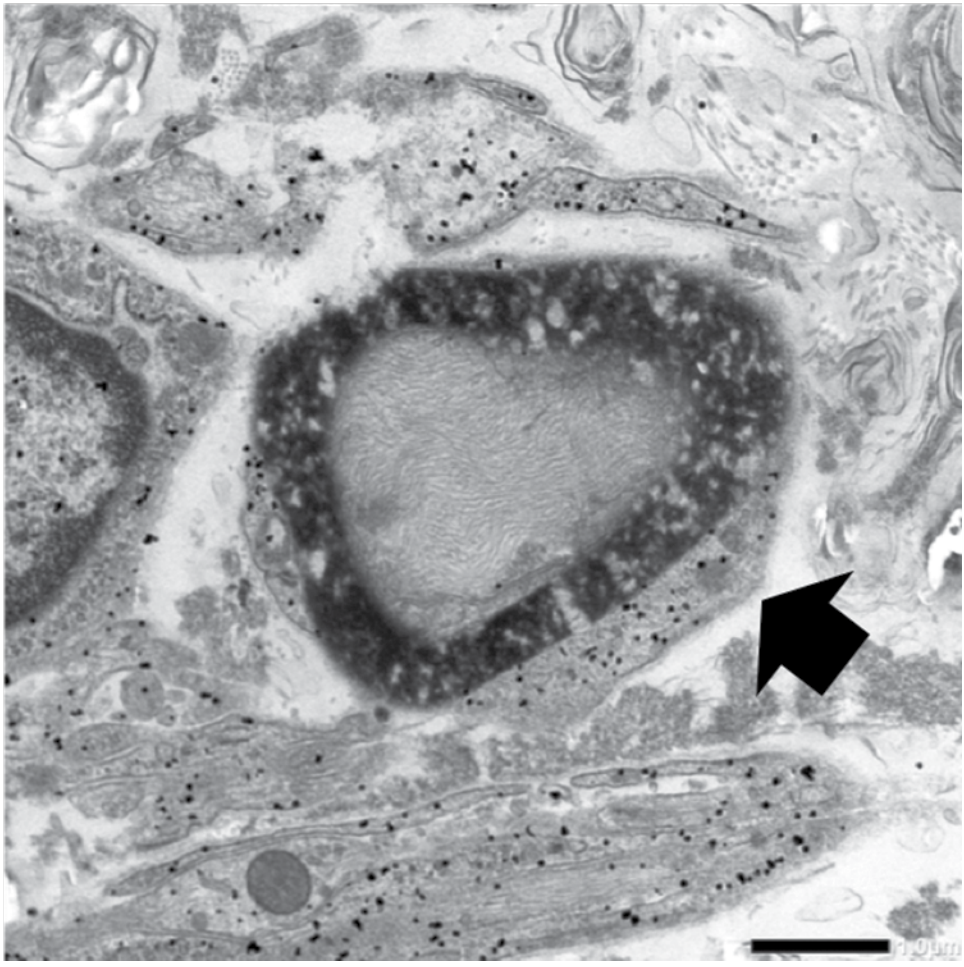

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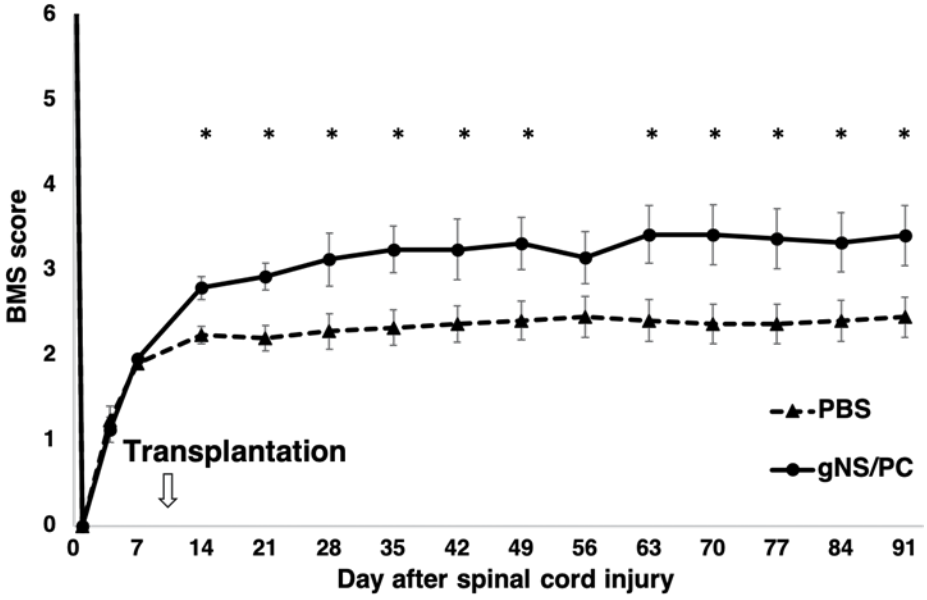

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Presentation #10

Is it Safe to Stop at C7 During Multi-Level Posterior Cervical Decompression and Fusion? - Multi-Center analysis

Eeric Truumees, MD, *Devender Singh, PhD, William Lavelle, MD, Ron Riesenburger, MD, Matthew Geck, MD, Swamy Kurra, MD, Anthony Yu, MS, Daniel Grits, BS, Robert Winkelman, BS, Thomas Mroz, MD, John Stokes, MD*

Introduction: Extension of long posterior cervical fusions into the thoracic spine has been recommended to decrease the risk of kyphosis and spondylolisthesis at the cervico-thoracic junction. In recent years, several studies have addressed this question with conflicting results. We hypothesized that extension of posterior cervical fusions into the upper thoracic spine improved clinical outcomes while decreasing kyphosis.

Materials and Methods: Analysis of multicenter radiographic and clinical databases of patients that had undergone a three or more-level posterior cervical fusion for degenerative disease from January 2013 to May 2015, with at least two years of post-operative (post-op) data. Patients were divided into three groups: Group I (fusion terminating at C6), Group II (fusion terminating at C7), Group III (fusion extending into the thoracic spine). All radiographic measurements were performed by an independent, experienced clinical researcher.

Results: 264 patient cases were reviewed and sorted into the three outlined groups, Group 1 (n=80), Group II (n=88) and Group III (n=96). Demographically, mean age, percentage of non-smokers and anterior support were greater in Group III than in Groups I and II ($p<0.05$). The number of spinal levels treated ranged from a minimum of three in all groups, to four (Group I), five (Group II) and ten (Group III). Mean estimated blood loss (EBL), operative time (OR) and length of hospital stay (LOS) were significantly higher in Group III ($p<0.05$). Mean cervical lordosis at two years post-op improved in all groups (12.0° vs. 12.8° vs. 14.1°); however, there was no significant statistical difference in change for mean cervical lordosis (2 wk vs. 2 year post-op) between the three groups. Similary, there were no significant statistical differences in change for mean C2-C7 sagittal plumbline and T1 slope (2 wk vs. 2 year post-op) between the three groups($p>0.05$). Rate of revision was not clinically or statistically significantly different ($p>0.05$) between Group I (8.8%), Group II (7.95%) and Group III (9.4%). The majority of the revision surgeries occurred between two to five years post-operative. Groups I and II had greater number of subjacent degenration/spondylolisthesis compared to Group III (3.8% vs. 3.4% vs. 1.2%). There were significant improvements in mean clinical outcomes (i.e. visual analog scale [VAS] and oswestry disability index [ODI]) at two years post-operative in the three groups, but there were no statistically significant differences between the groups ($p>0.05$). All groups had similar post-op rate of return to work status (group I vs. group II vs. group III: 11.4 % vs. 14.7% vs. 12.5%).

Conclusion: All groups had similar clinical and radiographic outcomes and comparable revision rates. Higher EBL, OR and LOS in group III suggest that, absent focal C7-T1 pathology, extension of posterior cervical fusions into the thoracic spine may not be necessary. Extension of posterior cervical fusions into the thoracic spine may be recommended for higher risk patients with limitations to strong C7 bone anchorage. In others, it is safe to stop at C7.

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Presentation #11 ***Resident/Fellow Research Award***
Publicly Available Online Resources for ACDF are not Easily Read or Understood by the Average Patient

Christopher Lindsay, MD, *Mary Skalitzky, BA, Alan Shamrock, MD, Burke Gao, MD, Trevor Gulbrandsen, MD, Joshua Eisenberg, MD, Andrew Pugely, MD*

Introduction: Patients frequently use internet resources to learn about surgical procedures and to familiarize themselves with details of surgery and post-operative protocols before the procedure. Anterior cervical discectomy and fusion (ACDF) is a common short stay spine procedure that patients are likely to research online. In order to be fully understood by the average English-speaking adult, online health information must be written at an elementary school reading level (below 6th grade). To be helpful to patients, educational resources should also be generally understandable to patients and have actionable direction that positively affects their healthcare interactions. There are several previously validated indices for reading level of written materials [1-3]. In addition, the Patient Education Materials Assessment Tool (PEMAT) provides a reliable and validated method to measure the understandability and actionability of online patient education materials [4-6]. The goals of this study were to objectively define the reading level of publicly available online resources for ACDF, as well as the understandability and actionability of these resources to understand whether they are providing patients with useful perioperative information.

Materials and Methods: Online patient education materials were identified using two independently conducted Google searches with the term “anterior cervical discectomy and fusion”. Using the top 50 search results, articles were included if they specifically served to educate patients regarding ACDF. Exclusion criteria included news articles, non-text material (video), research manuscripts, industry websites, and articles not related to ACDF. The readability of included articles was quantified using a total of five objective algorithms: Flesch-Kincaid Reading Ease, Flesch-Kincaid Grade Level (FKGL), Gunning-Fog Index (GFI) Simple Measure of Gobbledygook index (SMOG), Coleman-Liau Index (CLI), and Automated Readability Index (ARI). The PEMAT form for printed materials was used to assess actionability and understandability using a 0-100% scale. A PEMAT-P score of 70% or below is considered poorly understandable or poorly actionable. Spearman’s correlation coefficient was utilized to examine the relationship between a website’s appearance on Google (from first to last) and its readability, understandability, and actionability. P-values of less than 0.05 were considered significant.

Results: Of 52 identified studies, 30 websites met inclusion criteria. The mean FKGL, GFI, SMOG, CLI, and ARI, which represent reading grade levels were 11.1±2.5, 14.1±2.7, 10.7±2.0, 13.1±1.3, 11.2±3.0, respectively (Figure 1). The mean understandability and actionability scores were 62.5±13.2% and 31.2±23.2%, respectively. Only 9 (30%) and 3 (6.67%) education materials met the understandability and actionability PEMAT threshold (Figure 2). Readability scores ($p=0.29$), overall understandability ($p=0.24$), and overall actionability ($p=0.43$) were not associated with Google search rank.

Conclusion: In this objective study of online resources for ACDF, every website studied was

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written at a level higher than the nationally recommended 6th grade reading level. In addition, materials scored poorly in regard to understandability, and actionability. Overall, these data suggest that none of the publicly available information is adequate to inform the average patient regarding ACDF. This is important to understand for providers so that patients are educated appropriately in clinic relative to their individual level of education and health literacy.

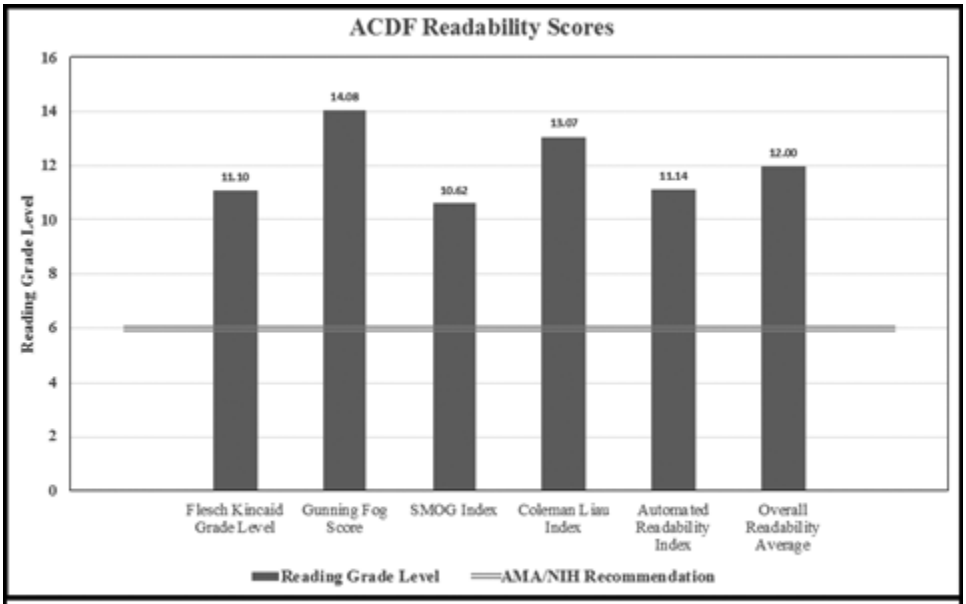

Figure 1: Mean Readability scores. The American Medical Association (AMA) and National Institutes of Health (NIH) recommend health information to be written at a 6th grade or lower reading level (orange line). All mean readability scores exceed this recommended reading level.

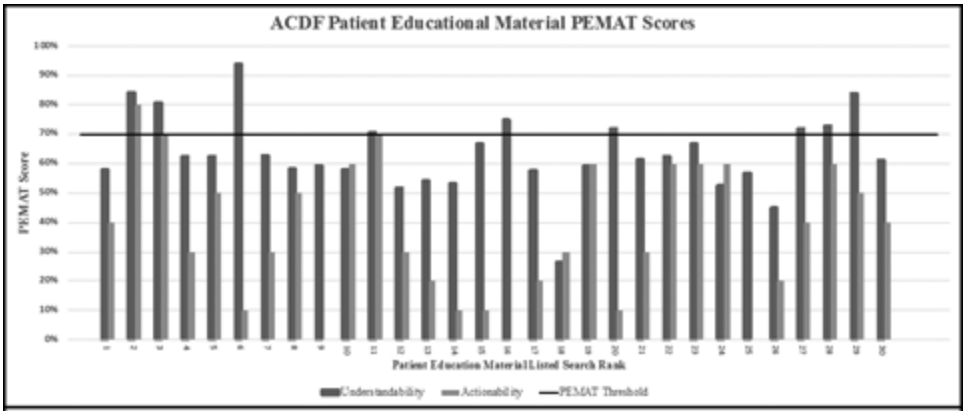

Figure 2: PEMAT scores. Previous literature reports that a PEMAT score of 70% or below is considered poorly understandable or actionable. Of the evaluated patient educational resources, 30% were above Understandability threshold, and 6.67% were above Actionability threshold.

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Presentation #12 ***Basic Science Award***

Expression analysis of susceptibility genes for ossification of the posterior longitudinal ligament

Shuji Watanabe, MD, PhD, *Hideaki Nakajima, MD, PhD, Kazuya Honjoh, MD, PhD, Ai Takahashi, MD, PhD, Arisa Kubota, MD, Akihiko Matsumine, MD, PhD*

Introduction: Ossification of the posterior longitudinal ligament (OPLL) is a hyperostotic condition of the spine that can cause progressive spinal cord dysfunction. Ossifying extension in patients with OPLL may be influenced by multiple etiologies that are largely unknown, but genetic factors are important in the pathophysiology. The purpose of our experimentation is to analyze the expression of susceptibility genes and ossification-related transcription factors in OPLL using human vertebral ligament ossification samples and ttw/ttw mouse (Enpp1 gene mutant mouse commonly used as a model mouse for ligament ossification) cervical vertebrae. We report detailed changes in gene expression sites, changes over time, changes in ossification morphology, and effects of mechanical tensile strain.

Materials and Methods: Ossification of the posterior longitudinal ligament (OPLL) is a hyperostotic condition of the spine that can cause progressive spinal cord dysfunction. Ossifying extension in patients with OPLL may be influenced by multiple etiologies that are largely unknown, but genetic factors are important in the pathophysiology. The purpose of our experimentation is to analyze the expression of susceptibility genes and ossification-related transcription factors in OPLL using human vertebral ligament ossification samples and ttw/ttw mouse (Enpp1 gene mutant mouse commonly used as a model mouse for ligament ossification) cervical vertebrae. We report detailed changes in gene expression sites, changes over time, changes in ossification morphology, and effects of mechanical tensile strain.

Results: In human OPLL tissues, RSPO2 was expressed in chondrocytes, and particularly in proliferating chondrocytes in the fibrocartilage area near the calcification front. However, the expression was rare in patients with segmental OPLL. Hypertrophic chondrocytes were Runx2-positive in calcified cartilage areas. Proliferating chondrocytes were strongly positive for Sox9 and CD90 in the fibrocartilage area where RSPO2 was positive. Application of cyclic tensile strain to cultured human OPLL cells resulted in increases in mRNA levels for RSPO2, HAO1, and CCDC91. However, individual differences in expression in human OPLL-related samples were seen.In the 3- to 6-week-old ttw/ttw mice, HAO1 and RSPO2 were found to be expressed in the PLL attachment site, but the both did not become double-positive in the same sample. In the region where many RSPO2-positive cells were found, many Sox9-positive cells were found, but Runx2 and CD90-positive cells were not found.

Conclusion: Among the five susceptibility genes, RSPO2, HAO1 and CCDC91 might be associated with initiation and progression of OPLL, which increased significantly in its mRNA level induced by cyclic tensile stress. This result suggests that mechanical stress may contribute to the initiation or extension of ossification. The expression of RSPO2 was frequently found in patients with mixed- or continuous-type OPLL and ttw/ttw mice that might be involved through endochondral ossification and indicated ossification activity. HAO1 may be an initiation factor for OPLL that was difficult to observe in mature human OPLL samples, while the expression was detected in 3- to

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6-week-old ttw/ttw mice before appearance of hypertrophy of the PLL. Our results could give important insights into the origins of OPLL.

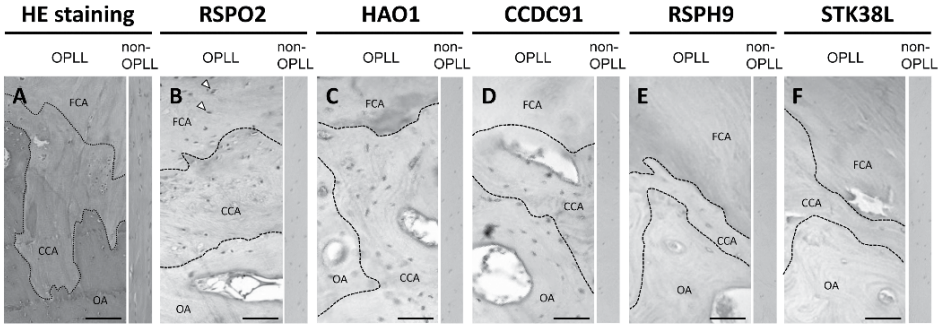

Figure 1

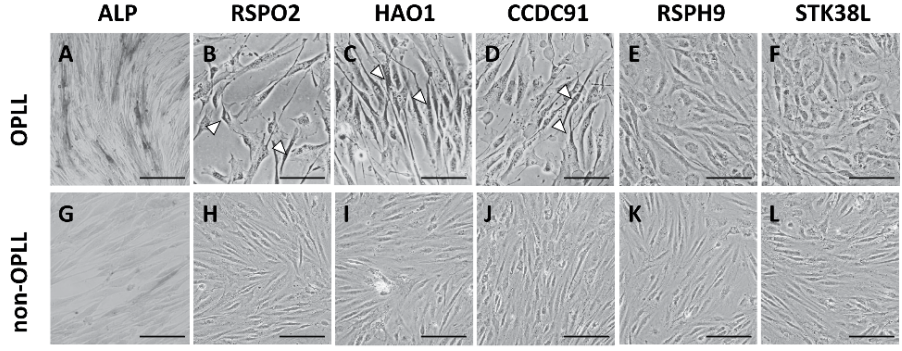

Figure 3

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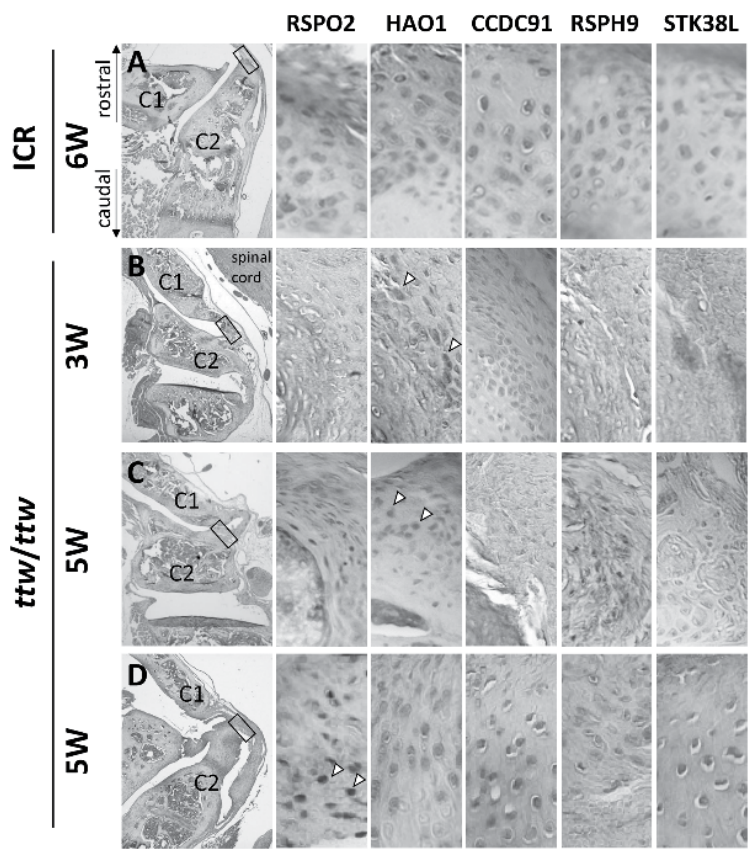

Figure 5

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Presentation #13

Complex cervical spine surgery improves quality of life in the extremely elderly age group; results from an ambispective study of 582 patients over 75 years old from a single institution.

Jamie Wilson, MD, FRCS, *Jetan Badhiwala, MD, Hetshree Joshi, BA, Ali Moghaddamjou, MD, Raja Rampersaud, MD, Stephen Lewis, MD, Eric Massicotte, MD, FRCSC, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: Degenerative spine disease is an emerging epidemic in the elderly age group, however a knowledge gap exists regarding the efficacy and safety of cervical spine procedures in those over 75 years old (Wilson et al 2019, Nouri et al 2019). The objectives of this study was to investigate the factors that affect the outcomes of cervical spine surgery in the >75 age group.

Materials and Methods: Prospectively-collected database records from a single tertiary spine care center were retrospectively interrogated from January 1st 2005 until July 31st 2018 to identify all patients > 75 years who underwent cervical spine surgery. Descriptive demographics were collected, including type of surgery, operated levels, perioperative complications and patient reported outcome measures (PROM). Multivariate regression analysis was performed to compare increasing age with the chance of complications by region, number of levels, rate of revision surgery, and quality of life (QOL) outcomes at 2 years (SF36 scores and Neck Disability Index [NDI]).

Results: 582 patients were included, mean age 78.2 [range 75-89], 42% were female with a mean follow-up of 32 [95%CI 29.7-33.8] months. The most common indication for surgery was degenerative disease (n=520, 89%), followed by inflammatory disease, deformity, and infection. Degenerative stenosis (myelopathy) accounted for 55% of all cases (n=323). Instrumented fusion was undertaken in 65% of cases, and the number of operated levels ranged from 1-9. Intraoperative complications occurred in 18% (dural tear = 71%), with a revision rate of 23% (n=135). Univariate analysis showed increasing age was not correlated with risk of complication or revision (p=0.192, p=0.953), but positively correlated with increasing levels operated (p=0.043). However, multivariable logistic regression adjusting for type of surgery showed increasing age was weakly associated with a reduced risk of revision (OR 0.91[0.84-0.99]; p=0.045), but increasing number of levels operated was strongly predictive of risk of revision (OR1.13 per extra level [1.0-1.3]; p=0.009). Multivariable regression demonstrated improved QOL outcomes (SF36 and Neck Disability Index) in patients who underwent instrumented fusion, adjusting for age and number of operated levels (p=0.016, p=0.001). Using the same regression model, fusion surgery (OR 10[3.4-30]; p<0.001) was also a significant predictor of reaching the Minimum Clinically Important Difference (MCID) for arm pain, with age negatively correlated (OR 0.62 per year older [0.55-0.69]; p<0.001), but neither had significant effect size on the MCID for neck pain.

Conclusion: In one of the largest case series of patients >75 years with 2 year Patient Reported Outcome Measures, complex cervical spine surgery appears a safe and effective treatment. Quality of life outcomes and post-operative pain scores are improved with instrumented fusion surgery over non-fusion surgery, but increasing number of levels is associated with an increased risk of revision surgery. These factors should be considered when counselling elderly patients pre-operatively.

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Presentation #14

Concomitant foraminotomy for radiculomyelopathy is directly involved in postoperative upper limb palsy in cervical laminoplasty

Hiroyuki Ishiguro, MD, PhD, *Shota Takenaka, MD, DMSc, Masafumi Kashii, MD, PhD, Yuichiro Ukon, MD, Yukitaka Nagamoto, MD, PhD, Masayuki Furuya, MD, PhD, Takahiro Makino, MD, DMSc, Yusuke Sakai, MD, Takashi Kaito, MD, PhD*

Introduction: Postoperative upper limb palsy (ULP) is a well-recognized complication of cervical spine surgery. Previous studies have reported that concomitant foraminotomy for radiculomyelopathy increases the risk of ULP after posterior cervical decompression. These findings suggest that concomitant decompression of the stenotic foramen may paradoxically cause ULP after laminoplasty. However, because of its low incidence [1], no studies have revealed the detailed characteristics of ULP after laminoplasty with concomitant foraminotomy. In particular, it is crucial to confirm the consistency between the site of foraminotomy and the distribution of ULP. The purpose of this study was to clarify the effects of concomitant foraminotomy on ULP after laminoplasty using a matched case-control study with a sufficient sample size based on a prospective, surgeon-maintained multicenter database.

Materials and Methods: A total of 4080 consecutive patients undergoing primary cervical laminoplasty between 2012 and 2018 were reviewed from a surgeon-maintained database for spinal surgery at 27 affiliated institutions. We identified 19 patients who developed ULP after laminoplasty with concomitant foraminotomy (F-group). An age- and sex-matched control group (C-group) who developed ULP after laminoplasty without concomitant foraminotomy (n=76, 4:1 ratio with the F-group) was selected from 124 candidate patients. Detailed information of the two groups including pre- and postoperative manual muscle testing (MMT) grades and the characteristics of ULP including the time of ULP onset and distribution of ULP (side and level) were retrospectively collected. In the F-group, the site of foraminotomy (side and level) was recorded.In our affiliated institutions, concomitant foraminotomy was performed only in patients with nerve root impingement and was not a form of prophylactic foraminotomy for the prevention of ULP. ULP was defined as a postoperative upper-limb muscle weakness of two or more MMT grades or postoperative deterioration to an MMT grade of 0–2. Statistical analyses used were Student's t-test, Mann-Whitney U test, and Fisher's exact test.

Results: The two groups were comparable in terms of age, sex, disease, operative procedure, operative time, estimated blood loss and follow-up period. The incidence of ULP in patients who underwent concomitant foraminotomy (19/126, 15.1 %) was significantly higher than that in those who did laminoplasty only (124/3954, 3.1%; $p<0.001$). The site of foraminotomy was consistent with the distribution of ULP in 79% (15/19) of the F-group. The F-group included more patients with preoperative upper-limb muscle weakness than the C-group (74% vs. 37%, $p=0.005$), reflecting the existence of preoperative radiculopathy in the F-group (Table 1). The proportion of early-onset ULP that occurred by postoperative day 1 was significantly higher in the F-group than in the C-group (63% vs. 33%; $p=0.02$) (Table 2).

Conclusion: Our results indicate that the foraminotomy procedure in the stenotic foramen is

directly involved in ULP. Combined with a previous report suggesting that early-onset ULP is associated with thermal nerve damage [2], our results indicate that thermal nerve damage partly explains the increased incidence of ULP in the F-group.

Table 1. Comparison of patient demographics between the F-group and C-group

	F-group (N=19)	C-group (N=76)	p-value
Age (year)	67.5 ± 9.2 (47–83)	68.9 ± 8.5 (46–83)	0.68[S]
Female	3 (16%)	12 (16%)	>0.99[F]
OPLL	4 (21%)	11 (14%)	0.49[F]
Preoperative upper-limb muscle weakness	14 (74%)	28 (37%)	**0.005[F]**
Procedure distribution, open door: double door	18:1 (95:5%)	68:8 (89:11%)	0.68[F]
Operative time (min)	139 ± 40 (66–206)	126 ± 55 (53–379)	0.36[S]
Estimated blood loss (g)	110 ± 150 (20–350)	70 ± 138 (10–925)	0.27[M]

Study groups were compared by [S]Student's t test, [F]Fisher's exact test, and [M]Mann-Whitney U test. OPLL = ossification of the posterior longitudinal ligament. Significant p-values are indicated in bold.

Table 2. Comparison of the characteristics of postoperative upper limb palsy (ULP) between the F-group and C-group

	F-group (N=19)	C-group (N=76)	p-value
Time of onset (days)	1.0 ± 5 (0–17)	2.5 ± 3 (0–20)	0.08[M]
Early onset (POD0 or POD1)	12 (63%)	25 (33%)	**0.02[F]**
Open side ULP	17 (89%)	41 (54%)	**0.004[F]**
Hinge side ULP	2 (11%)	41 (54%)	**0.001[F]**
Bilateral ULP	0 (0%)	6 (8%)	0.34[F]
Level, proximal (C5–C6):distal (C7–C8):diffuse (C5–8)	17:1:1 (89:5:5%)	64:7:5 (84:9:7%)	>0.99[F]

Bilateral ULP, which occurred in six patients with open-door laminoplasty in the C-group, was counted as both open- and hinge-side palsy. Study groups were compared by [M]Mann-Whitney U test and [F]Fisher's exact test. POD = postoperative day; ULP = upper limb palsy. Significant p-values are indicated in bold.

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Presentation #15 ***Clinical Research Award***

Intrathecal administration of recombinant human hepatocyte growth factor for acute traumatic cervical spinal cord injury: double-blinded, placebo-controlled and randomized phase I/II study.

Masaya Nakamura, MD, ***Kazuya Kitamura, MD, PhD,*** *Narihito Nagoshi, MD, Osahiko Tsuji, MD, Kota Suda, MD, PhD, Takeshi Maeda, MD, PhD, Yoshiyuki Yato, MD, PhD, Daichika Hayata, PhD, Morio Matsumoto, MD, Hideyuki Okano, MD*

Introduction: Hepatocyte growth factor (HGF) was first identified as a potent mitogen for mature hepatocytes and has gained attention as a strong neurotrophic factor in the central nervous system. We reported the therapeutic efficacy of intrathecal infusion of pharmaceutical recombinant human HGF (KP-100) for acute spinal cord injury (SCI) in animal models including non-human primate (ref. 1). The purpose of this study was to evaluate the safety and efficacy of intrathecal KP-100 administration for traumatic SCI patients in the acute phase.

Materials and Methods: This study was a multicenter, double-blinded, randomized, placebo-controlled, parallel-group phase I/II clinical trial and was performed from June 2014 to May 2018 at 3 high-volume SCI centers in Japan. Patients meeting the following criteria were registered: 1) cervical SCI with modified Frankel grade of A/B1/B2 at 72 hours after injury (B1: light touch preservation only at sacral segments, B2: light touch preservation at wider area, B3: pinprick preservation at sacral segments), 2) 18-75 years old. The randomization was imbalanced at 2:1, predominantly in the KP-100 group. The study drug (0.6mg of KP-100) was for the first time administered intrathecally through lumbar puncture procedures within 6 hours after registration at 72 hours after injury (Day 0) and was repeated once a week for a total of 5 times. The observation period was until 24 weeks after the primary administration (Day 168). Adverse events were evaluated during the follow-up period. Efficacy was evaluated in change from baseline in American Spinal Injury Association (ASIA) motor and sensory scores.

Results: 1) 45 subjects were divided into the two groups (28 in KP-100; 17 in placebo). The subjects did not show any serious adverse events caused by KP-100. 2) Two patients were excluded in the KP-100 group because of respiratory dysfunction after first drug administration and neurological functional analysis was performed for 43 patients (26 in KP-100; 17 in placebo). KP-100 contributed to motor improvement at several time points and the changes from baseline in the ASIA motor score were different between the KP-100 and placebo groups at Days 140 (12.6 ± 2.4 vs. 4.8 ± 3.0, P=0.050) and 168 (12.4 ± 2.4 vs. 5.3 ± 3.0, P=0.079). 3) Whereas slightly better motor improvement was observed in upper extremities in the KP-100 group compared to the placebo group without statistical significance (final scores 4.9 ± 0.9 vs 4.3 ± 1.2), significant recovery occurred in the lower extremity at Days 140 (7.5 ± 1.8 vs. 1.1 ± 2.2, P=0.031) and 168 (7.3 ± 1.9 vs. 1.3 ± 2.3, P=0.049). 4) In the subset of subjects with Frankel grade A, the proportions of subjects who gained at least 1 point on their lower-extremity motor scores were 33.3% (5/15) and 6.3% (1/16) in the KP-100 and placebo groups, respectively (P=0.083).

Conclusion: Intrathecal KP-100 is a potential therapeutic strategy for traumatic SCI at acute phase. Phase III trial would be required for further investigation of its therapeutic effects on neurological recovery.

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Presentation #16

Pain catastrophizing impacts outcome scores but not recovery kinetics after 1-2 level anterior cervical surgery

Sheeraz Qureshi, MD, MBA, ***Sohrab Virk, MD,*** *Avani Vaishnav, MBBS, Chirag Chaudhary, MBBS, Ryan Lee, MBA, Hikari Urakawa, MD, Kosuke Sato, MD, Jung Mok, BS, Darren Chen, BS, Steven McAnany, MD, Sravisht Iyer, MD, Todd Albert, MD, Catherine Gang, MPH*

Introduction: For a subset of patients that catastrophize pain, communication of symptoms/disability is a challenge for themselves and for practitioners to interpret. We wanted to determine if patients that catastrophize pain had worse clinical outcomes after anterior cervical surgery.

Materials and Methods: We performed a retrospective review of patients undergoing 1-2 level ACDF/CDR for cervical radiculopathy/myelopathy. Included patients needed to have 1 year follow-up and health related quality of life scores (HRQOLs) at 6 weeks, 3 months, 6 months and 1 year out from surgery. The HRQOLs followed were neck disability index (NDI), short-form 12 physical component score (SF-12 PCS), short-form 12 mental component score (SF-12 MCS), PROMIS score, visual analog scale arm (VAS-arm) and neck (VAS-neck) pain scores. Patients with pre-operative VAS-neck or VAS-arm score of 9-10/10 were classified as pain catastrophizing (PC cohort) and the rest as non-pain catastrophizing (non-PC cohort). HRQOLs were compared between cohorts at the 6-week, 3 month, 6 month and 1 year time points. We compared recovery kinetics between the PC versus non-PC cohorts. This was done by normalizing all HRQOLs at each interval time point. The area under the curve (AUC) was then calculated for a plot of the normalized score versus follow-up time point as has been done in previous studies (IHS, Integrated Health State). We confirmed normality of our HRQOLs at each time point by running a komogorov-smirnov test for normality. A student's t-test was used to compare mean values from the two cohorts.

Results: There were 48 patients with 1-year follow-up (mean age 50.0±11.8 years old, 22 female). There were 13 patients in the PC cohort. There were no significant differences in age, gender ($p = 0.53$) and pre-operative radiographic parameters (all $p > 0.41$). All HRQOL scores were normally distributed. Pre-op VAS-arm, VAS-neck, SF-12 PCS, SF-12 MCS, NDI and PROMIS were all worse for the PC cohort ($p<0.02$). At 6 weeks, NDI ($p=0.01$), VAS-arm ($p=0.01$), VAS-neck ($p=0.03$), PROMIS ($p=0.04$), SF-12 PCS ($p=0.01$) and SF-12 MCS ($p=0.02$) were worse for PC cohort. At 3 months, NDI ($p=0.01$), VAS-neck ($p=0.003$), VAS-arm ($p=0.04$) and SF-12 PCS ($p=0.003$) were worse for the PC cohort. At 6 months, only SF-12 PCS ($p=0.005$) were worse for the PC cohort. At 1 year, NDI ($p=0.02$), VAS-neck ($p=0.01$) and VAS-arm ($p=0.01$) were worse for the PC cohort. Contrastingly, the recovery kinetics for NDI ($p=0.32$), SF-12 PCS ($p=0.69$), VAS-neck ($p=0.92$), VAS-arm ($p=0.97$) and PROMIS ($p=0.24$) were similar between the two cohorts. The only HRQOL that was associated with worse recovery kinetics was SF-12 MCS ($p=0.04$).

Conclusion: Our findings demonstrate that patients that catastrophize pain may have worse overall outcome scores after ACDF/CDR. After normalizing their outcome scores, however, through an analysis of recovery kinetics we have demonstrated that PC patients have similar rates of improvement after ACDF/CDR. PC patients might communicate pain in a more extreme manner, but clinicians should counsel these patients that outcomes are positive after ACDF/CDR.

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Presentation #17

A Novel Method to Classify Cervical Incomplete Spinal Cord Injury based on Potential for Recovery: A Group-Based Trajectory Analysis

Jetan Badhiwala, MD, *Jefferson Wilson, MD, PhD, Christopher Witiw, MD, MS, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: The outcomes of cervical incomplete spinal cord injury (SCI) are heterogeneous. Using a novel technique, this study sought to dissociate subgroups of cervical incomplete SCI patients with distinct longitudinal temporal profiles of recovery in upper limb motor function.

Materials and Methods: Patients with cervical incomplete SCI (AIS B-D; C1-C8) were identified from four prospective, multi-center SCI datasets (NACTN; STASCIS; Sygen; NASCIS III). A group-based trajectory model was fit to longitudinal upper extremity motor scores out to 1-year follow-up. The association of trajectory grouping with functional independence, as assessed by the Functional Independence Measure (FIM) motor domains, was investigated by logistic regression analyses. Multivariable multinomial logistic regression was performed to identify features that characterize each trajectory group. A classification system for predicting trajectory group at baseline was developed by recursive partitioning.

Results: In total, 801 patients were eligible. Four distinct trajectory groups were identified (Figure 1):1. 'Poor outcome': Severe neurological injury with very minimal, gradual recovery; severe residual impairment2. 'Moderate recovery': Moderate-to-severe neurological injury with moderate recovery; moderate residual impairment 3. 'Good recovery': Moderate neurological injury with good recovery; mild residual impairment.4. 'Excellent outcome': Mild neurological injury with good recovery; very minimal to no residual impairmentTrajectory grouping demonstrated significant association with functional independence for all motor domains examined. On adjusted analyses (Table 1), older age was associated with lower likelihood of an 'excellent outcome' ($P=0.020$). Compared to AIS B injuries, AIS C injuries were associated with 'moderate recovery' ($P<0.001$), 'good recovery' ($P<0.001$), and 'excellent outcome' ($P<0.001$), and AIS D injuries were significantly associated with 'good recovery' ($P<0.001$) and 'excellent outcome' ($P<0.001$). Mid cervical injuries occurred more frequently in 'moderate recovery' ($P<0.001$), 'good recovery' ($P<0.001$), and 'excellent outcome' ($P<0.001$) groups, as compared to upper cervical injuries. The presence/absence of central cord syndrome did not predict temporal recovery profile. Early surgical decompression (<24 hrs) was independently associated with an increased propensity for 'good recovery' ($P=0.039$) and 'excellent outcome' ($P=0.048$). A classification model developed by recursive partitioning could predict trajectory group using age, AIS grade, and neurological level with an AUC of 0.81 (Figure 2).

Conclusion: Patients with cervical incomplete SCI demonstrate distinct temporal profiles of recovery in upper limb motor function. These trajectory groups correlate with long-term functional outcomes. The trajectory a patient is likely to follow may be predicted by baseline characteristics. The presence of central cord syndrome does not impact prognosis, whereas early surgery may support conversion to a more favorable recovery trajectory.

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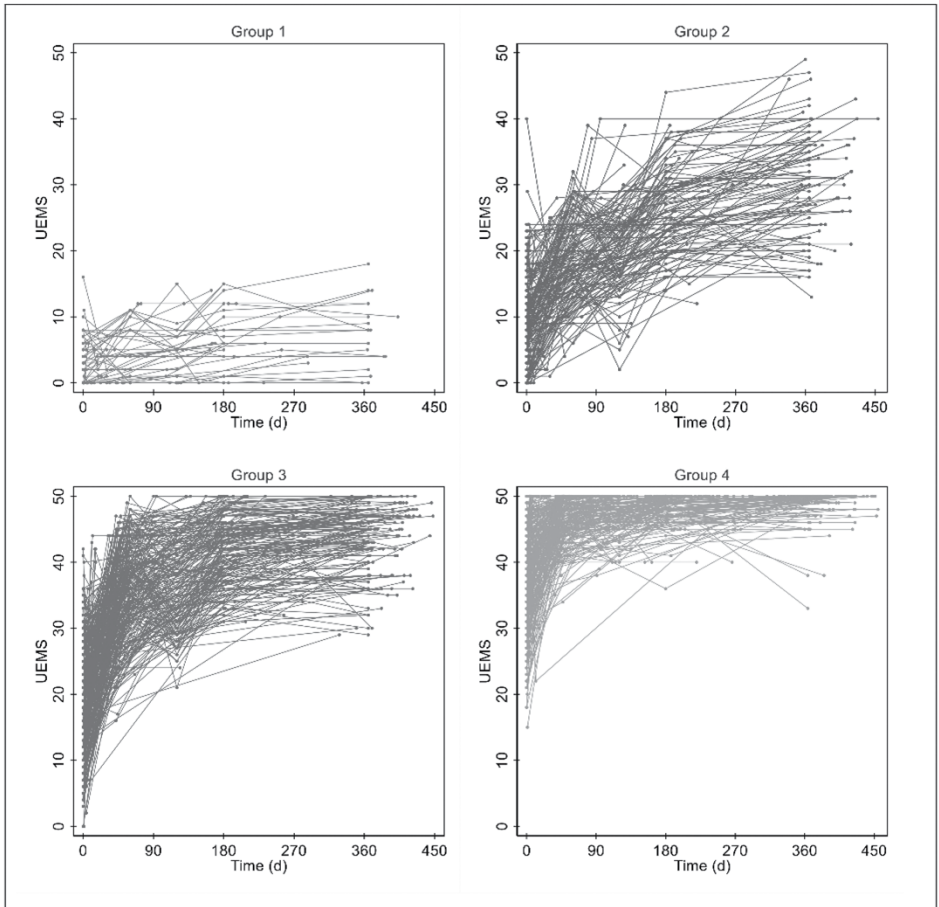

Figure 1. 'Spaghetti' plot of individual patient trajectories by group classification

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Table 1. Results of adjusted analysis for association of baseline characteristics with group membership†

	'Moderate recovery'		'Good recovery'		'Excellent outcome'	
Variable	**RRR (95% CI)**	**P value***	**RRR (95% CI)**	**P value***	**RRR (95% CI)**	**P value***
Age	1.00 (0.97-1.02)	0.917	0.99 (0.96-1.02)	0.465	0.97 (0.94-0.99)	0.020*
Female	0.96 (0.38-2.42)	0.927	1.44 (0.55-3.74)	0.453	1.08 (0.37-3.18)	0.890
Mechanism of injury						
Fall	reference		reference		reference	
Motor vehicle collision	2.37 (0.88-6.40)	0.088	2.49 (0.89-6.98)	0.082	1.30 (0.42-4.03)	0.649
Other	1.68 (0.57-4.98)	0.350	1.68 (0.54-5.24)	0.373	1.90 (0.54-6.69)	0.318
AIS grade						
B	reference		reference		reference	
C	4.16 (1.80-9.62)	0.001*	9.50 (3.89-23.22)	<0.001*	10.75 (3.49-33.14)	<0.001*
D	5.25 (0.50-55.25)	0.167	163.31 (17.00-1,568.61)	<0.001*	9,146.14 (848.77-98,556.72)	<0.001*
Neurological level—no. (%)						
Upper	reference		reference		reference	
Mid	12.23 (4.01-37.34)	<0.001	38.95 (12.46-121.79)	<0.001*	91.69 (26.79-313.74)	<0.001*
Lower	ND		ND		ND	
Central cord syndrome	1.37 (0.37-5.04)	0.638	1.53 (0.41-5.75)	0.527	0.39 (0.10-1.60)	0.191
Early surgical decompression	2.28 (0.96-5.40)	0.061	2.58 (1.05-6.35)	0.039*	2.71 (1.01-7.27)	0.048*
MPSS	1.76 (0.78-3.98)	0.176	2.03 (0.86-4.77)	0.104	2.54 (0.99-6.57)	0.054

†'Poor outcome' (Group 1) is the reference
*Statistically significant association (P<0.05)

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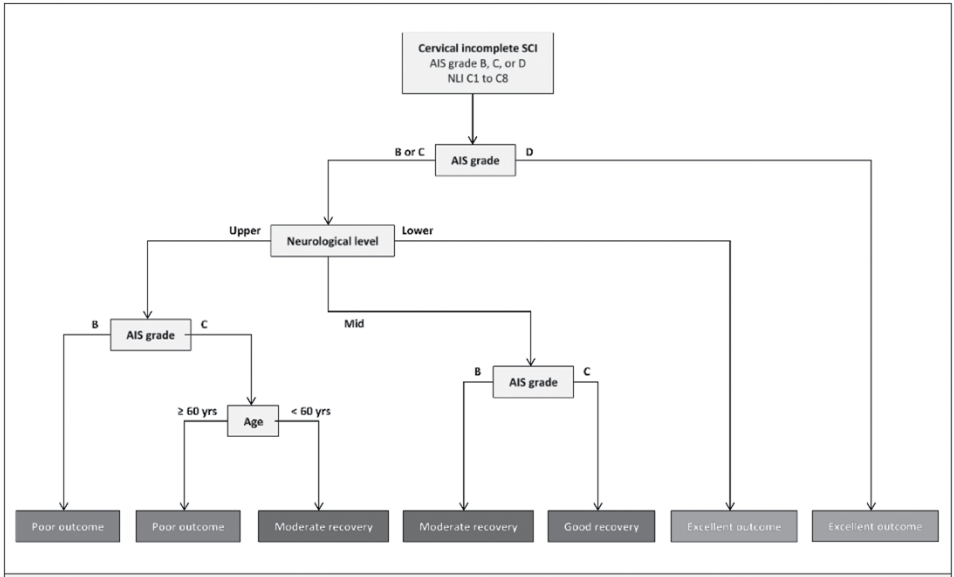

Figure 2. Classification tree developed by recursive partitioning for predicting trajectory group from baseline patient and injury characteristics

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Presentation #18

Does the Lowest Instrumented Vertebra (LIV) Level Predict Mechanical Failure in Posterior Cervical Fusion?

Joseph Labrum IV, MD, *Inamullah Khan, MBBS, Kristin Archer, PhD, Amir Abtahi, MD, Byron Stephens, MD*

Introduction: Posterior cervical fusion is a common spinal procedure indicated for the treatment of a variety of spinal pathologies. Recent studies indicate that selection of the caudal extent of a fusion construct - the lowest instrumented vertebra (LIV), in posterior cervical fusion (PCF) may play a role in the risk of mechanical failure. To date, the evidence available to guide spine surgeons in the selection of PCF LIV remains limited.[1-4] The purpose of this study is to evaluate the incidence of mechanical failure at different LIV levels in PCF.

Materials and Methods: All patients undergoing posterior cervical fusion at our institution were prospectively entered into a spine outcomes registry which was retrospectively queried for inclusion in the study. Inclusion criteria for enrollment in the study included the following: (1) history of PCF, (2) construct LIV of C7, T1, or T2, and (3) radiographic and clinical follow-up of at least 1-year. Exclusion criteria for this study included the following: (1) Patients younger than 18, (2) patients with paraplegia above the level of T2, (3) patients with fusion construct extending to the occiput and (4) patients with anterior fusion overlapping the CTJ. Data collection included recording demographic variables, underlying pathology, operative variables (EBL, length of surgery, length of hospital stay), patient-reported outcome measures (PROs), LIV, number of levels fused, and LIV failure / revision. LIV failure was defined as LIV revision, LIV hardware failure, pseudoarthrosis at the level directly above the LIV, and surgeon-documented adjacent segment disease radiculopathy/myelopathy.

Results: Of 438 patients reviewed, 196 patients met initial inclusion criteria based on the LIV. 106 patients met study inclusion criteria and had a minimum of 1-year follow-up. LIV groups included - C7 LIV (36), T1 LIV (42), and T2 LIV (28). There were no between-group differences in post-operative follow-up, patient demographics, or operative variables across the three LIV cohorts (Table 1). Revision rates in the cohort for C7, T1 and T2 LIV were 25.0%, 11.9%, and 0%, respectively (p=0.013, Table 2). Mechanical failure rates for C7, T1 and T2 LIV were 30.6%, 23.8%, and 0%, respectively (p=0.007, Table 2). No difference was noted in time to revision/ failure between C7 and T1 LIV cohorts (Figure 1, Table 2).

Conclusion: The findings in this study indicate that selection of the LIV in PCF may play a significant role in the development of mechanical complications and the need for subsequent revision surgery. Among the LIV groups in this series, T2 demonstrated the lowest rate of mechanical complications and revision surgery. Instrumentation to T2, therefore, may be protective against mechanical failure and revision surgery.

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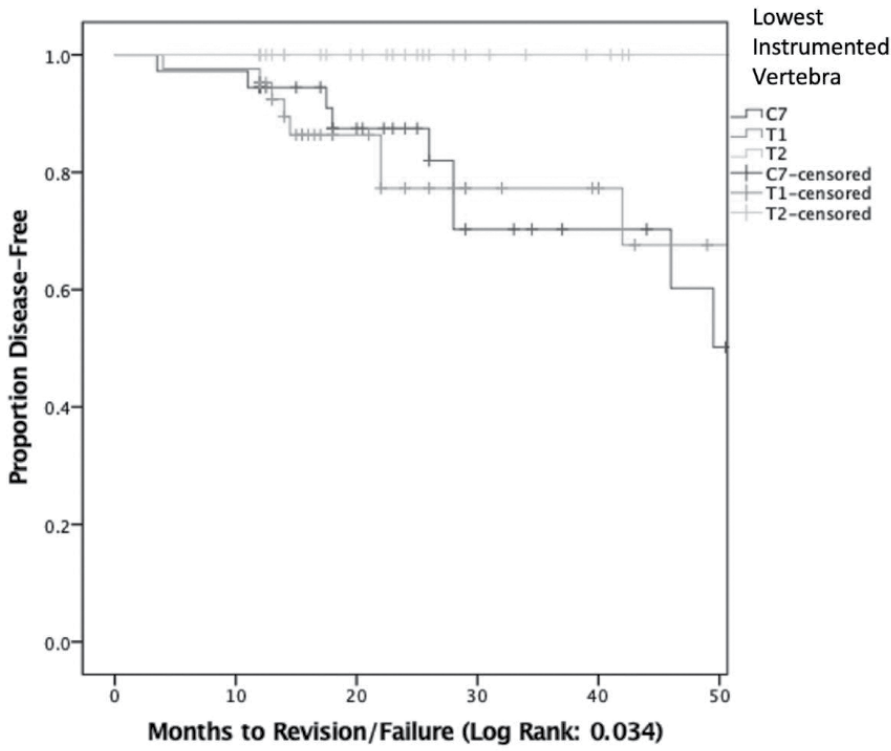

Figure 1
Kaplan-Meier survivorship curve depicting the time to revision/failure stratified by the PCF construct Lowest Instrumented Vertebra (LIV).

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Table 1. Patient Demographics and Operative Metrics

		Total (N=106)	C7 LIV (N=36)	T1 LIV (N=42)	T2 LIV (N=28)	p-value
Age		60.58 ±10.70	59.19 ±9.28	62.58 ±10.59	59.35 ±12.38	0.299
Gender: Female		46 (43.4%)	16 (44.4%)	18 (42.9%)	12 (42.9%)	0.988
Race	Caucasian	92 (86.8%)	32 (88.9%)	36 (85.7%)	24 (85.7%)	0.901
	Other	14 (13.2%)	4 (11.1%)	6 (14.3%)	4 (14.3%)	
BMI		29.79 ±6.81	30.65 ±7.88	29.51 ±6.23	29.11 ±6.30	0.636
Current Smoker		25 (23.6%)	8 (22.2%)	12 (28.6%)	5 (17.9%)	0.569
Currently Employed		33 (31.1%)	10 (27.8%)	16 (38.1%)	7 (25.0%)	0.443
Insurance: Private		38 (35.8%)	14 (38.9%)	17 (40.5%)	7 (25.0%)	0.374
Hx of CAD		22 (20.8%)	6 (16.7%)	13 (31.0%)	3 (10.7%)	0.094
Hypertension		71 (67.0%)	25 (69.4%)	30 (71.4%)	16 (57.1%)	0.427
Myocardial Infarction		4 (3.8%)	2 (5.6%)	2 (4.8%)	0 (0.0%)	0.466
Hx of COPD		7 (6.6%)	2 (5.6%)	4 (9.5%)	1 (3.6%)	0.588
Diabetes		16 (15.1%)	4 (11.1%)	10 (23.8%)	2 (7.1%)	0.116
Arthritis		74 (69.8%)	28 (77.8%)	27 (64.3%)	19 (67.9%)	0.418
Anxiety and Depression		66 (62.3%)	21 (58.3%)	26 (61.9%)	19 (67.9%)	0.736
Preoperative Ambulation	With Assistant	43 (40.6%)	16 (44.4%)	13 (31.0%)	14 (50.0%)	0.392
	Independent	62 (58.5%)	20 (55.6%)	28 (66.7%)	14 (50.0%)	
	Wheelchair bound	1 (0.9%)	0 (0.0%)	1 (2.4%)	0 (0.0%)	
Duration of Symptoms	<3 months	9 (8.6%)	2 (5.6%)	3 (7.1%)	4 (14.8%)	0.068
	3-12 months	36 (34.3%)	11 (30.6%)	11 (26.2%)	14 (51.9%)	
	>12 months	60 (57.1%)	23 (63.9%)	28 (66.7%)	9 (33.3%)	
Preoperative Opioid use		43 (41.0%)	16 (45.7%)	15 (35.7%)	12 (42.9%)	0.655

Neurologic Exam and Operative Metrics

		Total (N=106)	C7 LIV (N=36)	T1 LIV (N=42)	T2 LIV (N=28)	p-value
Motor Deficits		73 (68.9%)	27 (75.0%)	28 (66.7%)	18 (64.3%)	0.606
Primary Diagnosis	Myelopathy	84 (79.2%)	27 (75.0%)	37 (88.1%)	20 (71.4%)	0.225
	Radiculopathy	11 (10.4%)	3 (8.3%)	4 (9.5%)	4 (14.3%)	
	Pseudoarthrosis	11 (10.4%)	6 (16.7%)	1 (2.4%)	4 (14.3%)	
ASA Grade: >2		82 (77.4%)	29 (80.6%)	31 (73.8%)	22 (78.6%)	0.765
Estimated Blood Loss (ml)		372.55 ±372.26	355.56 ±287.30	310.24 ±326.91	487.86 ±499.42	0.140
Length of Surgery (mins)		184.32 ±58.01	186.14 ±48.83	182.79 ± 64.43	184.29 ±60.71	0.969
Length of Stay (Days)		3.39 ±2.15	3.64 ±2.03	3.33 ±2.62	3.14 ±1.43	0.648

mean ± S.D. for continuous variables and n (%) for categorical variables.
BMI=Body mass index, CAD= Coronary Artery Disease, COPD= Chronic Obstructive Pulmonary Disease, ASA= American Society of Anesthesiology grade.

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Table 2. PCF Construct Metrics

PCF Construct Complications					
	Total (N=106)	C7 LIV (N=36)	T1 LIV (N=42)	T2 LIV (N=28)	p-value
Construct LIV Revision	14 (13.20%)	9 (25.0%)	5 (11.9%)	0 (0%)	0.013
Construct LIV Failure	21 (19.81%)	11 (30.6%)	10 (23.8%)	0 (0%)	0.007
Average Time to LIV Failure*	35.00 ±31.52	39.68 ±35.64	29.85 ±27.19	-	0.489
PCF Construct Design					
	Total	C7 LIV (N=36)	T1 LIV (N=42)	T2 LIV (N=28)	p-value
Number of Motion Segments Fused	4.50 ±1.66 (N=106)	3.17 ±1.13	4.60 ±1.25	5.96 ±1.37	< 0.001
Number of Motion Segments Fused with Construct Survival	4.72 ±1.58 (N=85)	3.20 ±1.04	4.84 ±0.99	5.96 ±1.37	< 0.001
Number of Motion Segments Fused with LIV mechanical failure	3.42 ±1.52 (N=21)	3.09 ±1.38	3.80 ±1.69	-	0.302
p-value	0.001	0.795	0.090	-	-
Etiology of LIV Mechanical Failure†					
	Total (N=21)	C7 LIV (N=11)	T1 LIV (N=10)	T2 LIV (N=0)	
ASD	12 (57.1%)	7 (63.6%)	5 (50.0%)	-	
Hardware Failure	7 (33.3%)	2 (18.2%)	5 (50.0%)	-	
Pseudoarthrosis	7 (33.3%)	2 (18.2%)	5 (50.0%)	-	
Subjacent Fracture	2 (9.5%)	2 (18.2%)	0 (0%)	-	
DJK	1 (4.8%)	1 (9.1%)	0 (0%)	-	
All Cause PCF Revision Rates					
	Total (N=106)	C7 LIV (N=36)	T1 LIV (N=42)	T2 LIV (N=28)	
All Cause Revision Rates	18 (16.98%)	9 (25.0%)	8 (19.0%)‡	1 (3.6%)§	

mean ± S.D. for continuous variables and n (%) for categorical variables.
**mean time to failure displayed in unit of months*
†some cases displayed multiple etiologies of LIV mechanical failure
DJK = Distal Junctional Kyphosis
‡Three additional T1 construct failures secondary to craniocervical settling (1), proximal ASD (1) and proximal pseudoarthosis with revision of upper instrumented vertebra, LIV not revised
§One additional T2 construct failure secondary to C5 UIV psuedoarthrosis and hardware failure, stable distal fusion, LIV not revised

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Presentation #19

Outcomes of Neurologic Complication and Utility of Intraoperative Neuromonitoring for Lower Cervical and Upper Thoracic Posterior Based Three Column Osteotomies for Cervical Deformity

Darryl Lau, MD, *Alexander Haddad, BS, Vedat Deviren, MD, Christopher Ames, MD*

Introduction: Neurologic morbidity associated with correction of fixed cervical deformity (CD) via posterior based 3-column osteotomy (3CO) has not been well defined. The utility of neuromonitoring (NM) during 3CO for CD has yet to be studied. Therefore, this study seeks to define the incidence of neurological deficit following 3CO for CD and determine the performance of NM to detect postoperative weakness.

Materials and Methods: This study performed a retrospective review of a single surgeon experience from 2011 to 2018 of CD patients who underwent posterior based 3CO. Medical and neuromonitoring records were reviewed. Neurological status was reviewed at 2 years follow-up.

Results: 49 patients were included: 31 PSO and 18 VCR. Mean age was 61.1 years and 44.9% were male. 65.3% were myelopathic and 30.6% had preop weakness. Pre- and post-operative measures were cSVA (6.8 and 3.7 cm, $p<0.001$), lordosis (0.0 and 9.1 degrees, $p=0.030$), and T1-slope (49.8 and 36.7 degrees, $p<0.001$). Mean blood loss was 1674.5 ml and surgery length was 314.6 minutes. Complication rate was 44.9% and neurological deficit rate was 20.4%. When stratified by osteotomy level, there was significantly higher rates of neurological deficits at C7 and T1: C7 (37.5%), T1 (37.5%), T2 (20.0%), T3 (15.4%), T4 (0.0%) ($p=0.023$). Deficits were most consistent with nerve root weakness rather than spinal cord injury; C8-hand intrinsic being most common. There were 8 NM changes with 3 true positives and 7 false negatives. Performance measures were: accuracy 75.5%, PPV 37.5%, NPV 82.9%, sensitivity 30.0%, and specificity 87.2%. In patients with new neurological deficits, 42.9% recovered, 14.3% improved, and 28.6% were unchanged at 2-year follow-up.

Conclusion: Complication rates are high following posterior 3CO for CD. 3CO at C7 and T1 have the highest rates of neurological deficit. NM have modest performance in predicting postoperative deficits. Less than half recover to baseline at 2-year follow-up.

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #20

Patient Specific Cervical Deformity Corrections with Consideration of Associated Risk: Establishment of Risk Benefit Thresholds for Invasiveness Based on Deformity and Frailty Severity

Peter Passias, MD, *Katherine Pierce, BS, Renaud Lafage, MS, Virginie Lafage, PhD, Eric Klineberg, MD, Alan Daniels, MD, Themistocles Protopsaltis, MD, Richard Hostin, MD, Breton Line, BS, Douglas Burton, MD, Shay Bess, MD, Frank Schwab, MD, Christopher Shaffrey, MD, Justin Smith, MD, PhD, Christopher Ames, MD*

Introduction: Cervical deformity (CD) severity has been linked to poor quality of life and severe neck pain. However, little is known of the relationship between surgical invasiveness accounting for cervical deformity severity and frailty status. The purpose of this study was to investigate the outcomes of CD surgery by invasiveness, frailty status and baseline degree of deformity.

Materials and Methods: Inclusion criteria was defined as operative CD patients (C2-C7 Cobb>10°or CK>10°, cSVA>4cm or CBVA>25°) >18yr with follow up (1-year) radiographic and HRQL scores, NDI, mJOA and EQ5D. Patients were stratified by severity of deformity by TS-CL, categorized by the new-mJOA based modifiers: Low/Mod <45°[Low-Mod]; Severe >45°[Sev]. Frailty scores were calculated based upon the modified CD frailty index by Passias et. Al and categorized into Severely Frail[SF] ≥0.5 and Not SF[N-SF]<0.5. Patients were categorized by their frailty and deformity status (Low-Mod/N-SF; Low-Mod/SF; Sev/N-SF; Sev/SF). Logistic regression analysis assessed the relationship between increasing invasiveness and outcomes(DJK, complications). Within the significant frailty/deformity risk groups, decision tree analysis assessed thresholds for an invasiveness severity cut-off point, below which experiencing a reoperation, complication, DJK occurrence and poor mJOA were higher.

Results: 96 CD patients met inclusion criteria (62.2±10.2 years, 66% female, 28.4±7.4 kg/m2). By approach: 19.8% anterior-only, 47.9% posterior-only, 32.3% combined (levels fused: 7.7±3.9). By deformity severity: 23.7% Low, 40.9% Moderate, 34.4% Severe, while frailty assessment placed 32.3% in N-SF and 67.7% SF. This categorized the patients into deformity/frailty groups as follows: 19.8% Low-Mod/N-SF(19), 13.5%(13) Sev/N-SF, 44.8%(43) Low-Mod/SF, 21.9%(21) Sev/SF. Logistic regression analysis found a significant relationship between increasing deformity severity and occurrence of severe postop DJK(1.053 [1.016-1.093], p= 0.005), complications(1.045 [1.012 – 1.080], p=0.007), revision by 1-year(1.059 [1.000-1.122], p= 0.049). Additionally, increasing invasiveness and occurrence of severe DJK (1.030 [1.007-1.054], p= 0.024) and revision (1.026 [1.008 – 1.044], p=0.005). Invasiveness increased with deformity and frailty severity: 53.6 Low-Mod/N-SF, 81.4 Sev/N-SF, 56.4 Low-Mod/SF, 79.8 Sev/SF; p=0.002. After defining a favorable outcome as no occurrence of severe DJK, no major complications and no revisions, and 1Y mJOA improvement(28.1%), invasiveness scores were compared within deformity/frailty groups between patients who met/did not meet the favorable outcome. For the NSF deformity groups, those with a favorable outcome had larger invasiveness scores (Low-Mod: 58.7 vs. 48.5; Sev: 77.7 vs 89.6). For the SF deformity groups, the favorable outcome had significantly lower invasiveness scores for the Low-Mod deformity group (38.1 vs 62.9, p=0.008), while the Sev/SF deformity favorable outcome group remained larger (86.8 vs 79.4), though this was not significant. For the Low-Mod/SF group an invasiveness cutoff score of <48 where achieving a favorable outcome was 3x higher (3.08[1.2-7.9],p=0.019).

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Conclusion: For severely frail patients, when deformity severity is low to moderate, surgeons may limit the invasiveness of their procedures in order to account for the patient's susceptibility to poor outcomes.

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CSRS Research Grant Presentations

On-Demand content available Dec. 7-Jan. 15, 2021 on the Annual Meeting Virtual Platform.

2018-2020

Presentation #21*
Medtronic Research Grant Recipient
Analysis of the Human Serum Proteome in Cervical Radiculopathy Patients to Predict Who Will Fail Conservative Treatment and Require Surgery
Steven Presciutti, MD
*Unable to participate in this year's Annual Meeting

2017-2020

Presentation #22
21st Century Research Grant Recipient
Biodegradable Microspheres and Hydrogel Drug Delivery System of Anti-Inflammatory Therapeutics for the Treatment of Chronic Degenerative Disc Disease
Ana Chee, PhD

2018-2020

Presentation #23
Resident/Fellow Research Grant Recipient
Advanced Quantitative MRI to Measure Cervical Cord Tissue Injury and Predict Outcomes
Muhammad Ali Akbar, MD

2019-2020

Presentation #24
Resident/Fellow Research Grant Recipient
Regeneration of Cervical Relay Circuits after Traumatic Spinal Cord Injury
Michael Fehlings, MD, PhD, FRCSC, FACS

2019-2020

Presentation #25
Resident/Fellow Research Grant Recipient
Cervical Spine Research Society-Cervical Stiffness Disability Index (CSRS-CSDI): A Novel Cervical Scoring System Quantifying the Effect of Post-Arthrodesis Stiffness on Patient Quality of Life
Andrew Jack, MD, MSc, FRCSC

2017-2020

Presentation #26
Medtronic Research Grant Recipient
Microstructural imaging and mechanistic microRNA biomarkers to assess the severity of Degenerative Cervical Myelopathy and to predict the outcomes of surgery; a combined quantitative imaging and serum biomarker approach.
Jamie Wilson, MD

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2019-2020

Presentation #27
21st Century Research Grant Recipient
Can Circulating microRNAs Predict Severity and Progression in Degenerative Cervical Myelopathy?
Srikanth Divi, MD

2019-2020

Presentation #28
Resident/Fellow Research Grant Recipient
The Confounding Burden of Psychological Impairments in Cervical Spine Surgery
Peter Passias, MD

2011-2020

Presentation #29
21st Century Research Grant Recipient
Determination of the True 5-year Incidence of Adjacent Segment Disease after Total Disc Arthroplasty for Cervical Myelo-radiculopathy at One and Two Levels
Pierce D. Nunley, MD

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #30

Randomized, Placebo-controlled, Double-blinded Trial of Granulocyte Colony Stimulating Factor-Mediated Neuroprotection for Acute Spinal Cord Injury (G-SPIRIT study)

Masao Koda, MD, PhD, *Masashi Yamazaki, MD, PhD*

Introduction: Granulocyte Colony Stimulating Factor (G-CSF) is generally used for neutropenia. Previously, we showed through the animal experiments that G-CSF promoted neurological recovery after spinal cord injury (SCI) via various mechanisms. Next we moved to early phase of clinical trials. In a phase 1/2a trial, no adverse events were observed. Next, we conducted a non-randomized, non-blinded, comparative trial, which suggested the efficacy of G-CSF for promoting neurological recovery.

Materials and Methods: The current trial included cervical SCI (severity of American Spinal Injury Association (ASIA) Impairment Scale (AIS) B or C) within 48 hours after injury. Patients were re-assessed for neurological status at 48 hours after injury, and those whose palsy is AIS B or C were enrolled. Patients are randomly assigned to G-CSF and placebo groups. The G-CSF group was administered 400 μg/m2/d×5d of G-CSF in normal saline via intravenous infusion for 5 consecutive days. The placebo group was similarly administered a placebo. Allocation was concealed between blinded evaluators of efficacy/safety and those for laboratory data, as G-CSF markedly increases white blood cell counts that can reveal patient treatment. Efficacy and safety was evaluated by blinded observer.Our primary endpoint was changes in ASIA motor scores from baseline to 3 months after drug administration. Each group includes 44 patients (88 total patients). Our protocol was approved by the Pharmaceuticals and Medical Device Agency in Japan and this trial is funded by the Center for Clinical Trials, Japan Medical Association.

Results: There was no significant difference in the primary endpoint, acquired points of ASIA motor score 3 months after drug administration, between the G-CSF and the placebo control groups. In contrast, one of the secondary endpoints showed that the ASIA motor score 6 months ($p=0.062$) and 1 year ($p=0.073$) after drug administration tend to be higher in the G-CSF group compared with the placebo control group ($p=0.13$). Moreover, in patients aged over 65 years old, motor recovery 3 months after drug administration tend to be better in the G-CSF treated group ($p=0.094$) compared with the placebo group.

Conclusion: The present trial failed to show significant effect of G-CSF in primary endpoint. However, sub-analysis showed suggestive efficacy of G-CSF in elderly population.

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Presentation #31

Bioengineered SMaRT Human Neural Stem Cells to Degrade Scar and Enhance Regeneration in Chronic Spinal Cord Injury

Christopher Ahuja, MD, *Mohammad Khazaei, MD, James Hong, PhD, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: Human induced pluripotent stem cell-derived neural stem cell (hiPS-NSC) therapies are highly-promising for chronic spinal cord injury (cSCI) as NSCs are the only cell type capable of differentiating into neurons, oligodendrocytes, and astrocytes(1). Unfortunately, in chronic injuries a dense perilesional chondroitin sulfate proteoglycan(CSPG) scar significantly impairs any regeneration(Fig.1A)(1). Scar-modifying enzymes can enhance recovery, however, intrathecal catheter injection increases the risk of off-target CNS effects. Therefore, we aimed to generate a novel, genetically-engineered line of hiPS-NSCs, termed Spinal Microenvironment Modifying and Regenerative Therapeutic(SMaRT) cells, capable of expressing a scar-degrading enzyme directly into their local microenvironment to safely enhance recovery.

Materials and Methods: hiPS-NSCs were differentiated to NSCs by dual-SMAD inhibition(2,3). Using CRISPR-Cas9, a proprietary scar-degrading enzyme was genetically integrated under a doxycycline-inducible Tet-ON promoter(Fig. 1B)(4). A monoclonal line of resultant SMaRT cells was selected by cell sorting(FACS), morphology assessment, inducible reporter-expression, and biochemical assays(5).T-cell deficient rats underwent a translationally-relevant C6-7 contusion-compression injury(Fig. 2A). After 9 weeks, animals were randomized to: (1) wild-type hiPS-NSCs, (2) SMaRT enzyme-expressing hiPS-NSCs(dox+), (3) SMaRT hiPS-NSCs(dox-), or (4) vehicle-only control. Animals received doxycyline (10-16wks), treadmill rehabilitation (13-20wks), and a biweekly battery of neurobehavioural tests until sacrifice at 20wks post-injury(Fig. 2C). A subset of non-behavioural animals underwent lineage tracing by transplanting different colors of fluorescent cells into the injury epicenter, rostral sites, or caudal sites respectively. An additional subset of animal cords underwent high-throughput single-cell RNA sequencing (scRNAseq) of both host rat and grafted human cells.

Results: The scar-degrading enzyme and fluorescent reporter are inducibly expressed by transgenic SMaRT cells(Fig. 1D). SMaRT cells retain key human NSC characteristics including the capacity to spontaneously form neurospheres(Fig. 1C) and differentiate along all three neuroglial lineages(Fig. 1F). The enzyme expressed by SMaRT cells appropriately degrades CSPGs in vitro and allows GFP+ human NSCs to extend into CSPG-dense scar-like areas after 7 days in culture(Fig. 1G). Conditioned SMaRT cell media also rapidly degrades in situ rodent CSPGs in ex vivo injured spinal cord cryosections(Fig. 1E). Activated SMaRT cells significantly improve forelimb grip strength (751±58 vs 404±55g vehicle; $p<0.01$)(Fig. 2B). Grafted human cells are also extending remarkably long (cervicomedullary junction to mid-thoracic) axons through rodent white matter(Fig. 2D). Lineage tracing shows that grafts can extend across the injury site(Fig. 2E). Numerous human cells stain for mature neuron marker, NF200, and growth associated protein, GAP43, suggestive of active axonal growth long after transplant(Fig. 3B). Grafted cells also demonstrate differentiation to oligodendrocytes(Fig. 3C/D). Preliminary scRNAseq results suggest that SMaRT oligodendrocytes express higher levels of myelin-assembly protein, annilin, and

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SMaRT neurons express higher galectin-3, an axon pathfinding protein.

Conclusion: This work provides exciting proof-of-concept data that genetically-engineered SMaRT cells can degrade CSPGs in vitro and that human NSC grafts can form long axonal processes in the typically inhibitory chronic cervical SCI niche. SMaRT cells hold the potential to be the first effective regenerative therapy for individuals with chronic spinal cord injury where even modest motor recovery can have tremendous implications for quality of life.

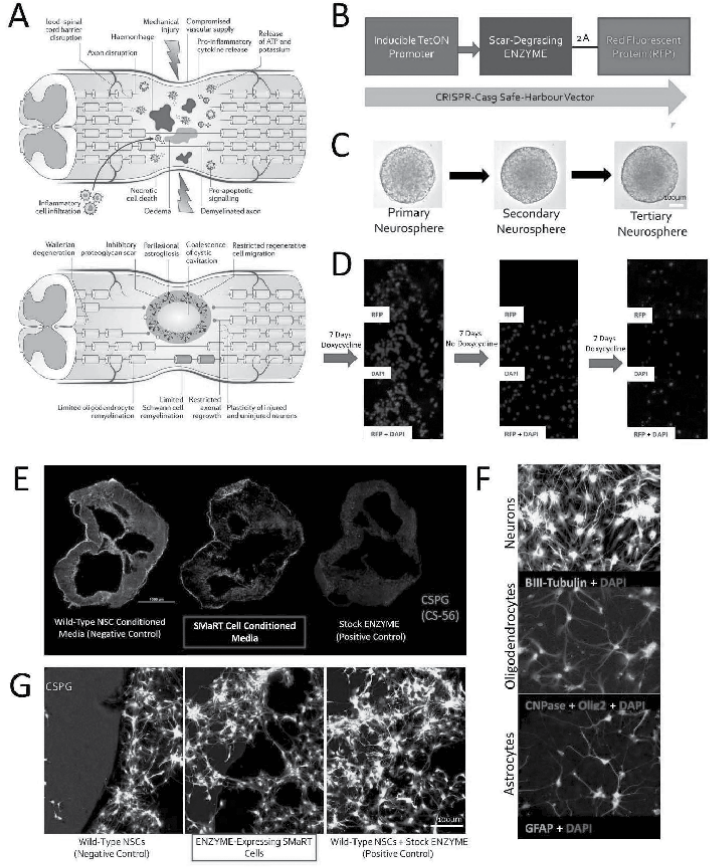

Figure 1. Generation and characterization of enzyme-expressing SMaRT human iPS-NSCs. (A) Human SCI is characterized by an acute phase (top) and a chronic phase (bottom) where dense CSPG scar inhibits regeneration. (B) CRISPR-Cas9 Tet-ON promoter construct driving expression of the scar-degrading enzyme and RFP reporter. (C) SMaRT cells can form neurospheres, (F) demonstrate tripotency, and (D) inducibly express the enzyme-RFP transgenes. (E) Unlike wild-type NSCs, SMaRT cells can degrade in situ CSPGs and (G) allow growth into CSPG-dense scar-like regions.

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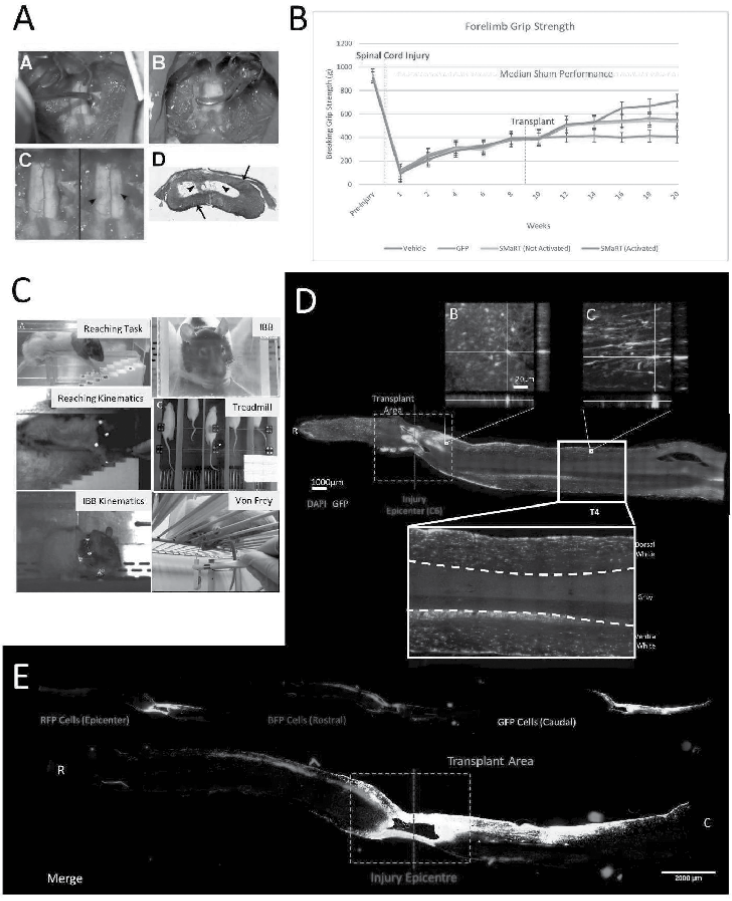

Figure 2. In vivo and ex vivo assessments. (A) Illustration of clip-contusion cervical SCI model (modified from Wilcox J, et al.[6]) and (C) behavioural assessment techniques. (B) Grip strength assessments from pre-injury to 22 weeks post-injury (N=50 at 22 weeks). (D) Sagittal chronic spinal cord cryosection demonstrating graft-derived (GFP$^+$; Green) processes extending from C2 to the mid-thoracic cord along white matter. (E) Lineage tracing demonstrating grafts extending across the injury epicenter.

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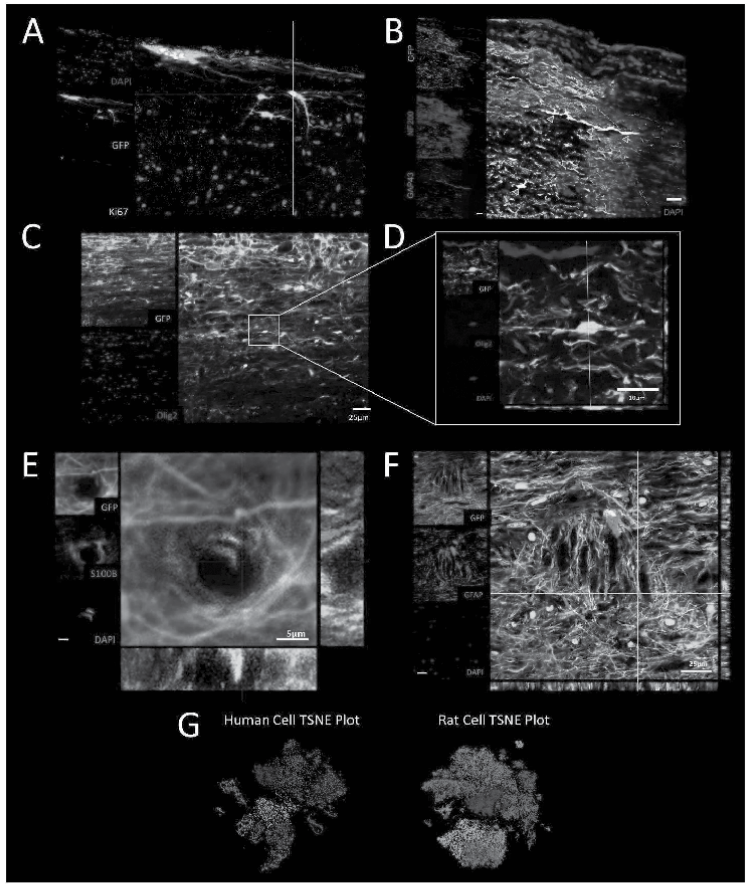

Figure 3. IHC Assessments. (A) Grafted (GFP⁺; green) cells survive without tumor formation or proliferation in NOD-SCID mice at 6 months. (B) Human axons express mature neuronal marker, NF200⁺ (red), including a proportion expressing growth associated protein, GAP43⁺ (purple). (C, D) Subpopulations of grafted cells express oligodendrocyte marker, Olig2⁺ (red). (E) Human grafts are associated with capillary-like BSCB structures (S100B⁺, purple) and (F) glial scar-like rat astrocytes (GFAP⁺; purple). (G) TSNE plots of dissociated human and rat scRNAseq-derived clusters demonstrating cluster separation.

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Presentation #32

Human Cervical Spinal Cord-Specific Neural Progenitor Cells Support Functional Recovery after Cervical Spinal Cord Injury

Mohammad Khazaei, MD, *Christopher Ahuja, MD, Amirali Toossi, PhD, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: Transplantation of neural progenitor cells (NPCs) is a promising therapeutic strategy for traumatic spinal cord injury (SCI). NPC-derived neurons have the potential to integrate into endogenous neural networks and reestablish interrupted neuronal pathways. Despite recent progress, the level of graft-host integration and the degree of trans-segmental relay circuits regenerated by the transplanted neurons has been modest. This is due to the difference in the identity of transplanted cells with the identity of spinal cord tissue. To date, almost all pluripotent cell-derived NPCs used for transplantation into the spinal cord have possessed forebrain identity. These cells terminally differentiate into neuronal cell types (cortical glutamatergic neurons and cholinergic neurons) which don't developmentally reside in the cervical spinal cord and are not able to differentiate to functionally essential cells that are lost in spinal cord including ventral motor neurons and spinal interneurons.In this study, we have generated specific NPCs for the cervical spinal cord injury (csNPC) that express spinal Hox genes and can generate functional motor-neurons and V2a-interneurons. We compared the efficacy of csNPCs to the conventional NPCs with a forebrain identity (fbNPCs) in the treatment of cervical SCI.

Materials and Methods: We generated fbNPCs from a human-induced-pluripotent stem cell (hiPSC) using established methods. The csNPCs were derived from hiPSCs using a unique protocol. Briefly, we applied a temporal and graded interplay of FGF, retinoic acid, WNT, BMP, and Shh to simultaneously balance the rostral-caudal and dorsoventral differentiation profile of the culture. To assess the in-vivo efficacy, the cells were transplanted into T-cell-deficient RNU rats with cervical-SCI at two weeks post-injury, and differentiation of cells to neurons, their synaptic connectivity, and integration into tissue was analyzed.

Results: Our data suggest that csNPCs are highly neurogenic in-vivo where the proportional differentiation of NPCs to neurons was significantly higher for csNPCs compared to fbNPCs. All transplanted csNPC continue expressing spinal Hox genes while only undifferentiated fbNPC keep expressing FoxG1 and Otx2, the brain-identity markers (Fig.1). csNPC-derived neurons predominantly adopted excitatory neuronal fates. They generated a variety of spinal interneuronal subtypes, including Chx10+ excitatory V2a interneurons, FoxP1+ excitatory neurons, Chat+ motor neurons, and premotor interneurons. Transplantation of csNPCs results in significantly better synaptic and electrical integration with the endogenous spinal network leading to enhanced functional recovery, compared to that of the fbNPCs. At 8 weeks post-transplantation, the recovery of the forelimb strength was significantly better in csNPCs compared to fbNPCs. Furthermore, gait parameters were significantly improved in rats transplanted with csNPCs but not for fbNPC group (Fig.2).

Conclusion: This study demonstrated that csNPCs integrated better with the spared networks of the spinal cord and resulted in superior functional recovery from SCI compared to fbNPCs.

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These data represent the first application of highly region-specific human NPC transplants that represent a key step in optimizing NPC-transplantation treatments for SCI. The ability to transplant NPCs with the exact regional identity of the injured spinal cord (in this case cervical) moves us closer to the development and translation of targeted and optimal stem cell therapy for individuals living with the sequelae of traumatic-SCI.

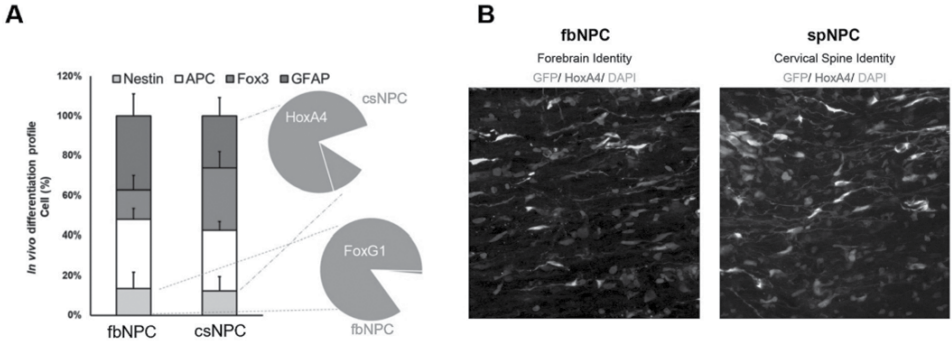

Fig1:
A) At 8 weeks post transplantation, csNPCs showed more differentiation into neurons, in vivo, however, a proportion of cells in both lines remained in an undifferentiated Nestin positive state. **B)** csNPCs were differentiated to HoxA4 positive cell.

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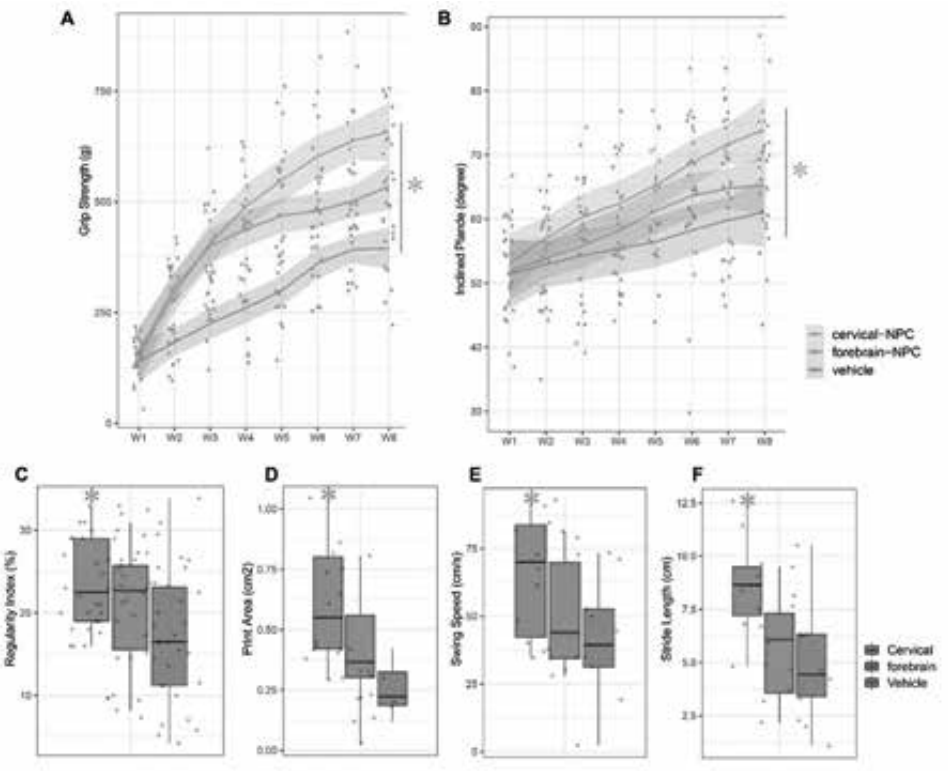

Fig 2:
Transplantation of csNPCs resulted in better functional recovery. **A, B)** Forelimb strength and trunk stability were assessed with grip strength and inclined plane behavioral tasks. * $p < 0.05$ compared to vehicle, repeated measures two-way NAOVA. **C-F)** Digital gait analysis shows significantly better forelimb stride length and swing speed recovery for csNPCs compared to fbNPCs. * $p < 0.05$ compared to vehicle, two-way NAOVA.

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Presentation #33

Quantifying the interplay between translations of the intervertebral discs and facet joints in the cervical spine

Haiming Wang, MD, Chaochao Zhou, PhD, Yan Yu, MD, Cong Wang, MS, Tsung-Yuan Tsai, PhD, Chaofan Han, MD, Guoan Li, PhD, ***Thomas Cha, MD***

Introduction: Functional neck motion is achieved by the cervical segments, each of which is composed of an intervertebral disc (IVD) and two facet joints (FJs). It is widely acknowledged that the abnormality or surgical treatment of one joint could cause biomechanical changes in other joints. Most previous studies investigated the intervertebral joints with few on the FJs. In this study, we quantified the relationship between the ranges of sliding motion of the IVDs and FJs of human cervical spine during various functional neck motions.

Materials and Methods: Eighteen asymptomatic subjects (7 males and 11 females; age: 40.5±10.9 years) were included in this study. The cervical spines were scanned using MRI or CT to construct 3D models of the vertebrae from C3 to C7. A dual fluoroscopic imaging system was used to image the cervical spines, when the subjects performed three functional neck motions: flexion-extension (FE), lateral-bending (LB), and axial twisting (AT). A manual 2D-3D registration method validated previously was used to reproduce the in vivo positions/alignment of the neck. During the registration, each 3D model was independently translated and rotated, until their projections coincided with the osseous outlines/features captured on the biplanar fluoroscopic images. The translational ranges of motion (ROMs) of both the IVDs and FJs at each cervical segment in the anterior-posterior (AP), left-right (LR), and proximal-distal (PD) directions were calculated according to local coordinate systems of both joints (Fig. 1). Furthermore, we introduced an IVD-FJ translation ratio, which represents the ratio of the IVD translational ROM to the FJ translation ROM. A repeated-measures analysis of variance (ANOVA) was used to compare the IVD-FJ translation ratio among different segments.

Results: As shown in Table 1, the primary translations of both the IVD and FJs occurred in the sagittal plane during all neck motions and the AP translations of the facets were significantly greater than those of the corresponding IVD joints ($p < 0.05$) at all segments. In EF neck motion, the IVD-FJ AP translation ratios decreased from the proximal to distal levels. In LB neck motion, the smallest IVD-FJ translation ratios occurred at C4/5 for both AP and LR translations. In AT neck motion, the largest IVD-FJ AP translation ratio that occurred at C3/4 was significantly different from those at C4/5 and C5/6 ($p < 0.05$).

Conclusion: From a structural point of view, FJs are more mobile than IVDs in sliding motion. Our study quantified the relationship of the sliding ranges of both joints, and further reinforced the notion that the IVD and the FJs coordinate with each other during functional neck motions; segmental motion is primarily constrained by the disc and is guided by the FJ articulation. Furthermore, there were statistically significant differences in the IVD-FJ translation ratios among different segment levels. These data could be used as references for improving motion-preserving cervical treatment methods to achieve the normal ranges of sliding motion of both IVD and FJs.

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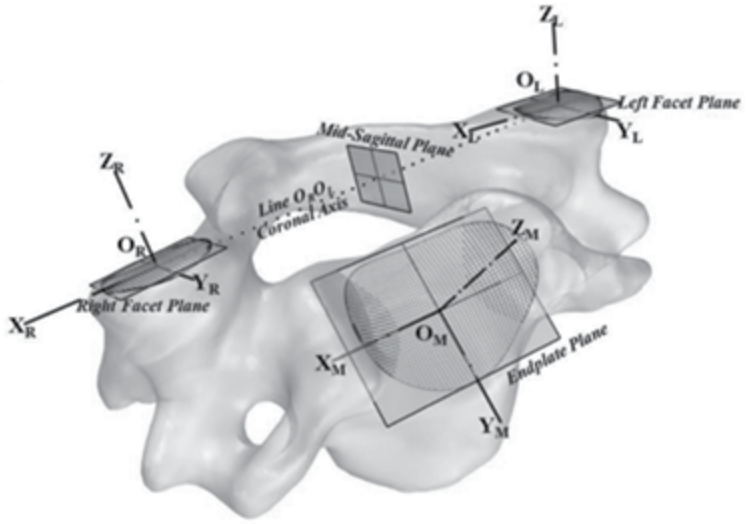

Fig. 1. The local coordinate systems of the IVD and FJs used to measure joint translations. The centroid of each surface was chosen as the origin of the coordinate system. The left-right direction was defined by connecting the two centroids of the left and right facet surfaces. The plane perpendicular to the left-right direction was then defined as the sagittal plane for all joints.

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Table 1. The translational ROMs (mm) of the IVD and facet joints as well as the IVD-facet translation ratios at each cervical segment in EF, LB, and AT neck motions. A smaller ratio indicates a greater facet joint ROM relative to the IVD ROM at the same segment.

		AP Translation			LR Translation			PD Translation		
		IVD	FJ	Ratio	IVD	FJ	Ratio	IVD	FJ	Ratio
Neck Flexion-Extension	C3/4	**2.7±0.7**	**3.5±1.1**	0.81±0.18^{b,c,d}	**1.3±0.8**	**1.6±0.6**	0.77±0.35^{b,d}	1.1±0.5	1.3±0.6	0.85±0.38
	C4/5	**3.2±0.6**	**4.6±1.0**	0.72±0.15^{d}	1.1±0.5	1.1±0.4	1.00±0.33	**0.8±0.6**	**1.2±0.4**	0.65±0.35^{d}
	C5/6	**2.2±0.8**	**3.9±1.2**	0.61±0.27	**1.0±0.5**	**1.2±0.5**	0.83±0.23	1.0±0.5	1.4±0.6	0.84±0.48
	C6/7	**1.6±0.5**	**3.2±1.0**	0.52±0.19	1.0±0.4	1.0±0.4	1.00±0.31	1.1±0.5	1.2±0.4	0.95±0.53
Neck Lateral Bending	C3/4	**0.9±0.5**	**4.6±1.1**	0.20±0.09^{b}	**1.6±0.6**	**2.2±0.7**	0.72±0.20^{b,c}	**0.6±0.3**	**1.0±0.4**	0.62±0.33^{b,d}
	C4/5	**0.5±0.3**	**3.9±1.0**	0.14±0.09^{d}	**1.0±0.7**	**2.2±0.8**	0.43±0.30^{d}	1.1±0.8	1.1±0.4	1.13±0.92^{c}
	C5/6	**0.7±0.4**	**3.7±0.3**	0.20±0.10	**0.8±0.5**	**1.7±0.7**	0.50±0.30^{d}	**0.7±0.3**	**1.2±0.5**	0.63±0.50^{d}
	C6/7	**0.7±0.4**	**3.3±1.0**	0.23±0.12	1.1±0.7	1.4±0.7	0.90±0.48	1.1±0.5	1.3±1.1	1.19±0.76
Neck Axial Twisting	C3/4	**1.0±0.5**	**3.1±1.0**	0.42±0.21^{b,c}	**1.1±0.6**	**2.3±0.7**	0.75±0.34	0.7±0.4	0.8±0.3	0.91±0.40
	C4/5	**1.1±0.4**	**4.1±0.6**	0.34±0.13	**0.9±0.4**	**2.1±0.6**	0.60±0.23	0.6±0.3	0.9±0.4	0.90±0.56
	C5/6	**0.7±0.3**	**3.7±1.0**	0.29±0.12	**1.6±0.8**	**2.0±1.3**	0.83±0.65	**0.6±0.2**	**1.1±0.4**	0.69±0.42^{d}
	C6/7	**0.6±0.4**	**3.2±1.3**	0.32±0.20	**1.0±0.4**	**1.3±0.8**	1.07±1.08	1.1±0.7	1.0±0.4	1.04±0.56

Note: (1) Bold values indicate statistically significant differences (p<0.05) between the translational ROMs of the IVD and FJs at the cervical segments. (2) For ratios, the significant inter-level differences (p<0.05) were indicated by the subscript letters, in which letters a, b, c, and d represent C3/4, C4/5, C5/6, and C6/7, respectively.

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Presentation #34

REMOTE ISCHEMIC PRECONDITIONING AMELIORATES ISCHEMIA REPERFUSION INJURY ASSOCIATED WITH DECOMPRESSION SURGERY FOR DEGENERATIVE CERVICAL MYELOPATHY

James Hong, PhD, *Hiroyuki Katoh, MD, PhD, Kazuya Yokota, MD, PhD, Pia Vidal, PhD, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: Degenerative cervical myelopathy (DCM) is caused by progressive compression of the cervical spinal cord(1). Surgical decompression (DEC), while effective in most cases, results in ischemia reperfusion injury (IRI) and hinders a return to baseline function (2, 3). Remote ischemic preconditioning (RIPC) is a non-invasive intervention that uses transient ischemia distal to the site of injury to protect the host from ischemic insult (4). In this study, we posit that RIPC prior to DEC will enhance neurological recovery through the amelioration of DEC-induced IRI.

Materials and Methods: DCM was induced in mice and at 12-weeks they either underwent: 1) hindlimb RIPC prior to DEC; or 2) DEC alone ($n = 50$, respectively). Acute (24h post-DEC) and chronic (5wk post-DEC) cohorts were subjected to molecular (Luminex, Western blot, RNA-seq) and behavioral analysis (Catwalk).

Results: Acutely, RIPC resulted in a significant decrease of nearly all proinflammatory markers relative to DEC alone (Fig 1, $p < 0.05$). Chronically, RIPC animals significantly outperformed both DEC and DCM groups in multiple gait metrics including body speed, stride length, cadence, and stand duration (Fig 2, $p < 0.05$). RNA-seq revealed that RIPC negated the change of thousands of DEC-associated genes, and resulted in the differential expression of transcripts associated with neutrophil activation and degranulation of lytic vacuoles suggesting a role of RIPC in altering the neutrophil response to IRI following DEC (Fig 3).

Conclusion: In conclusion, RIPC when performed prior to DEC, reduces neuroinflammation and confers robust long-term neurological recovery relative to DEC alone. As a non-invasive procedure, RIPC can complement DEC for rapid translation into the clinic.

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Figure 1. RIPC as a prophylaxis to DEC results in an overall reduction in A) inflammatory cytokines/chemokines; B) cleaved caspase-3, and C) albumin in the spinal cord

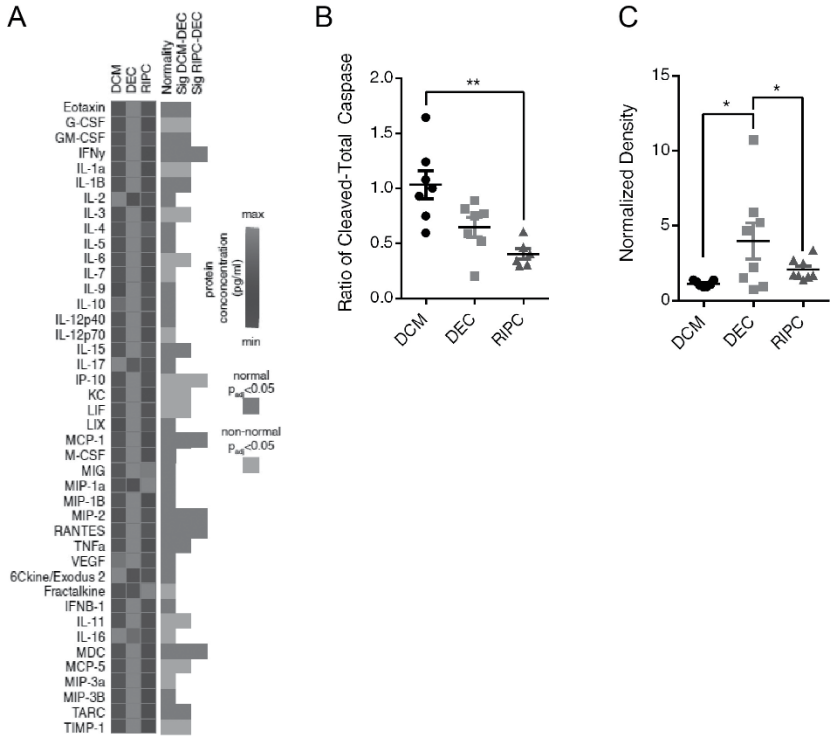

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Figure 2. RIPC as a prophylaxis to DEC results in a return to functional baseline in multiple Catwalk gait metrics

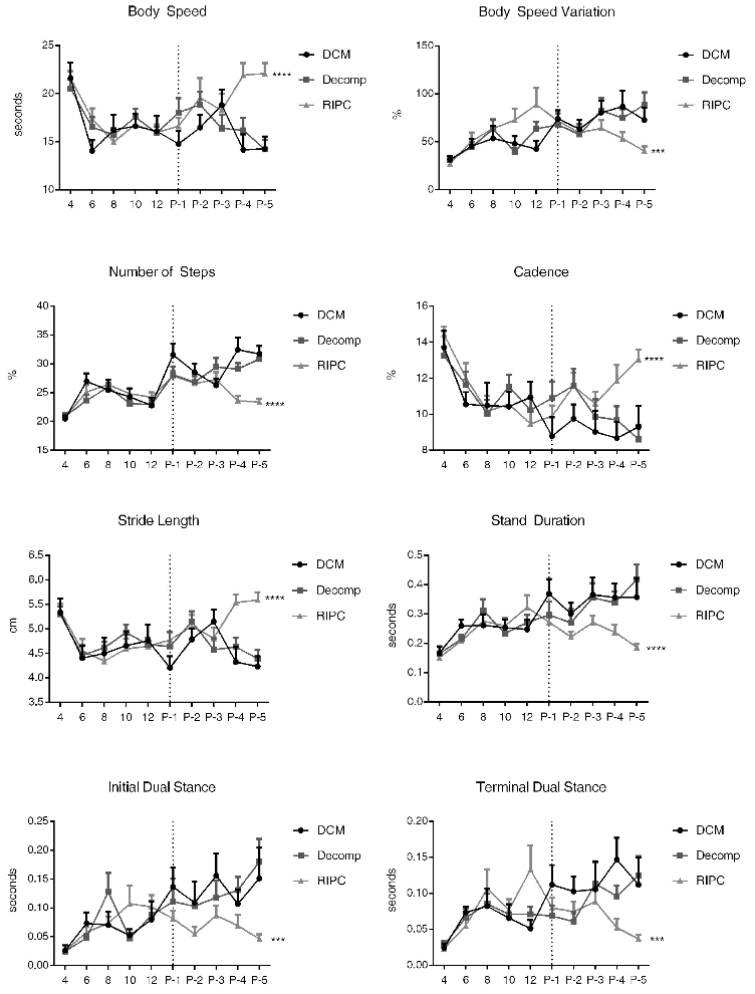

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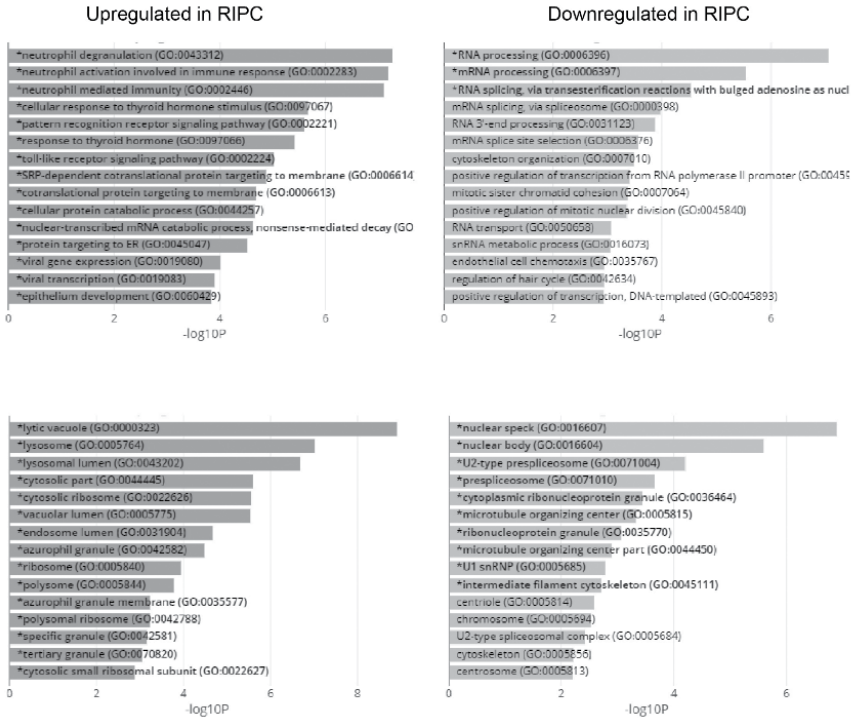
Figure 3. RIPC as a prophylaxis to DEC results in transcriptional changes corresponding to neutrophil activation and degranulation of lytic vacuoles

Top 7 differentially-expressed genes

Gene	logFC	AveExpr	P.value
Gpx3	0.54	5.22	0.000035
Lgals3	0.97	3.52	0.000035
Dbn	0.55	6.75	0.000086
C1qa	0.52	6.67	0.000118
Gm9800	1.76	0.60	0.000137
Cd9	0.38	6.12	0.000162



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Presentation #35

The efficacy of C5a receptor antagonist for human iPSC-derived neural stem/progenitor cell transplantation in the injured spinal cord of mice

Reo Shibata, MD, *Narihito Nagoshi, MD, Keita Kajikawa, MD, Yasuhiro Kamata, MD, Michael Fehlings, MD, PhD, FRCSC, FACS, Morio Matsumoto, MD, Hideyuki Okano, MD, Masaya Nakamura, MD*

Introduction: We previously reported the efficacy of human-iPS derived neural stem/progenitor cell (hiPSC-NS/PC) transplantation for spinal cord injury (SCI) in the subacute phase. However, this procedure is not effective in the acute phase due to the inflammatory response occuring immediately after SCI, which weakens transplanted cell survival and differentiation. C5a, which is one of the complement components, is a powerful chemoattractant and recruits inflammatory cells through binding C5a receptor. Therefore, the objective of this study is to suppress the inflammatory response immediately after SCI using C5a receptor antagonist (C5aRA) as an immunosuppressant, thus being enable to do effective transplantation of hiPSC-NS/PC for SCI in acute phase (Fig1).

Materials and Methods: We used immuodeficient SCID-Beige mice that lack lymphocytes and NK cells. First, to evaluate the influence of C5aRA on the inflammatory response post-SCI, we induced a thoracic spinal contusion injury in mice. We quantified inflammatory cytokines and inflammatory cells in injured spinal cord tissues using quantitative PCR, RNA sequence, and flow-cytometry. Next, we divided the SCI mice into 4 groups (PBS only, C5aRA only, PBS + transplantation (PBS+TP), C5aRA + transplantation (C5aRA+TP)). Immediately after SCI, C5aRA or PBS was administrated once a day for 4 consecutive days, and then, 5.0 $\times$ 105 hiPSC-NS/PCs were transplanted into the lesion epicenter on day 4 after SCI. We evaluated cell survival rate by Bioluminescent Imaging (BLI), hindlimb motor function by BMS score, and the differentiation profile of the graft hiPSC-NS/PCs by immunohistochemistry.

Results: C5aRA administration significantly reduced IL-1b, IL-6 and TNFa at 12 hours and neutrophils and macrophages at 4 days after SCI ($p<0.05$). RNA sequence revealed that C5a inhibition reduced several inflammatory cytokines at 12 hours after SCI and apoptotic marker at 4days after SCI. The figure2 showed that the C5aRA+TP group had better locomotor functional improvement as compared to the PBS only group ($p<0.05$)(Fig2). As shown in the figure3, BLI revealed that the C5aRA+TP group had a significantly higher cell survival rate compared to the PBS +TP group ($p<0.05$)(Fig3). There was no significant difference in the differentiation profiles of the graft hiPSC-NS/PCs between C5aRA+TP group and PBS+TP group.

Conclusion: The present study demonstrated that administration of C5aRA suppress the inflammatory response during the acute phase of SCI, and also improve the survival rate of transplanted hiPSC-NS/PCs and enhance motor functional restoration. The combination therapy of hiPSC-NS/PCs transplantation and C5aRA are a promising treatment for acute phase SCI patients.

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Fig1

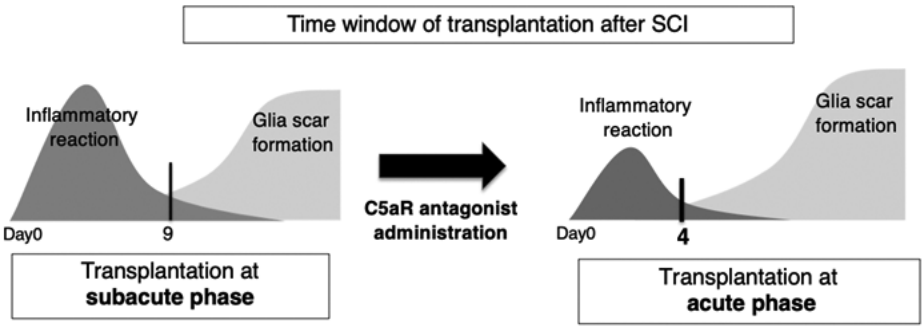
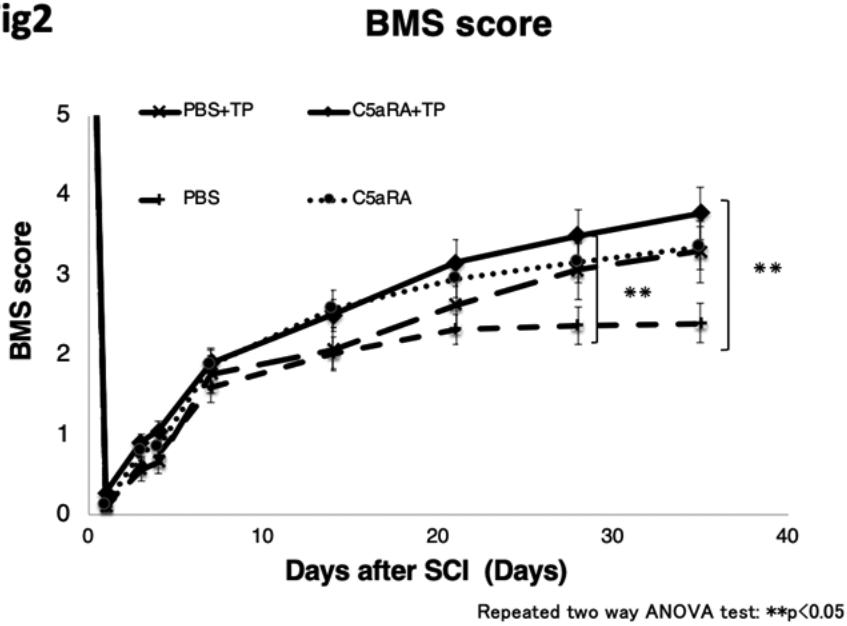


Fig2



Repeated two way ANOVA test: **p<0.05

Hindlimb motor function was assessed weekly by the BMS score.

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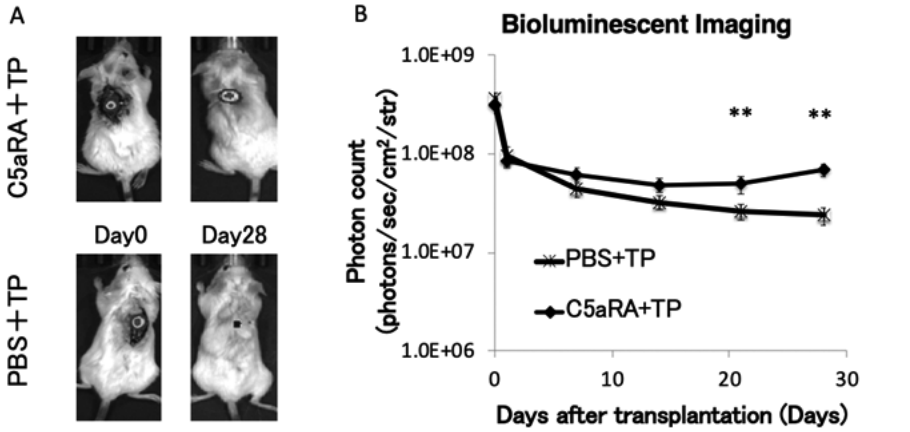
Fig3



A: Representative in vivo BLI of PBS+TP and C5aRA+TP group mice.
B: Quantification of photon count of both PBS+TP and C5aRA+TP group mice.

Repeated two way ANOVA test: **p<0.05

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #36

Off-label usage of rhBMP-2 in posterior cervical fusion is not associated with early increased complication rate and has similar clinical outcomes

*Jae Hyung Eoh, MD, **Douglas Weinberg, MD,** Wesley Manz, BA, Omolola Fakunle, BS, Alexander Dawes, BS, John Rhee, MD*

Introduction: Rh-BMP2(BMP) is frequently used off-label in posterior cervical fusion(PCF) as a bone graft substitute. However, early postoperative complications reported with its usage include compressive fluid collections, wound complications, radiculitis, and motor weakness. Much of the current literature on early complications of BMP in PCF consists of case reports, small case series, or database studies with inherent limitations. Therefore, the purpose of this study was to evaluate early postoperative complications associated with BMP in PCF, and whether BMP leads to adverse clinical outcomes.

Materials and Methods: 1313 consecutive patients who underwent PCF at a single academic center were identified using CPT codes for PCF over a 13-year period. Inclusion criteria were age>18, full documentation of perioperative complications, and minimum six weeks clinical follow-up. Exclusion criteria were PCF for malignancy, infection, and combined anterior-posterior surgery. 765 patients met criteria and formed the basis of this study. Surgical data, including preoperative diagnosis, levels fused, type of bone graft, BMP dose, and fusion technique were recorded.

Complications were assessed by reviewing the medical record encompassing the first 6-weeks postoperative. These included medical, neurological, and wound complications, and reoperation. Neurological complications were defined as any new weakness, radicular pain, or numbness. Patient reported clinical outcomes(PROs) included: SF36, VAS, EQ-5D and NDI scores.

Results: Average patient age was 65, 362 were male(47%). Mean operative time was 201 minutes, EBL 290mL, average of 4.1 levels fused. Myelopathy was the most common diagnosis(90%); others included pseudarthrosis, deformity, trauma.

Of the 765 patients undergoing PCF, 240(32%) had BMP and 525 had NOBMP. Other grafts included allograft(n=121,16%), DBM(31,4%), local bone(612,80%) and ICBG(191,25%).

BMP was placed strictly intra-facet(IF) and backfilled with bone so that BMP was not directly exposed to the epidural space in 149(62%) patients, and outside of the facet(extra-facet; EF) in 91 patients. Average dosing of BMP was 1.25mg/level fused.

There were no differences between the BMP and NOBMP groups with respect to wound complications, fluid collection, motor weakness, new radiculopathy, or reoperations within 6 weeks postoperative. Univariate analysis is shown in Table 1a; and no differences were noted on multivariate analysis($p>0.05$).

In the BMP group, univariate and multivariate sub-analysis showed that higher doses of BMP($p=0.04$), and BMP placed EF($p=0.04$), were significantly associated with increased wound complications vs BMP placed IF(Table 1b)

With respect to PROs(SF36, VAS, EQ-5D and NDI), univariate/multivariate analysis demonstrated

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no difference in outcomes between BMP and NOBMP($p<0.05$).

Conclusion: In a large consecutive series of PCF, BMP was not associated with a higher rate of early complications. Complications thought to be associated with BMP—compressive seroma, radiculitis, weakness, and wound complications—were not seen at a higher rate compared to the NOBMP group. PROs at early follow-up were similar between BMP and NOBMP. However, sub-analysis demonstrated that IF placement of BMP—usage of smaller doses, may lead to fewer wound complications. Future studies will need to assess long-term complications, outcomes, cost-effectiveness, and efficacy in achieving fusion. However, on the basis of this study, we conclude BMP can be used in PCF with no increase in early complication rate and similar early clinical outcomes.

Table 1a: Overall Complication Rates: BMP vs NOBMP

	BMP (n=240)		No BMP (n= 525)		*p*-value	Total (n=765)	
Total Complications	43	17.9%	93	17.7%	0.95	136	17.8%
Card/Pulm	8	3.3%	13	2.5%	0.50	21	2.7%
GI	0	0.0%	6	1.1%		6	0.8%
Neuro	24	10.0%	52	9.9%	0.97	76	9.9%
N - Motor	15	6.3%	37	7.0%	0.68	52	6.8%
N - C5 Palsy	10	4.2%	20	3.8%	0.81	30	3.9%
N - Pain	6	2.5%	18	3.4%	0.49	24	3.1%
N - Numbness	4	1.7%	4	0.8%	0.25	8	1.0%
Swelling	2	0.8%	1	0.2%	0.19	3	0.4%
Fluid Collection	5	2.1%	4	0.8%	0.12	9	1.2%
Wound (all wound related)	9	3.8%	17	3.2%	0.72	26	3.4%
W - Superficial Infection	4	1.7%	4	0.8%	0.25	8	1.0%
W - Deep Infection	1	0.4%	8	1.5%	0.19	9	1.2%
W - Dehiscence	2	0.9%	4	0.8%	0.92	6	0.8%
W – Prolonged Drainage	2	0.9%	1	0.2%	0.19	3	0.4%
W - Returned to OR	3	1.3%	13	2.5%	0.27	16	2.1%

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Table 1b: Overall Complication Rates with BMP Group Subanalysis: Intrafacet vs Extrafacet Placement

	Intra-Facet (n=149)		Extra-Facet (n=91)		*p*- value
Total Complications	22	14.8%	21	23.1%	0.10
Card/Pulm	4	2.7%	4	4.4%	0.47
GI	0	0.0%	0	0.0%	
Neuro	13	8.7%	11	12.1%	0.40
N - Motor	9	6.0%	6	6.6%	0.86
N - C5 Palsy	7	4.7%	3	3.3%	0.85
N - Pain	3	2.0%	3	3.3%	0.54
N - Numbness	1	0.7%	3	3.3%	0.12
Swelling	2	1.3%	0	0.0%	
Fluid Collection	3	2.0%	2	2.2%	0.92
Wound (all wound related)	2	1.3%	7	7.7%	<0.01*
W - Superficial Infection	0	0.0%	4	4.4%	
W - Deep Infection	1	0.7%	0	0.0%	
W - Dehiscence	0	0.0%	2	2.2%	
W - Prolonged Drainage	1	0.7%	1	0.7%	0.72
W - Returned to OR	1	0.7%	2	2.2%	

*Extra-facet placement of BMP was associated with wound complications compared to intra-facet placement

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Presentation #37

Porous 3D printed titanium cages in ACDF are associated with less settling, and similar clinical outcomes and fusion rates

Hardeep Singh, MD, *Nathan Kukowski, MD, Matt Lunati, MD, Alexander Dawes, BS, Chi Heon Kim, MD, PhD, John Rhee, MD*

Introduction: The ideal graft for use in ACDF remains to be identified. Recently, porous 3D printed titanium cages (3DTC) have been introduced as an option. Purported advantages over PEEK cages include a highly porous architecture mimicking cancellous bone which may promote osteoblastic ingrowth while maintaining structural strength. Additionally, the relatively larger footprint compared to standard allografts may lead to better load sharing and less subsidence. The purpose of this study was to investigate radiographic and clinical outcomes of 3DTC versus allograft in patients undergoing ACDF.

Materials and Methods: A consecutive series of patients undergoing ACDF with 3DTC (Stryker Tritanium C; Kalamazoo, MI) were compared to patients using fresh frozen machined corticocancellous allograft (VG2; Lifenet, Virginia Beach, VA). All patients had supplemental DBM and plating. Radiographic evaluation was performed on the closing intraoperative lateral xray, then compared to postoperative films at 6 weeks, 6 months, and 1 year. Cage subsidence was calculated based on the amount of settling into the superior and inferior endplates compared to the intraoperative x-ray. Fusion was assessed based on $<$ 1mm of flexion/extension motion on x-rays at 6 months and 1 year, in the absence of implant failure and lucent lines. Three observers performed the measurements independently, and the measurements were normalized based on the magnification at each time point. Inter-rater reliability was measured. Patient reported outcomes included SF36, VAS Pain, EQOL, and NDI.

Results: 44 patients (72 levels) in the 3DTC group and 48 patients (72 levels) in the allograft group were evaluated. No significant differences were noted in patient demographics with respect to age, sex, race, BMI, smoking status, or Charlson Comorbidity Index (CCI). The most common level fused was C5-6. No significant differences were noted with respect to the level that was fused or the number of levels fused between the groups. 3DTC had a significantly lower subsidence rate at all time points as compared to allograft at 6 weeks (0.91mm vs. 1.2mm), 6 months (1.53mm vs. 2.04mm), and 1 year (1.96mm vs. 2.45mm) ($p<0.05$). No significant differences were noted in fusion rate for 3DTC versus allograft at 6 months (56.02% vs. 65.20%, $p=0.13$) and 1 year (74.31% vs. 85.80%, $p=0.16$). There were also no significant differences in patient reported outcomes with respect to Euro QOL, NDI, VAS Pain, and SF36 scores. Intraclass Correlation Coefficient was 0.858 (95% CI: 0.819-0.891), and Cronbach Alpha was 0.948, suggesting a high degree of measurement reliability between the three observers and excellent internal consistency.

Conclusion: 3DTC had similar patient-reported outcomes and fusion rates as allograft, but less subsidence at all time points. The difference in subsidence was small but statistically significant. Although longer term evaluation is needed, based on these results, 3DTC appear to be viable graft options for ACDF that better maintain disc space height.

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Table 1. Demographic Table

	Graft Type		P-value
	3DPTC	Allograft	
Total Patients N (%)	72 (50%)	72 (50%)	
Age[2]	57.6±10.8	58.2±12.5	0.84
Sex[1] M:F	39:38	27:46	0.13
Race[1] N (%)			0.99
White	59 (77%)	56 (77%)	
Black	17 (22%)	16 (22%)	
Asian	1 (1%)	1 (1%)	
BMI[2]	29.6±6.8	29.6±6.5	0.96
Current Smoker[1] N (%)	8 (10%)	3 (4%)	0.32
Hypertension[1] N (%)	18 (23%)	16 (22%)	0.18
Anxiety/Depression[1] N (%)	8(10%)	5 (7%)	0.71
Charlson Comorbidity Index (CCI)[2]	1.74±1.24	1.55±1.48	0.19

[1]Analysis conducted using student's t-test
[2] Analysis conducted using Fisher's Exact Test

Table 1: Table outlining the demographics of the patients analyzed in the study; illustrates no significant difference amongst the two groups.

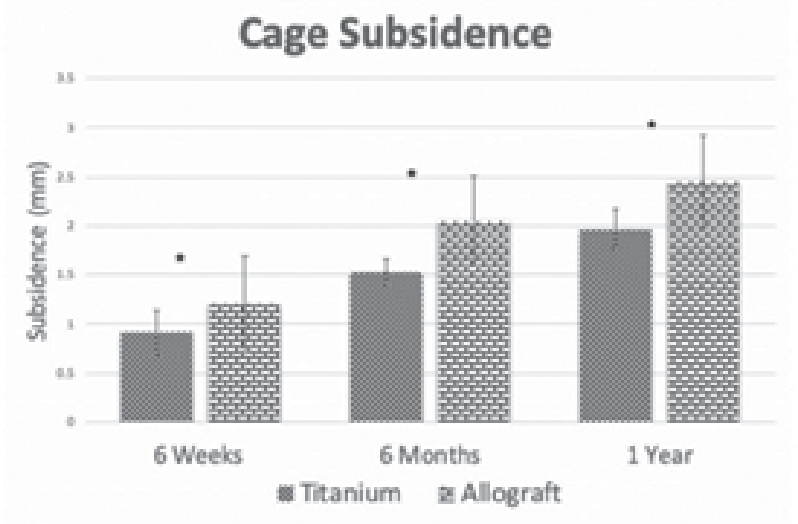

Figure 1: Illustrates the cage subsidence at 6 weeks, 6 months, and 1 year, all statistically signficiantly lower for Titanium versus Allograft ($p<0.05$). (* = statistical difference).

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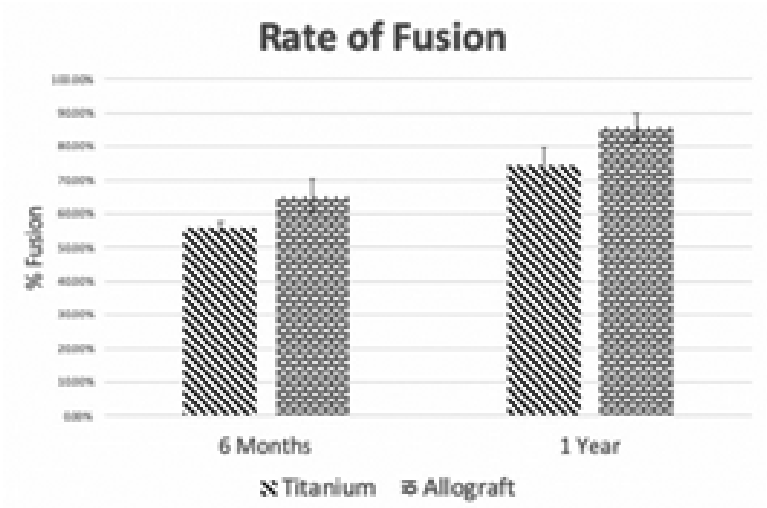

Figure 2: Fusion at 6 months and 1 year based on < 1mm flexion-extension motion with no lucent lines or implant failure. No significant difference was noted (p>0.05) between the two groups at either timepoint.

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Presentation #38

A Matched Cohort Analysis of Drain Usage in Elective Anterior Cervical Discectomy and Fusion: A Michigan Spine Surgery Improvement Collaborative (MSSIC) Study

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Introduction: Evidence to support the routine use of drains placed in the retropharyngeal space after elective anterior cervical discectomy and fusion (ACDF) is limited and their use remains controversial. Given the incentive by some payors to classify ACDF as an outpatient procedure, it is unlikely that routine use of drains can be maintained in such a setting without having the patient discontinue their drain at home. The aim of this study was to retrospectively analyze what effects, positive or negative, use of drains had on clinical outcomes after routine ACDF using a large spine database.

Materials and Methods: All patients undergoing ACDF, without corpectomy, between February 2014 and October 2019 were identified in the registry of the Michigan Spine Surgery Improvement Collaborative (MSSIC). Cases were divided into two cohorts, drain and no drain, and matched for: age, body mass index, diabetes, coronary artery disease, American Society of Anesthesiologists grade, ambulatory status, and number of levels of surgery. Primary outcome measures were: surgical site hematoma requiring return to the operating room (SSH), surgical site infection (SSI), dysphagia, readmission within 30 days (30RA) and 90 days (90RA), and length of stay (LOS).

Results: 8,283 patients underwent ACDF during the study period. After matching, 3,206 patients were in both the drain and no drain cohorts for a total of 6,412 patients analyzed. Comparing the drain to no drain cohort (table A, figures 1 and 2), the incidence of SSH was 0.7% vs 1.2% ($p=0.038$), SSI was 0.5% vs 0.4% ($p=0.570$), dysphagia was 6.3% vs 4.6% ($p=0.003$), 30RA was 3.2% vs 2.6% ($p=0.100$), 90RA was 5.5% vs 5.1% ($p=0.350$), and the median LOS was 1 day; LOS 0-1 day (57.3% vs 76.5%, IQR 1,1) vs 2+ days (42.7% vs 23.5%, IQR 1,2), $p<0.001$. On multivariate analysis, drain use was associated with a 47% relative risk reduction and a 0.5% absolute risk reduction for SSH (OR 0.53, CI 0.31 to 0.9, $p = 0.019$, number needed to treat = 200). There was a trend toward increased risk of 30RA (OR 1.26, CI 0.94 to 1.7, $p =0.08$) with drain usage and a significant risk of increased length of stay (OR 1.31, CI 1.2 to 1.44, $p<0.001$). Three or more level ACDFs were associated with a significant increase in SSI ($p=0.011$), dysphagia ($p=0.013$), LOS ($p<0.001$), and any complication ($p<0.010$), but not significantly associated with SSH ($p=0.060$), RA30 ($p=0.611$), RA90 ($p=0.571$), or return to the OR within 90 days ($p=0.327$).

Conclusion: This study demonstrates the largest retrospective review of the use of drains for ACDFs that the authors are aware of. If considering ambulatory ACDF to decrease the healthcare cost burden, patient selection is necessary to reduce the risk of complications. In particular, this study reinforces three or more level studies may be best suited still in a hospital setting and consideration for a drain. The use of a surgical drain after ACDF decreased the risk of SSH (47%

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and 0.5% relative and absolute risk reduction, respectively); whether this incremental benefit is worth the tradeoff of increased length of stay warrants consideration.

Varible	DRAIN (n)	NO DRAIN (n)	p-value
n (total)	3206	3206	-
SSH	21	37	0.038
SSI	17	14	0.570
Dysphagia	202	148	0.003
RA30	104	83	0.100
RA90	177	162	0.350
LOS 0-1	1837	2451	<0.001
LOS 2+	1368	754	<0.001

Table A. Comparing drain to no drain cohorts.

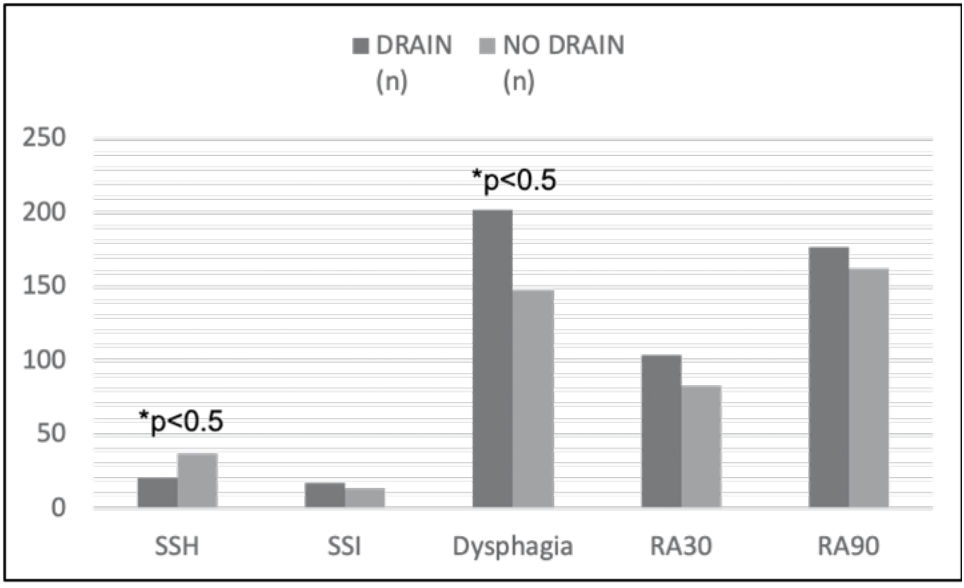

Figure 1. Comparing drain and no drain complications.

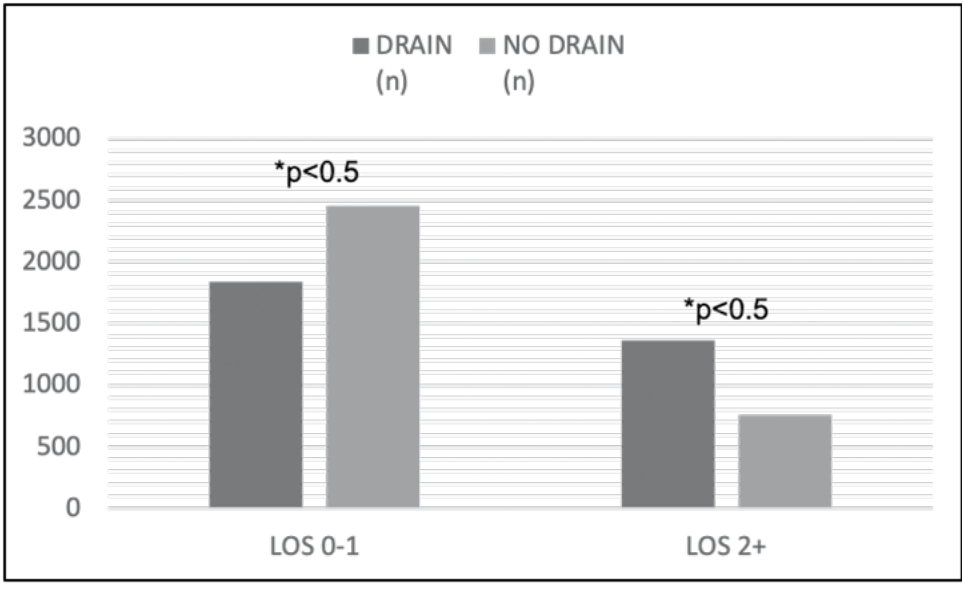

Figure 2. Comparing drain and no drain length of stay.

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Presentation #39

Failure to Extubate and Delayed Reintubation in Patients Undergoing Corrective Procedures for Adult Cervical Deformity

Peter Passias, MD, Katherine Pierce, BS, Sara Naessig, BS, Waleed Ahmad, MS, ***Bassel Diebo, MD***

Introduction: Adult cervical deformity (CD) patients are at a major risk for perioperative complications, as the procedure is extremely invasive in-nature. However, there is a paucity in the literature supporting this claim following Failure to Extubate (FTE) and Delayed Reintubation (DRI). The purpose was to investigate the morbidity and mortality associated with FTE and DRI after CD corrective surgery in a national dataset.

Materials and Methods: Patients ≥18 years undergoing corrective surgery for CD were identified. CPT codes of 22100 22110 22210 22220 22551 22552 22554 22590 22595 22600 63001 63015 63020 63040 63045 63050 63075 63076 63081 63082 63250 63265 63270 63300 63304 if positive ICD-9 scoliosis diagnosis (737.00-737.9). We excluded patients with disseminated cancer, metastatic disease to the neural axis, patient with spinal epidural abscess, and patients with ventilator dependency prior to the operation. FTE was defined as patients who left the operating room intubated, with these patients having recorded complication of being on the ventilator for over 48 h, with less than 3 days from the operation to that complication and no record of unplanned reintubation in those first 3 days. DRE was identified as any intubation occurring after the patient have left the operating room, a recorded "Occurrences Unplanned Intubation". The relationship between preoperative comorbidity with FTE and DRI patients was also explored via means and chi-squared analyses. Rates of postoperative morbidity and mortality were explored in CD patients with FTE or DRI versus successful extubation.

Results: 576 surgical CD patients (58.8 yrs, 55%F, 28.1 kg/m2) were identified. 53.5% of procedures involved decompression and 100% involved fusion. 7 patients (1.2%) were classified with an FTE, while 16 (2.8%) had a DRI. Patients with either FTE or DRI, preoperatively had a lower BMI (25.2 kg/m2), more alcohol dependence (25%), COPD (17%), hypertension (74%), steroid use (13%), CNS tumor (25%), and quadriplegia, (all $p<0.050$) compared to the remainder of the CD cohort. Demographics and comorbidities between FTE and DRI patients were similar ($p>0.050$), except FTE patients had overall greater incidence of preoperative steroid use (43%, $p=0.003$). Total operative time was significantly longer in those with FTE or DRI (337.4 minutes vs successful extubation: 252.7, $p=0.009$), as well as total length of hospital stay (21 vs 5.4 days, $p<0.001$). Complication analysis found that those with either a DRI or FTE patients had a significantly higher occurrence of major complications (82.6% vs 55.9%, $p<0.050$), for a total of 3.8 fold- greater in the DRI/FTE group. Specifically, affected patients had 4.1 fold- greater occurrence of acute renal failure, urinary tract infection by 3.9 fold, cardiac arrest by 52.6 fold, sepsis by 10.2 fold, and DVT complications by 6.5 fold.

Conclusion: FTE and DRI were highly predictive of morbidity and mortality. Overall, investigations of the effects of FTE and DRI following CD procedures are lacking.

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #40

Disparities in Etiology, Clinical Presentation and Determinants for Distal Junctional Kyphosis Based on Timing of Occurrence: Are We Treating Two Separate Issues?

*Katherine Pierce, BS, **Peter Passias, MD,** Renaud Lafage, MS, Virginie Lafage, PhD, Han Jo Kim, MD, Alan Daniels, MD, Robert Eastlack, MD, Eric Klineberg, MD, Breton Line, BS, Robert Hart, MD, Douglas Burton, MD, Shay Bess, MD, Frank Schwab, MD, Christopher Shaffrey, MD, Justin Smith, MD, PhD, Christopher Ames, MD*

Introduction: Following cervical deformity(CD) corrective surgery, durability remains a challenge and distal junctional kyphosis(DJK) is an important risk for surgeons to consider. DJK is the result from fixation failure, adjacent level fracture or spondylolisthesis. The timing of DJK onset has yet to be investigated. The purpose of this study was to determine the timing of DJK development following CD corrective surgery

Materials and Methods: Included: surgical CD patients(C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) without pre-op DJK. DJK angle was defined as the change in kyphosis between lower-most instrumented vertebra(LIV) and LIV-2 from preop to postop(<-10). X2 analysis and post-hoc testing assessed annual and overall incidence of Early(3M follow-u) and Late(DJK development at 6M, 1Y, 2Y) DJK development among operative patients. Differences between Early and Late DJK(development after 3 months) were assessed. Pearson correlations determined significant variables associated with development of Early versus Late DJK. Severe DJK defined as DJK angle <-20°. DJK was considered symptomatic if associated with reoperation or the published thresholds of NDI>24 or mJOA<14. The natural progression of the disease was predicted with the use of a Kaplan-Meier survivorship analysis.

Results: 139 patients without pre-op DJK were included(16 re-op) (61.8yrs, 62.3%F, 29.1kg/m2). Surgical characteristics: 20.1% anterior approach, 42.4% posterior, 36.7% combined(levels fused: 7.6). Incidence of DJK from 2013-2018: 23%. Early: 9.4%, Late: 10.1%(6M delayed: 3.6%, 1Y delayed: 6.5%, 2Y delayed: 2.2%). No differences were observed between op and reop for development of Early or Late DJK at all f/u(p>0.050). Presence of upgoing plantar response at baseline neuro exam, C2-C7 angle, T1-C2 angle, CBVA and combined approach correlated with development of Early DJK. For Late DJK: history of tumor and pulmonary disease, pelvic incidence, T10-L2 angle, and L4 pelvic angle. Apex of the secondary driver was significantly lower in the Late group (mean early: T2/3; late: T10; p=0.023). 3M radiographically, Early DJK patients had greater TK (-57.9° vs -40°, p=0.024, while L4PA remained larger in the Late DJK group (14.5°, p=0.009). Between Early and Late groups, 41.7% of Early DJK patients met criteria for severe DJK, while 0% of Late DJK patient were severe(p=0.010); symptomatic DJK between the two groups was not significant(p=0.941). Kaplan-Meier survivorship analysis determined patients within the cohort to have a 91.1% cumulative probability of maintaining non-DJK status by 3-month follow-up, 85.9% at 6-month, 80% at 1-year, and 77.0% by 2-year follow-up.

Conclusion: Patients undergoing CD corrective surgery have incidence of early and late DJK. While the majority of DJK development occurs within the first 6 months, late DJK occurs and differs in presentation and etiologic factors. Early DJK occurrence is more likely to be

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severe radiographically, associated with neurological decline, and is more strongly related to biomechanical factors such as use of a combined approach at the time of surgery. Contrarily, although equally likely to be symptomatic as reflected in loss of clinical gains from surgery, late DJK is more likely mild radiographically and associated with suboptimal cervical realignment and lack of addressing secondary drivers, likely related to negative compensatory mechanisms. Customized prophylactic approaches for both occurrences is mandated.

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Presentation #41

Prospective Multicenter Assessment of Complication Rates Associated with Adult Cervical Deformity Surgery in 133 Patients with Minimum 1-Year Follow-Up

Justin Smith, MD, PhD, *Thomas Buell, MD, Christopher Shaffrey, MD, Han Jo Kim, MD, Eric Klineberg, MD, Themistocles Protopsaltis, MD, Peter Passias, MD, Gregory Mundis, MD, Munish Gupta, MD, Virginie Lafage, PhD, Renaud Lafage, MS, Frank Schwab, MD, Shay Bess, MD, Christopher Ames, MD, International Spine Study Group, none*

Introduction: Adult cervical spine deformity (ACSD) can have profound impact on quality of life, including pain, disability, and neurological compromise. Although surgical treatment can provide significant improvement of symptomatic ACSD, few reports have focused on the associated complications. The objective of this study was to assess complication rates at minimum 1-year follow-up based on a prospective multicenter series of ACSD patients treated surgically.

Materials and Methods: A prospective multicenter database of consecutive operative ACSD patients was reviewed for peri-operative (<30 days), early (30-90 days), and delayed (>90 days) complications with minimum 1-year follow-up. Enrollment required at least 1 of the following: cervical kyphosis >10º, cervical scoliosis >10º, C2-7 sagittal vertical axis >4cm or chin-brow vertical angle >25º.

Results: Of 167 patients, 133 (80%, mean age=62 years, 62% women) had minimum 1-year follow-up (mean=1.8 years). The most common diagnoses were degenerative (45%) and iatrogenic (17%) kyphosis. Almost 40% were active or past smokers, 17% had osteoporosis, and 84% had at least 1 comorbidity. Baseline Neck Disability Index (NDI) and modified Japanese Orthopedic Association (mJOA) scores were 47 and 13.6, respectively. Surgical approaches were anterior-only (18%), posterior-only (47%) and combined (35%). A total of 132 complications were reported (54 minor/78 major), and 74 (56%) patients had at least 1 complication (Table). On average, patients had approximately 1 complication, however 44.4% of patients did not have any complications, while the remaining patients experienced from 1 to 7 complications. The most common complications included dysphagia (12%), distal junctional kyphosis (DJK, 9%), respiratory failure (6%), deep wound infection (6%), new nerve root motor deficit (5%) and new sensory deficit (5%). A total of 4 deaths occurred that were potentially related to surgery, 2 prior to 1-year follow-up (1 cardiopulmonary and 1 from obstructive sleep apnea and narcotic use) and 2 beyond 1-year follow-up (both cardiopulmonary and associated with revision procedures). Twenty-six reoperations were performed in 23 (17%) patients, with the most common indications of deep wound infection (n=8), DJK (n=7), and neurological deficit (n=6). Although anterior-only procedures had a trend toward lower overall (42%) and major complications (21%), rates were not significantly different from posterior-only (57%/33%) or combined (61%/37%) approaches (p=0.29/p=0.38).

Conclusion: This report provides benchmark rates for ACSD surgery complications at minimum 1-year (mean=1.8 years) follow-up. The marked health and functional impact of ACSD, the frail population it affects, and the high rates of surgical complications necessitate a careful risk-benefit assessment when contemplating surgery. Collectively, these findings provide benchmarks

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for complication rates and may prove useful for **patient counseling and efforts to improve the safety of care.**

Table. Rates of complications in 133 patients surgically treated for adult cervical deformity who had minimum 1-year follow-up.

Complication Category	Minor/Major Complications (%)			
	Peri-op (<30 days)	Early (30-90 days)	Delayed (>90 days)	Total
Neurological	**8/5 (9.8)**	**1/6 (5.3)**	**2/7 (6.8)**	**11/18 (21.8)**
Mental status change	7/0 (5.3)	0/1 (0.8)	0/0 (0)	7/1 (6.0)
Nerve root- sensory deficit	1/1 (1.5)	0/1 (0.8)	0/3 (2.3)	1/5 (4.5)
Nerve root- motor deficit (not C5)	0/1 (0.8)	0/2 (1.5)	0/1 (0.8)	0/4 (3.0)
Radiculopathy	0/0 (0)	1/0 (0.8)	2/1 (2.3)	3/1 (3.0)
C5 motor deficit	0/3 (2.3)	0/0 (0)	0/0 (0)	0/3 (2.3)
Spinal cord deficit	0/0 (0)	0/1 (0.8)	0/1 (0.8)	0/2 (1.5)
Central (cranial)	0/0 (0)	0/0 (0)	0/1 (0.8)	0/1 (0.8)
Other	0/0 (0)	0/1 (0.8)	0/0 (0)	0/1 (0.8)
Cardiopulmonary	**6/11 (12.8)**	**0/7 (5.3)**	**0/2 (1.5)**	**6/20 (19.5)**
Respiratory failure	2/4 (4.5)	0/1 (0.8)	0/1 (1.8)	2/6 (6.0)
Cardiac arrest	0/4 (3.0)	0/0 (0)	0/0 (0)	0/4 (3.0)
Pneumonia	0/2 (1.5)	0/0 (0)	0/1 (0.8)	0/3 (2.3)
Cardiac event	0/1 (0.8)	0/2 (1.5)	0/0 (0)	0/3 (2.3)
Arrhythmia/tachycardia	3/0 (2.3)	0/0 (0)	0/0 (0)	3/0 (2.3)
Pulmonary embolism	0/0 (0)	0/2 (1.5)	0/0 (0)	0/2 (1.5)
Pulmonary other	0/0 (0)	0/2 (1.5)	0/0 (0)	0/2 (1.5)
Cardiac other	1/0 (0.8)	0/0 (0)	0/0 (0)	1/0 (0.8)
Dysphagia/Gastrointestinal	**9/6 (11.3)**	**2/0 (1.5)**	**3/0 (2.3)**	**14/6 (15.0)**
Radiographic	**0/2 (1.5)**	**3/2 (3.8)**	**3/5 (6.0)**	**6/9 (11.3)**
Infection	**3/6 (6.8)**	**3/1 (3.0)**	**0/1 (0.8)**	**6/8 (10.5)**
Operative	**6/3 (6.8)**	**0/0 (0)**	**0/0 (0)**	**6/3 (6.8)**
Implant	**0/0 (0)**	**0/1 (0.8)**	**0/5 (3.8)**	**0/6 (4.5)**
Vascular	**0/0 (0)**	**1/3 (3.0)**	**0/1 (0.8)**	**1/4 (3.8)**
Misc. Medical	**1/0 (0.8)**	**1/2 (2.3)**	**0/0 (0)**	**2/2 (3.0)**
Wound (excluding infection)	**1/0 (0.8)**	**1/0 (0.8)**	**0/1 (0.8)**	**2/1 (2.3)**
Mortality	**0/0 (0)**	**0/0 (0)**	**0/2 (1.5)**	**0/2 (3.0)**
Total (minor/major)	67 (34/33)	34 (12/22)	32 (8/24)	133 (54/79)
No. of patients affected (%)	52 (39.1)	11 (8.3)	27 (20.3)	74 (55.6)

Presentation #42

Analysis of the Effects of Intraoperative Neurophysiological Monitoring on Anterior Cervical Surgery: A Michigan Spine Surgery Improvement Collaborative (MSSIC) Study

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Introduction: The utility of intraoperative neurophysiological monitoring (IOM) for anterior cervical surgery remains controversial. Despite insufficient evidence demonstrating a clear benefit, IOM continues to be utilized and in some areas is considered standard of care.

Materials and Methods: Anterior cervical surgeries from February 2014 to November 2019 were included for analysis. IOM (EMG, MMG, SSEPs, or MEP) was the primary variable examined. Primary outcome measures were: new weakness after surgery, new radicular symptoms, return to OR, operative time and length of stay (LOS). Logistic Generalized Estimation Equations (GEE) were used for multivariate analysis adjusting for demographic, premorbid, and disease specific variables.

Results: There were 10,853 cases with 4,218 (38.9%) where IOM was used. Comparing IOM cases to those without there were no differences in weakness (6% vs 6% n.s.), radicular symptoms (10% vs 11% n.s.), return to OR (4% vs 3% n.s.) and LOS. Operative time was longer in the IOM group, 1.8 hours (CI 1.3-2.4) vs 1.4 hours (CI 1.1-2) $p<0.001$. On multivariate GEE, IOM was not found to decrease the risk of post-operative weakness, radicular symptoms or return to OR. For weakness, baseline weakness (OR 1.63, CI 1.29-2.06, $p<0.001$), myelopathy (OR 1.51, CI 1.21-1.9, $p<0.001$), CAD (OR 1.33, CI 1.07-1.65, $p<0.05$) and ASA>2 (OR 1.23, CI 1.01-1.5, $p<0.05$) were all associated with increased risk. For radicular symptoms, baseline weakness (OR 1.25, CI 1.04-1.49, $p<0.05$), ASA>2 (OR 1.24, CI 1.06-1.44, $p<0.05$ and previous spine surgery (OR 1.22, CI 1.06-1.4, $p<0.05$) were associated with increased risk. For return to OR, previous spine surgery (OR 1.51, CI 1.18-1.93, $p<0.001$), myelopathy (OR 1.52, CI 1.07-1.9, $p<0.05$), male gender (OR 1.32, CI 1.04-1.68, $p<0.05$) were associated with increased risk. Finally, IOM (OR 1.06, CI 1.03-1.09, $p<0.001$) was also associated with longer operative time.

Conclusion: Our study found no correlation between the use of IOM and reduction of post-operative weakness and new radicular symptoms. Conversely, we did find significant associations with increased operative time. Baseline weakness had the highest correlation with both negative outcomes.

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Presentation #43

Effect of Plate Thickness on Fusion, Complications and Outcomes in Anterior Cervical Spine Surgery

Steven Wahlmeier, MD, Daniel Park, MD, ***Graysen Petersen-Fitts, MD***

Introduction: Anterior cervical discectomy and fusion (ACDF) is a common procedure for cervical radiculopathy and myelopathy. The goals for ACDF include decompressing neural elements as well as obtaining a solid fusion while minimizing complications. Anterior plating is commonly performed during ACDF procedures to facilitate fusion. Plate thickness varies considerably among various ACDF systems. The purpose of the current study was to investigate the impact of plate thickness on fusion rate, complications and patient outcomes following ACDF.

Materials and Methods: Patient records were reviewed from February 2017 to December 2018. Patients who underwent ACDF for myelopathy or radiculopathy were selected for review. Demographic data were collected on all patients. Preoperative and postoperative radiographs were reviewed to determine fusion and measure the Pre-Vertebral Soft Tissue Swelling Index (PVSTS-I). Successful fusion was determined by <2mm motion on flexion/extension views and the presence of bridging bone. Continuous variables were analyzed using Student's T-Test, while nominal/ordinal values were compared using Z-test. Fusion status was analyzed using Pearson Chi-Squared test.

Results: Demographic data did not differ between the patient groups. Decreased plate thickness was associated with a lower rate of fusion at 12 months (82.5% vs 96.6%, p .0063). Decreased plate thickness was associated with increased rate of re-operation for hardware complications or pseudarthrosis (13.6% vs 0.0%, p .028). No outcome scores (EAT-10, NDI, VAS-Neck, VAS-Arm) reached the MCID between the two groups at any time point. EAT-10 dysphagia score correlated to Pre-Vertebral Soft Tissue Swelling Index (PVSTS-I) in both the abnormal dysphagia score group as well as the severe score group.

Conclusion: Decreased plate thickness was associated with decreased rate of fusion at 12 months as well as increased reoperation for hardware complications or pseudarthrosis. Decreased plate thickness was not associated with any significant improvement in patient reported outcome measures. Dysphagia scores were seen to correlate with the PVSTS-Index.

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #44

The Psychological Burden of Disease Among Patients Undergoing Cervical Spine Surgery: Are we Underestimating Our Patients' Inherent Disability?

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Introduction: Previous studies have utilized mental health questionnaires in different spine populations in order to identify the baseline effects of spine region disability has on baseline mental health. However, there is a paucity in the literature surrounding the degree of mental health for patients undergoing cervical spine surgery in comparison to other previously identified surgeries and spine regions.

Materials and Methods: 47patients age >18 with symptomatic cervical degenerative disease were included and those with active depression or history of major depression were excluded from the study. Basic demographics and baseline HRQL's (NDI, EQ5D, PCS,FABQ) were assessed via descriptive analyses. Patient psychosomatic scores that measure preoperative pain catastrophe and fear avoidance of procedure(PCS, FABQ) were compared to previously published benchmarks in lumbar spine, heart disease, and cancer patients. These mental health components and disability were further stratified by their severity as previously published(PCS>30; FABQ>34). Correlations assessed the relationship between these mental health components and severity of disability described by NDI. Furthermore, logistic regressions analyzed if NDI was an independent predictor of psychological burden described by PCS and FABQ.

Results: 47 patients were enrolled(53.6 years, 29.4 kg/m2). 32% of these patients were diagnosed with radiculopathy, 26% with myelopathy, and 42% with concomitant imaging diagnosis. These patients were all scheduled to undergo spinal fusions with decompression and had failed at least 3 months of conservative treatment. The average levels fused was 2.27±1.4. At baseline, the average PCS was 27.4 and FABQ: 40. By overall health metrics, the patient population had an average EQ5D score of 9.3 and an NDI of 25.6. 57.1% of patients had a severe FABQ and 40.8% had a severe PCS score. As compared to historical controls of lumbar patients, the patients in this study had greater levels of psychosomatic pathology measured by FABQ(40 vs 17.55; $p<0.001$) and PCS(27.4 vs 19.25; $p<0.001$). This same relationship was identified for FABQ scores of coronary heart disease patients(40 vs 18.2; $p<0.001$). However, cervical patients had lower rates of PCS than patients with ischemic heart disease or lung cancer(heart: 27.4 vs 38.9; lung: 27.4 vs 37.2; all $p<0.001$). PCS positively correlated with FABQ scores($r=0.55$; $p<0.001$). Increasing neck disability was correlated with greater PCS measured disability($r=0.7$; $p<0.05$). Baseline disability was also identified to have a significant relationship with having a severe PCS score independent of levels fused and diagnosis(OR=11.7[1.5-90.5];$p=0.019$). This trend was similarly identified for FABQ($r= 0.5$; $p<0.05$). Age was also not a significant predictor for baseline severe PCS and FABQ nor was diagnosis and presence of stenosis.

Conclusion: Cervical spine patients, have an overall great amount of mental health pathology, however; a large portion of these patients also have high fear avoidance beliefs and pain

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catastrophizing at baseline. These rates were identified to be higher than previously identified benchmarks of patients within other specialties. Since this study excluded patients with an official diagnosis of depression or other psychological condition, it is possible that the mental health pathology of patients undergoing cervical surgery is greatly underestimated which may warrant pre-operative treatment to help mitigate these mental health scores at baseline.

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Presentation #45

Incidence and Risk Factors for Anterior Chin Numbness after Anterior Cervical Spine Surgery: A Previously Unreported Complication

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Introduction: During the initial exposure for anterior cervical spine surgery, anterior chin numbness can occur, due to injury to the ascending branch of the transverse cervical nerves, which perforate the platysma. To our knowledge, there is no report in the literature regarding this complication of anterior cervical spine surgery. The purpose of this study was to analyze the incidence and characteristics of anterior chin numbness after anterior cervical spine surgery and to investigate the risk factors that contribute to it.

Materials and Methods: We retrospectively reviewed patients who underwent ACDF or ACDA from August 2016 to February 2020 for degenerative pathologies with a minimum follow-up of six weeks. Exclusion criteria were: (1) patients aged <18-years-old, (2) less than 6-week follow-up, and (3) preexisting chin numbness preoperatively. Numbness was classified into 3 groups (none/mild/severe), and subsequently dichotomized into no-numbness vs. numbness. Patients were grouped into the numbness group when they had mild or severe numbness at any postoperative follow-up. Additional variables included demographics and surgical measurements, including estimated blood loss (EBL), number of surgical levels, laterality of skin incision, and procedures.

Results: We evaluated a total of 172 patients. Thirty-one patients had mild and nine had severe numbness postoperatively. The incidence of both mild and severe numbness at each follow-up period was 21/81 (25%), 15/55 (27%), 5/25 (20%), 1/5 (20%), 0/11 (0%), and 0/4 (0%) at 6 weeks, 6 months, 1 year, 1.5 years, 2 years, and 3 years after surgery, respectively. Approximately 5-10% of patients had severe numbness up to 6 months after surgery (Figure 1). Patients in the numbness group had a significantly lower body mass index (BMI) (25.2 vs. 28.4, P<0.001) and a higher rate of smoking (10% vs. 2.5%, P=0.04). The numbness group had more surgical levels (2.8 [6, 9, 12, and 13 patients had 1, 2, 3, and 4 levels, respectively] vs. 2.4 [26, 45, 34, 14, and 2 patients had 1, 2, 3, 4, and 5 levels, respectively], P=0.014) and more right-sided approach (15% vs. 7.1%, P=0.10). Multivariate analysis revealed two factors that led to the risk of anterior chin numbness: lower BMI (odds ratio [OR] = 0.83; P < 0.001) and increased number of surgical levels (OR = 1.65; P = 0.010) (Table 1).

Conclusion: The incidence of anterior chin numbness after anterior cervical spine surgery was approximately 25 to 30% up to six months after surgery. Lower BMI and increased surgical levels were associated with an increased incidence of numbness. We hypothesize that in patients with greater BMI, subcutaneous fat may protect the branches of the transverse cervical nerve (deep to the fat and perforate the platysma) during skin incisions. Surgeons should be aware of this previously unreported complication of anterior cervical surgery.

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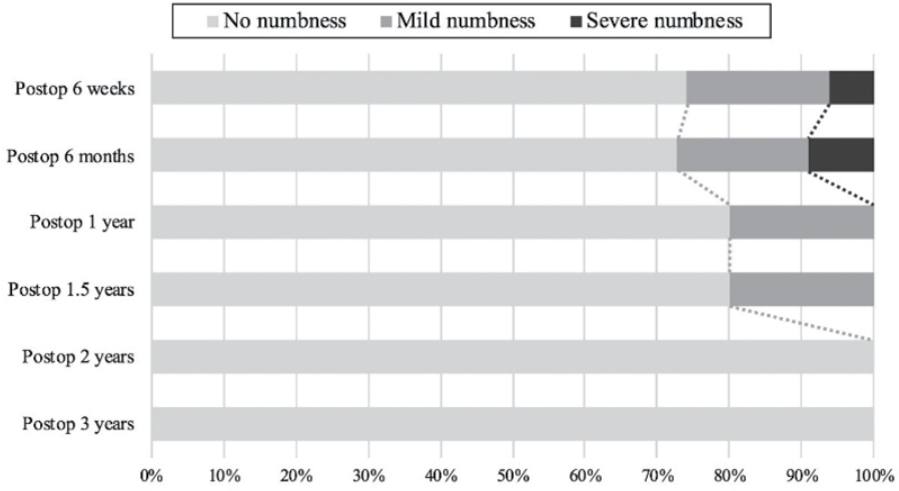
Table 1. Multivariate prediction model relating anterior chin numbness after anterior cervical spine surgery to perioperative factors.

Anterior chin numbness after anterior cervical spine surgery			
	Odds Ratio	95% CI	*P* Value
BMI	**0.83**	**0.75 - 0.92**	**< 0.001**
Number of levels	**1.65**	**1.13 - 2.42**	**0.010**
Incision side (REF = Right side)	2.94	0.81 - 10.7	0.10
Smoking	2.84	0.53 - 15.2	0.22
CI, confidence interval; BMI, body mass index.			

Figure 1. The incidence of anterior chin numbness at each follow-up.



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Presentation #46

Incidence and risk factors of symptomatic epidural hematoma following cervical spine surgery: A single institute experience over a decade

Tian XIA, MD

Introduction: Previous studies reported the estimated incidence of symptomatic spinal epidural hematoma (SSEH) is 0.09% to 1.5%[4-7]. Many of the researches have revealed a wide range of factors related to patients or treatments for SSEH development. Goldstein et al[5] have reported postoperative nonsteroidal anti-inflammatory drug (NSAID) use and increased Charlson Comorbidity Index (CCI) as significant predictors of the development of SSEH after posterior cervical surgery. Yin et al[5] reported hypertensive disease and the method of multilevel cervical procedure increased bleeding tendency and predict the formation of SSEH after cervical spinal surgery. The purpose of this study was to explore the incidence of SSEH after cervical spine surgery at a single Chinese institution and identify patient- and treatment-related risk factors for its development. To help prevent and decrease the occurrence of SSEH in clinical practice

Materials and Methods: A retrospective review was made on the clinical data of 38 patients with symptomatic epidural hematoma from June 2009 to February 2019, and pick patients without hematoma randomly through the same period as control group, collect gender, age, body mass index, ossification of the posterior ligament, hypertension, diabetes, vascular atherosclerotic diseases, anti-platelet or anti-coagulate treatment, platelet count, prothrombin time, activated partial thromboplastin time, international normalized ratio, segments, instrumental fixation, surgical approach, surgical procedure, duration of surgery and estimated blood loss, a total of 16 factors which might affect the occurrence of symptomatic epidural hematoma. T-test and Chi-square test were used to univariable test. Multifactor logistic regression analysis was used to investigate the correlation with symptomatic epidural hematoma, furthermore, its causes were explored.

Results: Among 13934 patients, 38 cases suffered symptomatic epidural hematoma, the incidence was 0.27%. The median time from the end of index surgery to symptomatic was 145 minutes(range: 30 min to 38d). 4 subjects first presented with numbness, other 34 subjects presented paralysis, finally, all subjects suffered paralysis before hematoma evacuation. 19 subjects were radiologically diagnosed by radiology assessment, the other 19 cases were diagnosed through clinical symptoms. All 38 patients received emergent hematoma evacuation. Before evacuation Frankel grade were B in 4 cases, C in 29 cases and D in 5 cases. All patients recovered at least one grade after evacuation. Multifactor logistic regression revealed revision surgery, posterior surgery, surgical procedure and OPLL involved segments are significantly correlated to the incidence of postoperative symptomatic epidural hematoma($P<0.05$).

Conclusion: Revision surgery, posterior surgery, surgical procedure and OPLL involved segments are significantly correlated to the incidence of postoperative symptomatic epidural hematoma, for patients with these risk factors, neurological functions should under restrict surveillance, and prevent drains from being obstructed.

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Presentation #47

The Utility of Neuromonitoring in Cervical Myelopathy Patients

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Introduction: Intra-operative neuro-monitoring (IONM) was developed and is now used as a method of monitoring and potentially preserving spinal cord function during critical spine procedures. Although there is in theory utility to the use of this technology, particularly for deformity surgery where corrections may be reversed in conjunction with IONM findings, the utility in degenerative cases for cervical spondylotic myelopathy (CSM) where no similar opportunity exists is lacking in practice. In fact, IONM does add cost and time to each surgery and it may just be used for medicolegal reasons by some physicians. The purpose of this study was to examine the utility, sensitivity and specificity of IONM for patients undergoing surgery for cervical spondylotic myelopathy (CSM). This study is a retrospective review of a consecutive series of CSM patients undergoing surgery in a safety net county hospital system.

Materials and Methods: Retrospective comparison of IONM findings was made against preoperative to immediate postoperative and peri-operative clinical examination findings for a consecutive series of 540 CSM surgeries performed over a 10-year period from 2009-2019 in a safety net hospital system. The senior author (K.R.) kept track of all positive and negative findings.

Results: There were seven positive IONM findings where loss of motor evoked potentials suggested a major intra-operative neurologic event despite none of these patients having any clinical neurological deterioration pre- to post-operatively, neither subjectively when asking the patient nor objectively on physical examination by the spine team. There were no false negative findings, and all IONM negatives were true negatives that maintained baseline neurologic function post-operatively (n=533). Thus, the overall sensitivity of detecting a new neurologic deficit was 0% given there were no true positive cases in this series. The specificity for ruling in normal post-operative neurologic function was 98.7%.

Conclusion: Though IONM is proposed to offer benefits during spinal surgery, the present series revealed only false positive findings for CSM surgeries. IONM added significant set-up time and additional cost without patient benefit. These data suggest the use of IONM may not be clinically valuable in practice apart from the idea of medico-legal or intra-operative security, but at the price of significant anxiety, not security, for the 1.3% false positive rate.

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Presentation #48

Cage Height is More Important than Surface Area for Subsidence in Multilevel Anterior Cervical Discectomy and Fusions (ACDF)

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Introduction: Various risk factors contribute to cage subsidence following an anterior cervical discectomy fusion1,2. The relationships between cage subsidence and height, as well as the surface area covered and the cage material are not clear within current literature3,4. The purpose of this study was to analyze the risk factors influencing cage subsidence following multilevel ACDFs, and the relationship of cage subsidence with cage dimensions, patient-reported outcomes (PROs) and fusion rates.

Materials and Methods: This retrospective study of a prospectively collected database was conducted from 2015 to 2018. Adult patients received primary multilevel ACDFs with minimum of 1-year follow-up were included. Exclusion criteria were corpectomy, revision, trauma, infection, or tumor cases. Patient demographic, surgical details, radiographic and cage-related parameters were obtained. Cage subsidence was evaluated using lateral radiographs and defined as any decrease of anterior or posterior disc height ³3mm. Two alternative methods, inter-screw distance (ISD) and screw-plate angle (SPA), were compared to evaluate for cage subsidence. Patients were separated into cage subsidence (CS) groups and no cage subsidence (nCS) groups. Neck disability index (NDI) scores were recorded at baseline and every clinic visit. Fusion rates were evaluated at final follow-up by dynamic plain film radiographs.

Results: 85 patients met inclusion with mean age 58.6±11.2 years and a mean of 12.7±1.8 months follow-up. The incidence of cage subsidence was 5%, 12%, 23%, and 31% at postoperative 6-week, 3-month, 6-month, and 1-year follow-up, respectively. The demographic, perioperative, and radiographic parameters were not different between groups. There were 212 levels in the 85 patients with 45 patients having had a 2-level, 35 with 3-level, and 5 with 4-level ACDFs. The incidence of subsidence at distal levels was significantly higher than at the proximal and middle levels (23.8% vs 11.9% vs 6.8%, p=0.02). The fusion rate was 88.5% and was not different between groups (p=1.00). The cage types, width, depth and the surface area of cages were not different between groups. (Table 1). There was no correlation between increasing surface area and incidence of cage subsidence(p=0.55).There was a positive correlation of cage height with cage subsidence ($p<0.001$, R=0.263) (Figure 1). A subgroup analysis of the distal level showed the ISD was not different between CS and nCS. The SPA at 1 year follow up was higher in the CS group than in the nCS group (8.1° vs 3.1°, $p<0.001$). The increase in SPA was positively correlated with cage subsidence ($p<0.001$, R=0.385) (Figure 2). Cage heights ³ 8mm were associated with a higher risk of cage subsidence (OR: 3.9, 95% CI: 1.8-8.5, $p<0.001$). There was no significant difference between baseline and 1-year follow-up NDI scores.

Conclusion: A significant correlation between cage height and extent of cage subsidence was identified in patients receiving multilevel ACDFs. We found that cage heights greater than 8 mm

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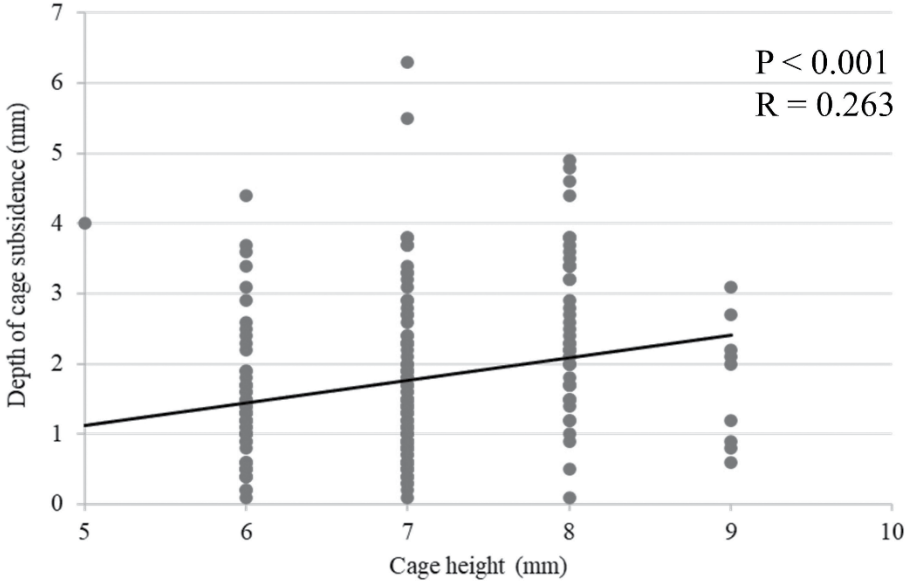
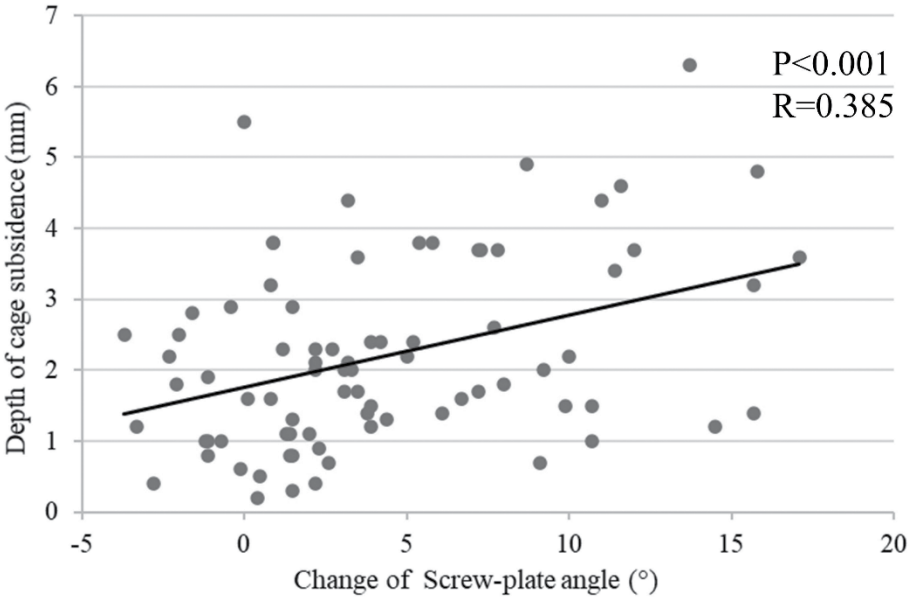
may be a risk factor of cage subsidence, while cages with larger surface areas did not provide any significant protection against subsidence.

Table 1: Cage-related risk factors of no cage subsidence (nCS) and cage subsidence (CS) groups

Variables	nCS group	CS group	*P* value
Number of levels	179	33	
Cage level			0.021
Proximal	74 (41.3%)	10 (30.3%)	
Middle	41 (22.9%)	3 (9.1%)	
Distal	64 (35.8%)	20 (60.6%)	
Cage type			0.341
Titanium	36 (20.1%)	4 (12.1%)	
Allograft	143 (79.9%)	29 (87.9%)	
Cage dimensions (mm)			
Height	6.9 ± 0.8	7.3 ± 0.9	0.021
Width	15.1 ± 3.1	15.3 ± 3.4	0.33
Depth	11.9 ± 1.2	11.9 ±1.3	0.838
Surface area (mm^2)	179 ± 41.7	184.1 ± 55.1	0.536





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Presentation #49

Association of Duration of Preoperative Opioid Use with Reoperation After One-Level Anterior Cervical Discectomy and Fusion in Non-Myelopathic Patients

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Introduction: Preoperative opioid use before cervical spine surgery has been linked to worse postoperative outcomes. However, no studies have determined the association of duration and type of opioid used with reoperations after anterior discectomy and fusion (ACDF).

Materials and Methods: Patients undergoing single-level ACDF without myelopathy with at least 5 year follow up were identified in one private insurance administrative database. Preoperative opiate use was divided into acute (within 3 months), subacute (acute use and use between 3-6 months), and chronic (subacute use and use prior to 6 months) preoperative use and by the opiate medication prescribed (tramadol, oxycodone, and hydrocodone). Postoperative rates of additional cervical spine surgery were determined at 5-years and multivariate logistic regression was used to determine the association of preoperative opiates with additional surgery.

Results: Of 445 patients undergoing single-level ACDF without myelopathy, 66.3% were taking opioid medications prior to surgery. The most commonly used preoperative opioid was hydrocodone (50.3% acute use, 24.7% chronic use). Opioid naïve patients had a 5-year reoperation rate of 4.7%, compared to 25.0%, 15.5%, and 23.3% with chronic preoperative use of tramadol (Figure 1), hydrocodone (Figure 2), and oxycodone (Figure 3). In multivariate analysis, controlling for age, gender, and Charlson Comorbidity Index, chronic use of hydrocodone (odds ratio [OR] = 2.08, $P = 0.05$), oxycodone (OR = 4.46, $P < 0.01$), and tramadol (OR = 4.01, $P = 0.01$) were all associated with increased reoperations. However, acute use of hydrocodone, oxycodone, and tramadol were not associated with reoperations ($P > 0.05$).

Conclusion: Both subacute and chronic use of common lower-dose opioid medications are associated with increased reoperations after single-level ACDF in non-myelopathic patients. This information is critical when counseling patients preoperatively and developing preoperative opioid cessation programs.

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Figure 1: Reoperation rate with preoperative tramadol use

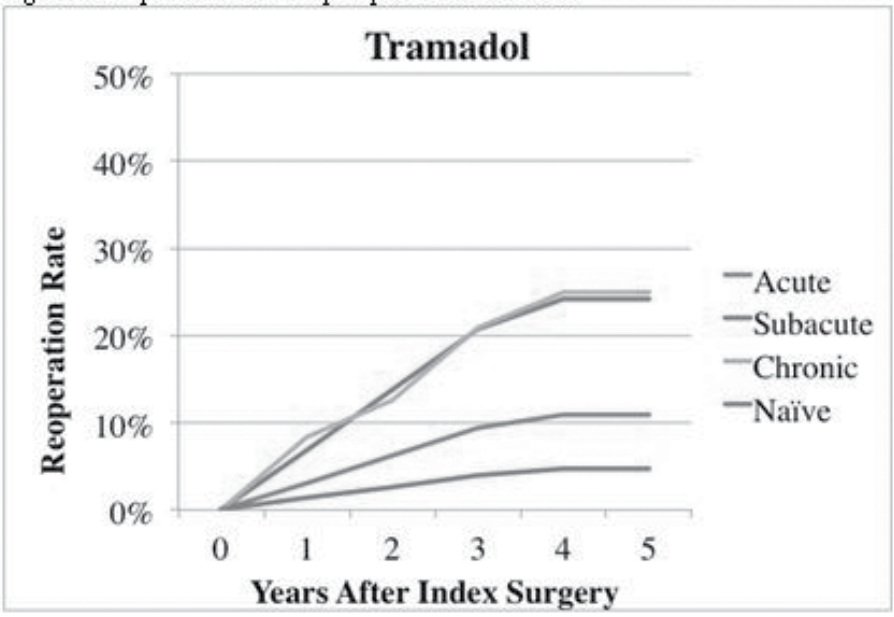

Figure 2: Reoperation rate with preoperative hydrocodone use

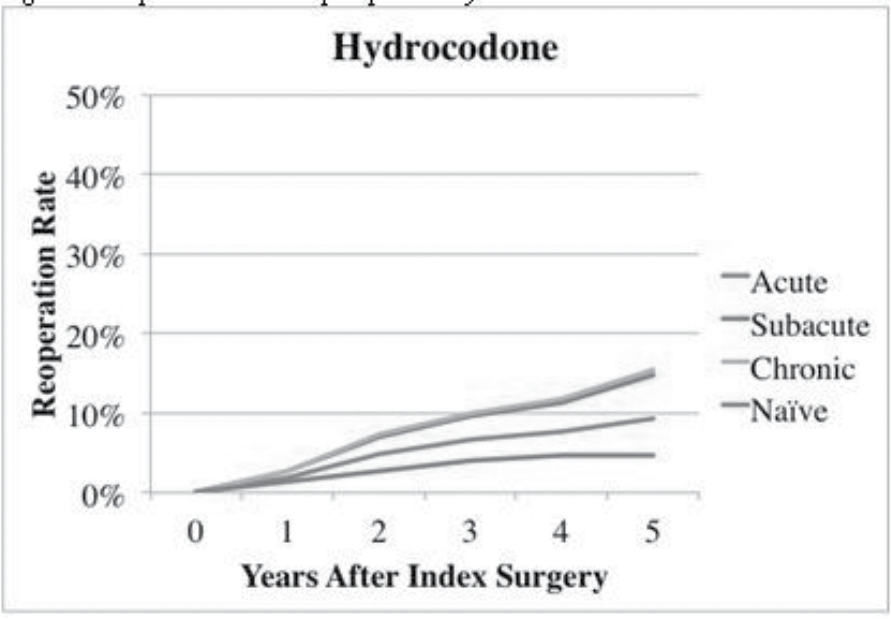

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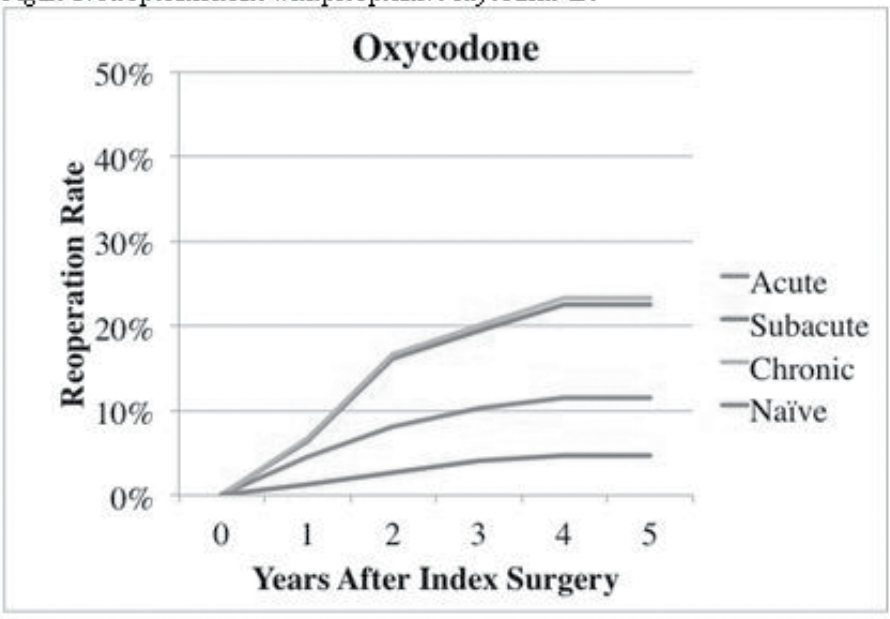
Figure 3: Reoperation rate with preoperative oxycodone use



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Presentation #50

Risk factors and countermeasures for prevention of postoperative C5 palsy after cervical open-door laminoplasty

Hideaki Nakajima, MD, PhD, *Shuji Watanabe, MD, PhD[1], Kazuya Honjoh, MD, PhD, Akihiko Matsumine, MD, PhD*

Introduction: The pathomechanism of C5 palsy after cervical open-door laminoplasty is unknown despite the relatively common occurrence of this condition postoperatively. A meta-analysis showed a prevalence of C5 palsy of 5.1%. The aim of this study was to review clinical and imaging findings in patients with C5 palsy and to propose countermeasures for prevention of this complication.

Materials and Methods: A total of 326 consecutive patients with cervical myelopathy underwent cervical laminoplasty at our hospital, of whom 10 (3.1%) developed C5 palsy (group P). C5 palsy was defined as a score of =3 on a deltoid manual muscle test conducted within 2 weeks after surgery. To compare imaging findings of these patients with those from patients without C5 palsy, a control group of 40 patients (group N) was selected from the 316 patients without C5 palsy, with consideration of age, gender, underlying diseases and preoperative Japanese Orthopaedic Association (JOA) scores. All patients in groups P and N underwent plain radiography, computed tomography (CT), and high-resolution magnetic resonance imaging (MRI) before and after surgery. Clinical features and radiological findings of patients with and without C5 palsy were analyzed.

Results: In patients with C5 palsy, the width of the C5 intervertebral foramen was narrower (2.1 vs. 3.3 mm, $p<0.01$) and the position of the bony gutter was wider beyond the medial part of the C5 facet joint (group P 103.2% vs. group N 85.4%, $p<0.01$). The distance between the lateral side of the spinal cord and bony gutter was significantly greater in patients with C5 palsy (4.7 vs. 2.6 mm, $p<0.01$). All patients in group P had a C5 intervertebral foramen = 2.6mm and a position of the bony gutter =100%. In contrast, 14 patients in group N (35.0%) had an intervertebral foramen =2.6 mm, and no patients had a position of the bony gutter =100%. The spinal cord occupied only 62.4% of the spinal canal, and that the distance between the lateral side of the spinal cord and the most medial part of the facet joint was 4.1 mm. Patients characteristics, disease, cervical alignment, spinal canal expansion rate (157.3±20.6% vs. 152.8±18.2%, p=0.557), anterior protrusion of the C5 superior articular process, high intensity area in the spinal cord on T2-weighted images, posterior shift of the spinal cord (4.3±1.5 vs. 4.2±1.5 mm, p=0.943), and operation time did not differ significantly between patients with and without C5 palsy.

Conclusion: The position of the bony gutter may have a central role in the pathomechanism of postoperative C5 palsy, especially in patients with a narrow C5 intervertebral foramen. Making an excessively lateral bony gutter might be a cause of C5 root kinking at the intervertebral foramen. To prevent occurrence of C5 palsy, it is important to confirm the medial line of the facet joint on preoperative CT, and a high-speed burr should be started from inside of the facet joint and manipulated in a direction that allows identification of the ligamentum flavum, which is an important anatomical landmark in the cervical spine for making an appropriate bony gutter.

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Presentation #51

Comparison of Clinical Guidelines for Authorization of Magnetic Resonance Imaging in the Evaluation of Cervical Radiculopathy in the United States

Daniel Berman, MD, *Ari Holtzman, MD, Zachary Sharfman, MD, Joseph Mendelis, MD, Nathaniel Tindel, MD*

Introduction: The American College of Radiology (ACR) has published appropriateness criteria to help guide when to implement the use of magnetic resonance imaging (MRI) in clinical practice (1). Health insurance carriers use proprietary clinical guidelines ("guidelines") for authorization for imaging studies. The purpose of this study was to compare the specific criteria in those guidelines, for neck pain both with or without radicular symptoms.

Materials and Methods: An online search was conducted to identify the guidelines for authorization of cervical spine MRI's used by the largest commercial insurance carriers in the United States by market share (2). Guidelines were analyzed for neck pain with and without radiculopathy. Guidelines for cervical trauma, myelopathy, infection, neoplasm, multiple sclerosis, and post-procedural care were excluded. Guidelines were broken down into categories including symptoms, treatment requirements, duration of treatment, clinical re-evaluation requirements, and "red flag" symptoms. Individual criteria within each of the categories were also compared to one another.

Results: Of the fifty top health insurance carriers evaluated, the majority use clinical guidelines issued by one of four third-party organizations. Two of four guidelines combined neck pain with or without radiculopathy together while the other two had separate criteria when radiculopathy is present. All four guidelines were similar in that they required some form of failed treatment for pain prior to an MRI, however there were discrepancies between clinical guidelines on what alternative therapies qualify as treatment. Three guidelines required six weeks of failed treatment while one required four weeks. Two of four guidelines required "clinical re-evaluation" for approval. One guideline differentiated "severe radicular pain" and "required" a pain score of "9/10" on "the VAS" without any references or definition of "VAS." One guideline allowed for bypass of treatment with abnormal nerve conduction studies, regardless of symptoms. One of four guidelines required cervical spine X-rays to be obtained prior to MRI in the absence of radiculopathy.

Conclusion: This study demonstrates that the criteria within the guidelines used by health insurance carriers for MRI authorization are inconsistent. The guidelines vary significantly from one another, and also vary from statements made by the ACR. There are also discrepancies between the published guidelines and the medical literature they reference. Finally, the guidelines utilized objective measures that have not been validated in the literature. Our findings suggest that insurance carriers lack uniform, validated criteria for cervical spine MRI imaging. Further study of guidelines is clearly warranted.

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Presentation #52

Laminoplasty versus Laminectomy and Fusion for Cervical Spondylotic Myelopathy: A Cost Analysis

Brian Goh, MD, PhD, *Brendan Striano, MD, Wylie Lopez, MD[1], Shivam Upadhyaya, MD, Chason Ziino, MD, Peter Georgakas, MD, Daniel Tobert, MD, Massachusetts Hospital, MD, Thomas Cha, MD, Joseph Schwab, MD, Christopher Bono, MD, Stuart Hershman, MD*

Introduction: Laminectomy with fusion (LF) and laminoplasty (LP) are commonly used to treat cervical spondylotic myelopathy (CSM). The decision regarding which procedure to perform is largely a matter of surgeon's preference, while financial implications are rarely considered [1]. We aimed to better understand the financial considerations of LF compared to LP in the treatment of CSM.

Materials and Methods: In this retrospective comparative study, patients who had undergone LF or LP for CSM from 2017-2019 at two large academic centers were identified. Patients who had undergone previous cervical spine surgery or undergone procedures that extended above C2 or below T2 were excluded. Patient demographics, surgical parameters, including estimated blood loss and operative time, and length of stay were collected. Operating room material – both implant and non-implant – cost data was also obtained. Total costs were calculated as the sum of implant and non-implant supply costs. Statistical analysis was performed using either Student t-test with unequal variance or Wilcoxon rank sum test for continuous variables and chi-square analysis for categorical variables.

Results: Two hundred fifty patients were identified who met inclusion criteria. There was no statistical difference in the mean age at time of surgery ($p = 0.25$), gender distribution ($p = 0.33$), or re-operation rate between the LF and LP groups ($p = 0.39$). Overall, operative time was similar between the LF (165.7 min, SD 61.9) and LP (173.8 min, SD 58.2) groups ($p = 0.29$), but the LP cohort had a shorter length of stay at 3.8 (SD 2.7) days compared to the LF cohort at 4.8 (SD 3.7) days. Implant costs in the LF group were significantly more at $6,204.94 (SD $1426.41) compared to LP implant costs at $1994.39 (SD $643.09). Mean total costs of LP were significantly less at $2,859.08 (SD $784.19) compared to LF total costs of $6,983.16 (SD $1,589.17). Furthermore, when adjusted for the number of operative levels, LP remained significantly less costly at $766.12 (SD $213.64) per level while LF cost $1,789.05 (SD $486.66) per operative level.

Conclusion: This study demonstrates that LF is on average at least 2.4 times the total cost of LP and at least 2.3 times the cost of LP when adjusted for the number of operative levels. In patients deemed appropriate for either LP or LF, these data may be incorporated into decision-making for the treatment of CSM.

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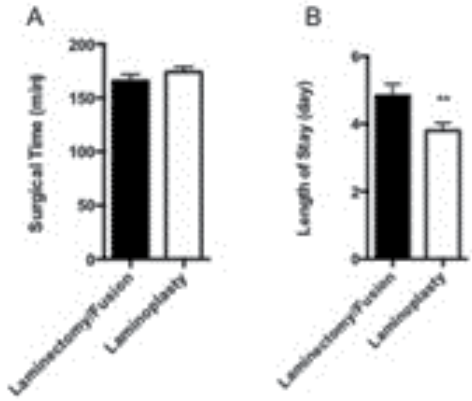

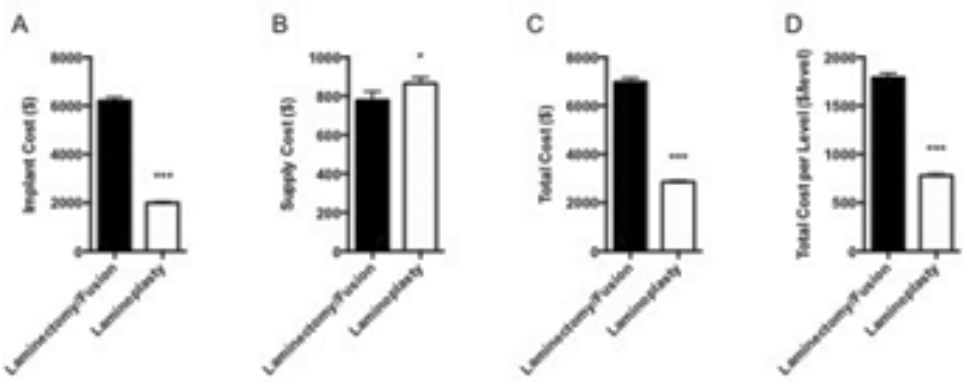

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Presentation #53

Return on Investment of Spine Society Research Grants: How does the CSRS compare?

*Addisu Mesfin, MD, **Nelson Merchan, MD,** David Bernstein, MD, MBA, MEI, Tochukwu Ikpeze, MD*

Introduction: Spine-related academic societies, such as the Cervical Spine Research Society (CSRS), Scoliosis Research Society (SRS), and North America Spine Society (NASS), have awarded numerous grants to residents, fellows, attendings, non-operative providers and basic scientists over the past two to three decades. The objective of this study is to evaluate the return on investment of CSRS, SRS and NASS grants as quantified by the number of publications generated and federal grants obtained (National Institute of Health [NIH], Department of Defense [DOD])

Materials and Methods: In March 2020, through publicly available data we identified grants awarded by three spine-related academic societies (CSRS, SRS, NASS) from 1989 to 2016. We collected the type of grant awarded, the highest degree of the Principal Investigator (PI), PI gender, PI institution and the dollar amount of the grant. We recorded the number of publications in PubMed stemming from each grant, the impact of the publication (number of citations in PubMed-indexed journals), and name of the journal where the article was published. The NIH Research Portfolio Online Reporting Tools (RePORT) and DOD website were then queried to determine which grantees from spine-related academic societies subsequently received either NIH or DoD funding.

Results: From 1989 to 2016: 81 (CSRS), 126 (SRS), and 93 (NASS) grants were awarded. From these grants 206 publications were found that acknowledged receiving financial support from the spine societies. The SRS funded 100 papers, followed by NASS with 62 papers and CSRS with 44 papers. A total of 32 NIH grants and 4 DoD grants were subsequently awarded following a spine society grant. The conversion rate of CSRS, SRS, and NASS grants to NIH grants was 15% (n=12 CSRS), 7.9% (n=10 SRS), and 11% (n=10 NASS), respectively. The conversion rate of CSRS, SRS, and NASS grants to DoD grants was 3.7% (n=3 CSRS), 0.8% (n=1 SRS), and 0% (n=0 NASS), respectively. For each spine society, over half of all grants were for basic science projects. When examining return on investment (ROI), spine society grant dollars per future NIH and DoD grants were the lowest for CSRS (Dollars Per NIH Grant: $207,434; Dollars Per DoD Grant: $829,734). The most common CSRS grant was a Resident/Fellow Grant (n = 31; 38%). For CSRS 85% of the grants were awarded to male investigators, SRS and NASS awarded 75% and 83% of their grants to male investigators, respectively.

Conclusion: CSRS grants appear to have the higher ROI of all spine society grants when evaluating subsequent NIH and DoD funding. However, the overall conversion rate to NIH and DoD grants remains low, and future work is warranted to determine how best to support scientific endeavors at the society level to lead to even greater NIH and DoD grants.

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Table 1. Results by Spine Society

Society	# of Grants	# of Papers	# of NIH Grants	# DoD Grants
CSRS	81	44	12(15%)	3(3.7%)
NASS	93	62	10 (11%)	0 (0%)
SRS	126	100	10(8%)	1 (0.8%)

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Presentation #54

Comparison of Commercial Health Insurance Clinical Guidelines for Authorization of Anterior Cervical Discectomy and Fusion for Cervical Radiculopathy in the United States

Ari Holtzman, MD, *Daniel Berman, MD, Zachary Sharfman, MD, Joseph Mendelis, MD, Nathaniel Tindel, MD*

Introduction: Anterior Cervical Discectomy and Fusion (ACDF) is an elective procedure performed for cervical radiculopathy and identified by the Current Procedural Terminology (CPT) code 22551. Health insurance carriers routinely utilize "clinical guidelines," to make medical necessity determinations when requesting authorization for procedures. The purpose of this study was to compare the specific criteria published by health insurance carriers for CPT code 22551.

Materials and Methods: Fifty commercial health insurance carriers in the United States (US) with the largest national market share value were selected for inclusion in this study (1). Accident, supplemental, and Medicaid managed-care policies were excluded from analysis. An online search was utilized to identify clinical guidelines published by each company for a single level ACDF procedure indicated for cervical radiculopathy. Clinical guidelines for trauma, instability, infection, neoplasm, myelopathy or rapidly progressive symptoms were excluded. Clinical guidelines from each carrier were broken down into categories including symptoms, physical examination, imaging, modalities of non-operative management and the duration of non-operative management. Individual criteria within each of the categories were compared.

Results: The health insurance carriers evaluated were found to hold 77% of US market share. Of the carriers included, only 62% had clinical guidelines accessible through their websites. Of the clinical guidelines evaluated, 39% were guidelines published by the individual health insurance carriers and the remaining 61% percent were guidelines from one-of-four third party health consulting firms. All clinical guidelines reviewed required documentation of significant symptoms of cervical radiculopathy including pain, paresthesia or weakness, and 86% of carriers required documentation of daily functional limitations. 39% of carriers required objective physical examination findings such as positive provocative tests, dermatomal sensory deficit, or motor deficit. Preoperative neuroimaging via magnetic resonance imaging (MRI) or computed tomography (CT) was required by all carriers. One of the third-party clinical guidelines specified that the neuroimaging must be performed within 6 months of surgery and also required cervical radiographs preoperatively. Non-operative treatments ("modalities") including analgesics, physical therapy, exercise programs, and steroid injections were listed throughout all clinical guidelines. However, there was significant variation in requirement of number of attempted modalities. At least one attempted modality was required by 32% of carriers, 57% required two modalities, 7% required three, and 4% required four modalities. Six weeks of failed alternative non-operative management was a requirement by 64% of carriers, while the remaining 36% required at least twelve weeks of non-operative management.

Conclusion: This study demonstrates a lack of transparency in insurance carriers' clinical guidelines for CPT code 22551 as 38% of carriers sampled do not readily provide their

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guidelines on the internet. Of the accessible guidelines, there is significant variation among the insurance carriers included in this study with regard to the individual criteria used to determine authorization for ACDF procedures. Patients and their doctors have a right to know insurance coverage determinant when making informed decisions regarding surgical procedures. Our data suggests that further study is warranted to assess the availability and the wide variations in coverage.

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Presentation #55

Medicare Economic Burden of Patient-Specific Factors Following Primary Anterior Cervical Discectomy and Fusion

Parthik Patel, MD, ***Jose Canseco, MD,*** *Barrett Woods, MD, Kris Radcliff, MD, Ian Kaye, MD, Jeffrey Rihn, MD, Mark F, MD, David Anderson, MD, Alan Hilibrand, MD, Christopher Kepler, MD, Alexander Vaccaro, MD, PhD, MBA, Gregory Schroeder, MD*

Introduction: The Bundled Payment for Care Improvement (BPCI) model, an alternative payment model outlined by the Center of Medicare and Medicaid (CMS), aims to improve patient outcomes and promote coordinated care among different providers. However, its integration into spine surgery can be limited due to the inherent heterogeneity of the field, including: a broad-range of pathologies within diagnosis-related groups (DRG), variety of care facilities, use of implants/grafts, and breadth of postoperative pain management protocols. These factors can lead to wide differences in reimbursements within particular DRG codes. As such, it has become important for providers to negotiate appropriate episode-of-care costs within a certain DRG using CPT codes, and modify care based on specific patient characteristics. The purpose of this study was to assess the influence of patient-specific factors on episode-of-care costs in Medicare patients undergoing primary ACDF.

Materials and Methods: A retrospective cohort study was conducted including patients who underwent primary ACDF from January 2014 to December 2018. Patients were identified from an institutional Medicare Bundled Payments for Care Improvement (BPCI) database, which was cross-checked with patient electronic medical records to collect patient demographic data, surgical case characteristics, and patient comorbidities. Cost information was obtained from the Medicare BPCI Advanced reimbursement model as claims data set at the Medicare rate. Data included index costs, 90-day post-acute care costs, and total episode-of-care costs. Multivariate linear regression analysis was performed to determine the patient comorbidities and related specific procedure factors associated with significant additional costs incurred.

Results: A total of 183 patients were included in the final analysis. Total episode-of-care costs were significantly higher in patients with a longer fusion construct (p: 0.01), increased length of stay (p: < 0.001), and a medical history of diabetes (p: 0.01) (Table 1). For index care costs, increased length of stay (p: < 0.001), a history of uncomplicated hypertension (p: 0.004), and diabetes (p: 0.003) were predictors of increased costs (Table 2). Finally, for post-acute care costs, longer fusion constructs (p: 0.04), increased length of stay (p: < 0.001), and a history of depression (p: 0.049) were associated with significantly higher costs (Table 3).

Conclusion: Bundled payment models are theoretically able to help control episode of care costs, while maintaining high quality of care for patients. Within this system, it is important to consider patient-specific characteristics and pre-existing conditions to fully evaluate total interventional costs. The results of this study can help identify areas needing improvement, so as to enhance postoperative clinical outcomes while optimizing healthcare expenditures.

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Table 1 Regression Analyses of Total Episode-of-Care Costs

Total Episode-of-Care Cost	β	Confidence Interval	p-value
Age	65.67	[-173.53, 304.87]	0.59
Gender	751.65	[3,870.08, 5,373.36	0.75
BMI	126.34	[-357.49, 610.16]	0.61
Levels Fused	3,059.67	[626.40, 5,492.94]	0.01*
Length of Stay	5,437.79	[3,897.39, 6,978.20]	< 0.001*
Myocardial Infarction	7,837.19	[-1,797.15, 17,471.52]	0.11
Cardiac Arrhythmias	4,446.10	[-2,067.49, 10,959.68]	0.18
Valvular Disease	-7,220.72	[-17,187.73, 2,746.28]	0.15
Uncomplicated Hypertension	1,502.54	[-3,253.59, 6,258.67]	0.53
Neurologic Disorders	5,052.71	[-4,079.12, 14,184.55]	0.28
Chronic Pulmonary Disease	-3,705.80	[-8,947.42, 1,535.81]	0.16
Diabetes	8,608.73	[2,235.22, 14,982.24]	0.01*
Hypothyroidism	3,168.76	[-2,651.51, 8,989.02]	0.28
Solid Tumor	-2,345.87	[-11,186.21, 6,494.46]	0.60
Rheumatic Disease/Collagen Disorder	-1,470.51	[-10,805.46, 7,864.44]	0.76
Anemia	3,452.08	[-5,850.07, 12,754.24]	0.46
Depression	2,619.82	[-2,826.90, 8,066.54]	0.95

Table 2 Regression Analyses of Index Care Costs

Index Care Cost	β	Confidence Interval	p-value
Age	-48.70	[-182.70, 85.30]	0.47
Gender	-968.88	[-3,557.94, 1,620.17]	0.46
BMI	51.76	[-219.27, 322.80]	0.71
Levels Fused	738.17	[-624.93, 2,101.27]	0.29
Length of Stay	1,748.95	[886.03, 2,611.88]	< 0.001*
Myocardial Infarction	1,454.72	[-3,942.36, 6,851.80]	0.59
Cardiac Arrhythmias	1,490.95	[-2,157.91, 5,139.82]	0.42
Valvular Disease	-441.28	[-6,024.72, 5,142.17]	0.88
Uncomplicated Hypertension	3,928.12	[1,263.77, 6, 592.47]	0.004*
Neurologic Disorders	-2,897.67	[-8,013.26, 2,217.92]	0.26
Chronic Pulmonary Disease	-2,077.71	[-5,014.03, 858.60]	0.16
Diabetes	5,410.95	[1,840.55, 8,981.34]	0.003*
Hypothyroidism	230.78	[-3,029.70, 3,491.25]	0.89
Solid Tumor	-2,056.64	[-7,017.93, 2,886.66]	0.41
Rheumatic Disease/Collagen Disorder	593.96	[-4,635.41, 5,823.45]	0.82
Anemia	-221.45	[-5,432.45, 4,989.55]	0.93
Depression	-2,236.78	[-5,287.99, 814.43]	0.15

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Table 3 Regression Analyses of Post-Acute Care Costs

Post-Acute Care Cost	β	Confidence Interval	p-value
Age	114.37	[-98.43, 327.16]	0.29
Gender	1,720.53	[2,391.00, 5,832.06]	0.41
BMI	74.57	[-355.85, 504.99]	0.73
Levels Fused	2,321.50	[156.83, 4,486.16]	0.04*
Length of Stay	3,688.84	[2,318.48, 5,059.20]	< 0.001*
Myocardial Infarction	6,382.47	[-2,188.34, 14,953.27]	0.14
Cardiac Arrhythmias	2,955.14	[-2,839.41, 8,749.70]	0.32
Valvular Disease	-6,779.45	[-15,646.20, 2,087.31]	0.13
Uncomplicated Hypertension	-2,425.58	[-6,656.68, 1,805.52]	0.26
Neurologic Disorders	7,950.38	[-173.40, 16,074.16]	0.06
Chronic Pulmonary Disease	-1,628.09	[-6,291.09, 3,034.91]	0.49
Diabetes	3,197.78	[-2,472.16, 8,867.72]	0.27
Hypothyroidism	2,937.98	[-2,239.79, 8,115.75]	0.26
Solid Tumor	-280.24	[-8,144.69, 7,584.22]	0.94
Rheumatic Disease/Collagen Disorder	-2,064.47	[-10,368.93, 6,240.00]	0.62
Anemia	3,673.54	[-4,601.76, 11,948.83]	0.38
Depression	4,856.60	[11.14, 9,702.06]	0.049*

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Presentation #56

Predicting Mechanical Failure Following Cervical Deformity Surgery: A Composite Score Integrating Age-Adjusted Cervical Alignment Targets

Renaud Lafage, MS, *Justin Smith, MD, PhD, Christopher Ames, MD, Gregory Mundis, MD, Themistocles Protopsaltis, MD, Munish Gupta, MD, Eric Klineberg, MD, Jonathan Elysee, BS, Han Jo Kim, MD, Shay Bess, MD, Frank Schwab, MD, Virginie Lafage, PhD, ISSG Foundation*

Introduction: Cervical Deformity (CD) surgery is a debilitating pathology. Due to the multifactorial nature of the disease and the complexity of the deformity, mechanical failure, such as Distal Junctional Kyphosis (DJK), following surgical corrections are common. Recent publications demonstrated the potential of a score evaluating the proportionality between parameters rather than individual values in thoracolumbar surgery. The purpose of this study was to investigate a composite score, derived from several radiographic parameters, to evaluate the effect of alignment proportionality and risk of severe DJK.

Materials and Methods: This study is a retrospective review of a multicenter database of CD patients with a minimum of 1-year follow-up without a complete fusion (no sacrum/pelvic fixation). Cervical score was constructed using offset from age-adjusted normative values previously published for the following parameters: SVA [(age -55)*2+25], T1 Slope [(age -55)/4 + 28.7], and TS minus cervical lordosis (CL) [cst: between 26.5 and 14.5°]. Points were assigned based on the offset from alignment targets and the Cervical Score was the sum of the three individual scores. The rates of mechanical failures were reported overall and for each individual Cervical Score. Logistical regressions were used to identify associations between early radiographic alignment, including Cervical Score, and rate of failure at 1 year (1Y).

Results: 84 patients were included in the current analysis (mean age: 61.1yo±10.3, 64.3%F). The overall rate of failure was 21.4% (N=18) with 10.7% having a surgical revision. Overall, patients underwent a significant change in sagittal alignment for all classic cervical and thoracolumbar parameters (all $p<0.01$). Multivariate logistical regression demonstrated that early T1S (OR: 0.935), TS-CL (OR:0.882) and SVA (OR:1.015) were all independent predictors of mechanical failure at 1Y (all $p <0.05$). Cervical Score ranged from -6 to 6, with 37.8% of the patients between -1 and 1, and 50.0% with a score of 2 or higher. The rate of mechanical failures ranged from 14% to 85% for a score greater than 1. Patients with a mechanical failures had a significantly higher cervical score (4.1±1.3 vs 0.6±2.2, $p=0.000$). Logistical regression demonstrated that patients with a score ≥ 3 were significantly more likely to develop a failure (71.4%) with an OR of 38.55 (95%CI [7.73 ; 192.26]) and a Nagelkerke r2 of 0.524 ($p<0.001$).

Conclusion: Prediction of mechanical failure is possible using a composite score of 3 well-described parameters: SVA (global alignment), T1Slope (orientation), and TS-CL (regional alignment). Having a score ≥ 3 early post-op was associated with a large increase in failure rate. This Cervical Score can be used to analyze sagittal alignment and help define realignment objectives in an effort to reduce mechanical failure.

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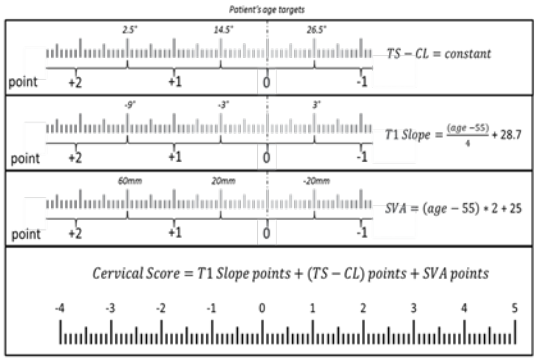

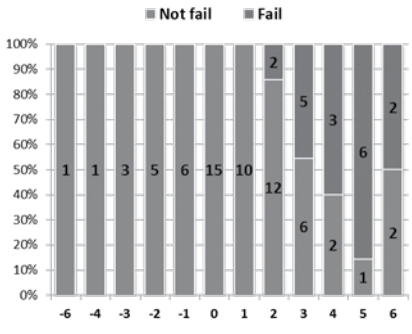

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Presentation #57

Impact of C3 Involvement on Postoperative Kyphosis Following Cervical Laminoplasty: Comparison between High and Low T1 slope

Myung-Hoon Shin, MD, PhD, *Se-Jin Song, MD*

Introduction: The impact of T1 slope (T1S) has emerged as a predictor of kyphotic alignment change after laminoplasty. Although it was reported that higher T1S had more pronounced lordotic curvature before surgery and higher loss of cervical lordosis (CL) after surgery, few studies have attempted to investigate these findings with the extent of laminoplasty. The goals of the present study were to investigate the impact of C3 involvement on the kyphosis following cervical laminoplasty in patients with high and low T1 slope.

Materials and Methods: The data from ossification of the posterior longitudinal ligament (OPLL) patients who had undergone laminoplasty between January 2016 and January 2019 were retrospectively reviewed. Patients were divided into two groups according to preoperative T1 slope, and subgroup analysis was done according to the C3 involvement in performing laminoplasty. Univariate tests and multivariate logistic regression analysis were used to assess the statistical relationship between postoperative kyphosis and radiological and surgical variables.

Results: Eighty-six patients were divided into two groups above and below preoperative T1S (20.0°). There were thirty-three patients (38.3%) in low T1S group and fifty-three patients (61.7%) in high T1S group. Twenty-three patients (26.7%) were performed with C3 involved laminoplasty. In multivariate logistic regression analysis, C3 involvement (OR; 9.671, 2.820-33.158, p= 0.000), high T1S (OR; 4.888,1.543-15.487, p= 0.007) and low T1S-CL (OR; 0.128, 0.037-0.449, p= 0.001) were significantly associated with postoperative kyphosis. In the subsequent subgroup analysis, C3 involvement was emerged as independent risk factor in high T1S group, increasing the odds of postoperative kyphosis by 27.315 -fold (1.560-478.282, p= 0.024). In high T1S group, the loss of CL was greater (p = 0.017) when C3 was involved whereas in low T1S group, the C3 involvement did not show the statistically significant difference in the change of CL (p = 0.190).

Conclusion: C3 involvement, low T1S-CL and high T1S increased the risk of postoperative kyphosis. Patients with high T1 slope tended to exhibit a greater loss of CL when the laminoplasty was performed extending to C3 segment.

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Presentation #58

When are Short fusions Successful in Cervical Deformity Surgery?

Themistocles Protopsaltis, MD, *Ethan Ayres, MD, MPH, Robert Eastlack, MD, Justin Smith, MD, PhD, Kojo Hamilton, MD, Alan Daniels, MD, Eric Klineberg, MD, Brian Neuman, MD, Robert Hart, MD, Shay Bess, MD, Christopher Shaffrey, MD, Frank Schwab, MD, Virginie Lafage, PhD, Christopher Ames, MD*

Introduction: Cervical deformity (CD) can have a profound impact on health status including increased pain and difficulty with activities of daily living. CD surgeries can be complex and result in serious complications and revision surgery. CD patients undergoing corrective surgery frequently require fusions extending to the thoracic or lumbar regions. Understanding the circumstances in which shorter fusions (SF) can be successful in CD surgery can help to minimize negative outcomes.

Materials and Methods: This is a retrospective review of a prospective CD databse. Operative CD patients were stratified as Short fusions (SF: ?4 levels fused, cervical LIV) or Long fusions (LF: >4 levels fused, LIV caudal to C7). Groups were compared in terms of demographics, BL and 1Y alignment, HRQL, and surgical parameters. The data were then reanalyzed after controlling for baseline cSVA using propensity score matching. Groups were compared via t-tests and X2 tests for continuous and categorical variables, respectively. Decision trees were used to identify baseline factors associated with postop alignment failure (1Y cSVA>40 or C2S>20°) among SF patients.

Results: 120 patients were analyzed (mean 61±10y; 62%F) with 94 LF and 26 SF pts. There were no differences in age, gender, BMI, CCI, or frailty between groups. SF had significantly less EBL (131ml vs 1001mL) and shorter Operative Time (223min vs 435min). At baseline, LF had significantly worse cervical alignment (cSVA = 42.6mm vs 23.0mm) and were more disabled by NDI (50 vs 38). There was 1 revision in the SF group for a neurologic deficit (LF=15 revisions). After matching by cSVA, the mean baseline cSVA decreased from 42.6mm to 27.6mm in the LF group and increased from 23.0mm to 27.2mm in the SF group (both n=21). 71% (n=15) of SF achieved the MCID for NDI vs 52% (n=11) of LF pts. In the decision tree analysis, SF patients with a baseline C2 Slope>26° (n=13) were 12.4x as likely as SF patients with C2 Slope<26° (n=13) to have postop alignment failure (85% vs 31%, p<.01) and 5.1x times as likely to have a postop complication (69% vs 31%, p=.05) (Figure 1).

Conclusion: Although short fusions can result in excellent outcomes with less extensive surgeries, optimal patient selection is critical and those with more severe deformity may require longer fusions. Shorter fusions should be avoided in patients with a baseline C2S>26° due to the increased risk of complications and realignment failure.

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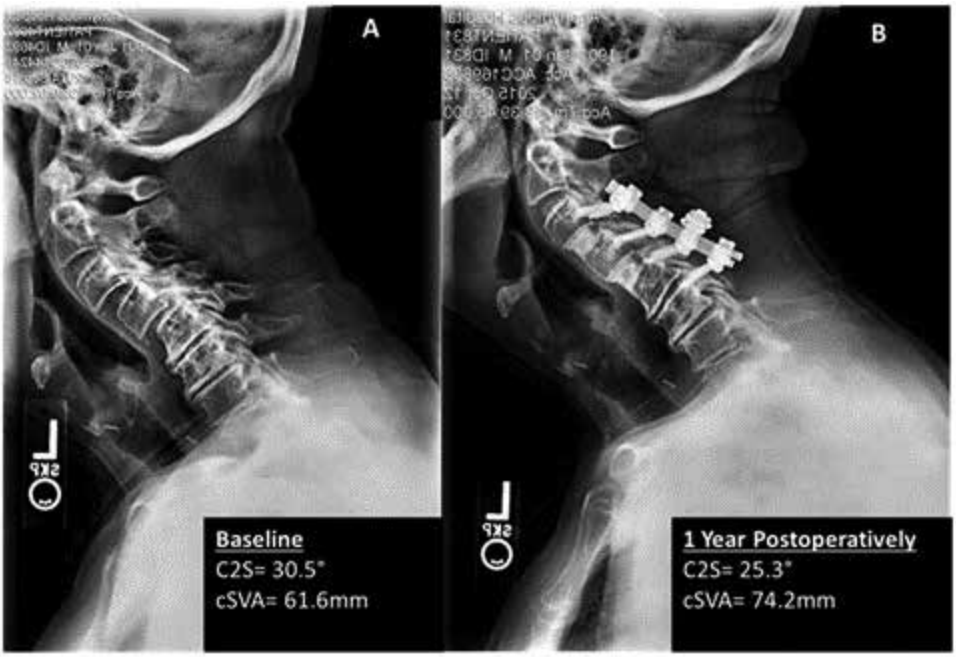

Figure 1: (A) Pre- and (B) Post-operative lateral radiographs illustrating alignment failure in a patient with a preoperative C2-slope >26° who underwent a short posterior fusion.

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Presentation #59

Outcomes of surgery for cervical deformity resulting from upper thoracic PJK are comparable to de novo cervical deformity surgery

Themistocles Protopsaltis, MD, *Ethan Ayres, MD, MPH, Robert Eastlack, MD, Justin Smith, MD, PhD, Kojo Hamilton, MD, Alan Daniels, MD, Eric Klineberg, MD, Brian Neuman, MD, Robert Hart, MD, Shay Bess, MD, Christopher Shaffrey, MD, Frank Schwab, MD, Virginie Lafage, PhD, Christopher Ames, MD*

Introduction: Proximal junctional kyphosis (PJK) is a well-studied complication following adult spinal deformity (ASD) surgery and can lead to new onset cervical deformity (CD). Previous studies have also shown that upper thoracic PJK can also lead to the development of new-onset cervical deformity. However, surgical management strategies and postoperative outcomes have not been well studied in this population. This study examines differences in management and outcomes between CD patients with prior thoracolumbar fusion with PJK and CD patients without previous spinal fusion (noPJK). We hypothesize that those with CD secondary to PJK require more aggressive corrections and have worse outcomes compared to patients without a history of spinal fusion.

Materials and Methods: This is a retrospective cohort study utilizing two prospective adult deformity databased. Operative CD patients with cSVA>4cm were included. Patients were categorized into 2 groups: 1) utPJK: Prior upper thoracic fusion (with UIV between T1 and T5) with baseline PJK. 2) noPJK: No prior fusion. utPJK was compared to noPJK in terms of surgical parameters, rates of complications, revisions, sagittal alignment and achieving a minimum clinically important difference (MCID) in HRQL. The impact on postop outcomes of fusion extension into the cervical region was assessed (Figure A).

Results: 135 CD patients (mean 62±10y, 64%F), 87 noPJK & 48 utPJK patients were included. utPJK had worse baseline alignment (cSVA 47vs35mm, p<.05). utPJK and noPJK did not differ in terms of revision rates (19% vs 11%), major complications (23% vs 22%) or proportion of patients who reached MCID for HRQL (54% vs. 55%). utPJK was associated with more 3CO (23% vs 7%, p<.05) and higher rates of implant failure (17% vs 5%, p<.05). At 1year, 60% of utPJK and 29% of noPJK had 1year cSVA>4cm (p<.05). The fusion was extended into the cervical region in 44% of PJK patients and 98% of noPJK, p<.05. 71% of those with a cervical fusion reached MCID for HRQL vs. 29% without a cervical fusion (p<0.05).

Conclusion: Although upper thoracic PJK was associated with worse postoperative alignment, higher 3 column osteotomy rates, and more implant failures, there were no differences in patient reported outcomes or revision rates compared to CD without a prior fusion. utPJK patients whose fusions extended into the cervical spine were more likely to reach the MCID than patients without cervical extension of the fusion.

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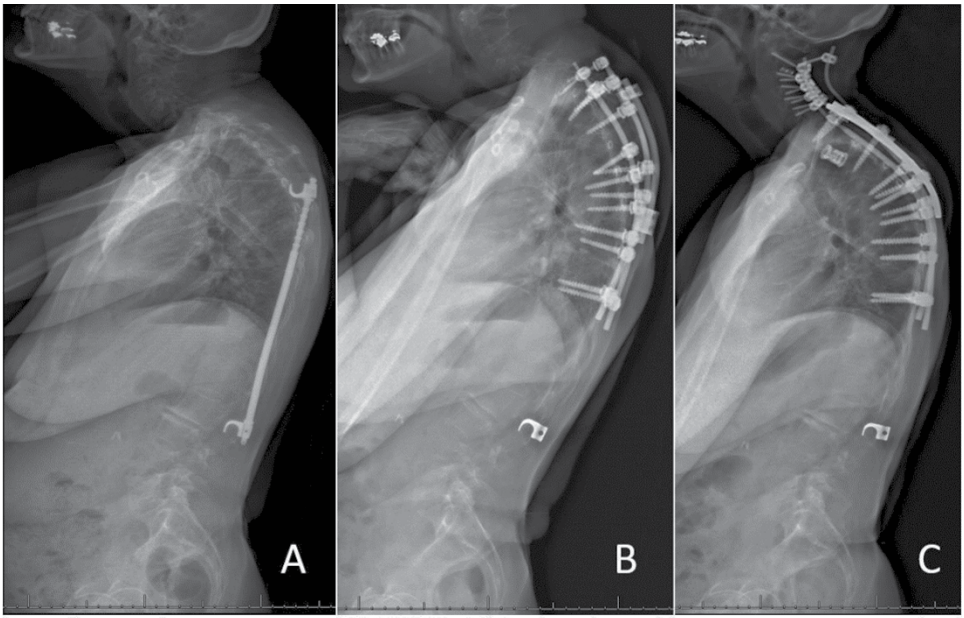

Figure: A) Baseline, B) 6 month postoperative following 1st surgery (T4 PSO) and C) 2 year f/u radiographs following 2nd surgery (T2 VCR) of a patient with a cervicothoracic deformity that suffered recurrent upper thoracic PJK. The definitive realignment required extension of the fusion to the upper cervical spine.

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Presentation #60

Patients with cervical deformity undergoing ACDF experience as good if not better patient reported outcomes at one year compared to those without deformity.

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Introduction: Cervical deformity has increasingly been recognized as a driver of disability in terms of both neck and global dysfunction. Although still a moving target, deformity has been defined as a cervical sagittal vertical axis (cSVA) of 40 mm or more by several studies, which have linked these patients to decreased patient reported outcomes measures (PROMs). How this population responds in terms of radiographic and outcome measures when surgery is performed to address the degenerative neurological component of disease rather than the deformity element itself has been less studied.

Materials and Methods: Patients who underwent a 1-3 level ACDF to address radiculopathy and/or myelopathy at a single, academic institution between 2014 and 2018 with at least one year of postoperative patient reported outcome measures (PROMs) were reviewed. Patients were categorized based on cervical deformity into two groups: those with cervical sagittal vertebral axis (cSVA) > 40, the deformity group (D), and those with cSVA < 40mm, the non-deformity group (ND). Patient demographics, surgical parameters, pre- and post-operative radiographs, and up to one-year PROMs were reviewed. For differences between the D and ND cohorts, continuous variables were compared using Student's T-test and categorical variables were compared using either chi-square or Fischer exact tests. Univariate analysis and multiple linear regression analysis were performed to compare between groups and determine whether existing deformity was an independent predictor of PROMs.

Results: 241 total patients were included in the final analysis with 201 patients in the ND group and 40 patients in the D group (mean cSVA 24.8+/-8.22mm vs 49.1+/-7.14mm, $p<0.001$). Patients with deformity were more likely to be men ($p<0.001$) and have a slightly higher BMI ($p=0.028$) but otherwise there were no demographic differences between the groups. In terms of radiographic parameters, the D group had significantly worse post-operative cSVA (44.2+/-13.8mm vs 25.1+/-9.59, $p<0.001$) but had relatively greater rates of improvement from pre to post cSVA (-4.87+/-11.0mm vs 0.25+/-8.10mm, $p=0.007$) (Table 1). While the D group had worse preoperative radiographic measures in terms of C2 slope, T1 slope, C2-7 lordosis, and craniocervical angle ($p<0.001$), both groups experienced equivalent rates of improvements in these parameters ($p>0.05$). Although both groups had significant improvements in all PROMs, the D group experienced significantly greater improvement in NDI and MCS-12 than the ND group (NDI delta: -19.45+/-21.5 vs -11.11+/-19.6, $p=0.027$, MCS-12 delta 7.68+/-12.9 vs 1.32+/-12.9, $p=0.009$) (Table 2). In the regression analysis, these relative improvements remained significant.

Conclusion: In our patients, those with cervical deformity undergoing ACDF have similar baseline

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disability to those without deformity. While all patients experience significant postoperative improvements, regardless of deformity parameters, patients with cervical deformity experience relatively greater success after ACDF.

Table 1. Differences in radiographic parameters between deformity and non-deformity groups

	Under 40 *N=201*	Over 40 *N=40*	P Value
PREOP			
Pre C2-C7 SVA (mm)	**24.8 (8.22)**	**49.1 (7.14)**	**<0.001**
Pre C2-C7 Lordosis	10.2 (7.39)	11.4 (8.14)	0.384
Pre C2 Slope	**18.8 (6.88)**	**27.7 (9.27)**	**<0.001**
Pre T1 Slope	**24.2 (9.07)**	**37.3 (1.72)**	**<0.001**
Pre CCA	**59.3 (6.80)**	**50.1 (6.71)**	**<0.001**
POSTOP			
Post C2-C7 SVA (mm)	**25.1 (9.59)**	**44.2 (13.8)**	**<0.001**
Post C2-C7 Lordosis	**10.9 (7.11)**	**13.1 (6.35)**	**0.050**
Post C2 Slope	**17.7 (6.35)**	**24.7 (9.90)**	**<0.001**
Post T1 Slope	**22.7 (7.75)**	**33.4 (3.69)**	**0.012**
Post CCA	**60.0 (6.37)**	**52.4 (10.7)**	**<0.001**
DELTA (preop-postop)			
Delta C2-C7 SVA (mm)	**0.25 (8.10)**	**-4.87 (11.0)**	**0.007**
Delta C2-C7 Lordosis	0.67 (7.17)	1.67 (8.64)	0.495
Delta C2 Slope	-1.10 (6.44)	-2.88 (8.85)	0.235
Delta T1 Slope	-1.02 (6.90)	-3.83 (2.48)	0.198
Delta CCA	0.66 (6.13)	2.10 (7.72)	0.294

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Table 2. Differences in PROMs between deformity and non-deformity groups

	cSVA < 40 *N=201*	cSVA > 40 *N=40*	P Value
Clinical Outcomes			
VAS Neck Pre	5.35 (2.89)	5.36 (3.09)	0.995
VAS Neck Post	2.64 (2.62)	2.36 (2.62)	0.545
VAS Neck Delta	-2.72 (3.22)	-3.00 (3.43)	0.636
VAS Arm Pre	4.73 (3.20)	4.59 (3.33)	0.804
VAS Arm Post	1.77 (2.39)	1.78 (2.26)	0.984
VAS Arm Delta	-2.96 (3.19)	-2.81 (3.88)	0.819
MCS-12 Pre	48.3 (11.7)	43.9 (13.9)	0.074
MCS-12 Post	49.3 (11.3)	51.8 (10.2)	0.163
MCS-12 Delta	**1.32 (12.9)**	**7.68 (13.4)**	**0.009**
PCS-12 Pre	34.1 (8.26)	33.9 (6.01)	0.842
PCS-12 Post	40.9 (11.0)	42.4 (11.4)	0.451
PCS-12 Delta	7.14 (11.0)	8.24 (11.4)	0.585
NDI Pre	40.6 (19.3)	41.4 (20.2)	0.808
NDI Post	**29.4 (20.8)**	**21.9 (18.3)**	**0.025**
NDI Delta	**-11.11 (19.6)**	**-19.45 (21.5)**	**0.027**

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Presentation #61

Surgical Strategy for the Management of Cervical Deformity is Based on Morphology

Virginie Lafage, PhD, Han Jo Kim, MD, ***Jonathan Elysee, BS,*** *Christopher Ames, MD, Peter Passias, MD, Christopher Shaffrey, MD, Gregory Mundis, MD, Themistocles Protopsaltis, MD, Munish Gupta, MD, Eric Klineberg, MD, Justin Smith, MD, PhD, Shay Bess, MD, Frank Schwab, MD, Renaud Lafage, MS, ISSG Foundation*

Introduction: A cervical deformity morphotypes classification using an AI approach and based on type and location of deformity has recently been described. While a follow-up study demonstrated differences in clinical presentation between these types of deformity, the relationship between pattern of deformity and surgical strategy remained unexplored. The purpose of this study was to examine the surgical strategies implemented to treat these deformity types and identify if differences in treatment strategies impact surgical outcomes.

Materials and Methods: This is a retrospective case control study of 109 cervical deformity patients. Adult patients enrolled into a prospective cervical deformity database were classified into 4 deformity types as previously described1: Flatneck (FN): anterior malalignment of the cervical spine despite some reserve of extension with a normal T1 Slope; Focal kyphosis (FK): localized rigid kyphosis with an overall maintained global alignment of the cervical spine; Cervicothoracic kyphosis (CTK): large anterior malalignment due to a steep T1 slope with no reserve of extension (maximum compensation used); Coronal (C): cervical scoliosis with a large coronal curve within the cervical spine. Group differences in demographics, preoperative symptoms, health related quality of life (HRQOL) and surgical treatment strategies were evaluated and postop radiographic and HROQL at minimum one year follow up compared.

Results: 90/109 eligible patients (mean age 63.3 +/- 9.2, 64% female, CCI 1.01 +/- 1.36) were evaluated. Group distributions included F=33%, FK=29%, CT=29% and C=9%. Significant differences were noted in the surgical approaches for the four types of deformities, with FN and FK having a high number of anterior/posterior (APSF) approaches while CTK and C had more posterior only (PSF) approaches. For FN and FK, PSF was utilized more in cases with prior anterior surgery (70% vs. 25%). For FN group, PSF resulted in inferior NDI scores compared to those receiving APSF, suggesting APSF is superior for FN types. CTK types had more 3-Column Osteotomies (3CO) ($p<0.01$) and longer fusions with the LIV below T7 ($p<0.01$). There were no differences in the UIV between all deformity types ($p=0.19$). All four types of deformities had significant improvement in NRS neck pain post-op ($p<0.05$) with their respective surgical strategies.

Conclusion: The four types of cervical deformities had different surgical strategies to achieve improvements in HRQOLs. FN and FK types were more often treated with APSF surgery while CTK and C deformities were more likely to undergo PSF. CTK deformities had the highest number of 3COs. This information may provide guidelines for the successful management of cervical deformities.

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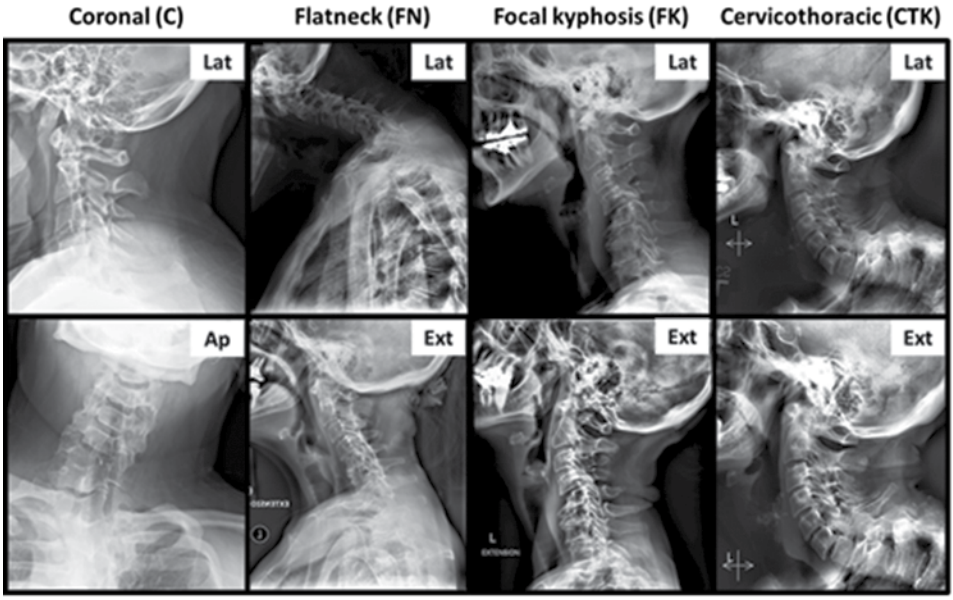

Figure 1: Example of the 4 deformity types as previously described by Kim et al.

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Presentation #62

Diagnostic usefulness of 10-Step Tandem Gait for the patient with Degenerative Cervical Myelopathy

Kyung-Chung Kang, MD, *Jung-Hee Lee, MD, Ki Young Lee, MD, Sang-Kyu Im, MD, In Uk Hwang, MD, Jong-Beom Park, MD, Jae Young Hong, MD, Jin-Sung Park, MD, Hyoungmin Kim, MD*

Introduction: Gait disturbance is one of cardinal symptoms of degenerative cervical myelopathy (DCM). For assessment of the gait abnormality, Japanese Orthopedic Association (JOA) Score, and Nurick scale have been used frequently. However, these scores are sometimes obscure because they are based on subjective questionnaires and unclear differences between grades. Tandem gait is considered one of the most useful diagnostic tools for gait impairment, but for evaluation of cervical myelopathy, the actual availability is minimal due to no standardized grading system. The aim of this study is to evaluate diagnostic usefulness of 10-step tandem gait in comparison to other diagnostic tools such as JOA score and Nurick scale by using gait analysis parameters in patients with the DCM.

Materials and Methods: A total of 62 patients (mean age: 59 years, 41 males) that consecutively underwent operations for DCM at our institution were retrospectively reviewed and compared to 72 persons without gait abnormality. For evaluation of the patients' gait disturbance, Japanese Orthopedic Association (JOA) subscore for lower extremity and Nurick scale have been assessed. The 10-step tandem gait were tested and the patients were sub-grouped into 5 Grades: Grade 0(impossible to walk), Grade 1(≤3 steps), Grade 2(<10 steps), Grade 3(10 steps, but unstable), and Grade 4(10 steps, normal) (Table 1). For objective evaluation of gait abnormality, gait analysis with Neurocom Balance Master were also performed. With this gait machine, all participants underwent modified clinical test of sensory integration and balance (mCTSIB), limits of stability (LOS), and rhythmic weight shift (RWS). The results of 10-step tandem gait and each score were compared and accuracy and concordance of all scores were evaluated by using the gait analysis parameters.

Results: In comparison to control group, the patients with DCM showed significantly reduced gait functions in all gait parameters ($p<0.001$). The mean values of each score were 2.9 ± 1.0 (JOA subscore) and 1.5 ± 0.9 (Nurick scale). Mean tandem gait steps and grades were 7.1 ± 3.6 and 2.6 ± 1.1, respectively. The patients' 10-step tandem gait grades were Grade 0(n=1), Grade 1(n=12), Grade 2(n=13), Grade 3(n=17), and Grade 4(n=19). Among the parameters, tandem gait grade and JOA subscore were correlated (rho=0.553, $p<0.001$). The Nurick scale was negatively correlated with both tandem gait grade (rho=-0.652, $p<0.001$) and JOA subscore (rho=-0.600, $p<0.001$). In correlation analyses with gait parameters, the tandem gait step/grade showed similar results to those for JOA subscore or Nurick scale (Table 2). In correlation analyses with balance parameters, the results of the tandem gait step/grade and Nurick scale were similar to or more than those of JOA subscore (Table 3).

Conclusion: The 10-step tandem gait can be accessed objectively and easily. For evaluation of gait disturbance in patients with cervical myelopathy, its diagnostic usefulness is thought to be similar to or more than the existing diagnostic tools. The authors convinced that this test would be a viable option for evaluation of gait disturbance in patients with DCM.

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Table 1. Comparisons of each item between JOA subscore for lower extremity and tandem gait grade

Score/Grade	JOA subscore (lower extremities)	Tandem gait grade
0	Impossible to walk	Impossible to walk
1	Needs cane or assistance on flat surface	≤ 3 steps
2	Needs assistance on stairs	< 10 steps
3	Walks unaided, but slowly	10 steps, unstable
4	Normal	10 steps, normal

Table 2. Results of correlation analyses between gait parameters and tandem gait steps/grade, JOA subscore and Nurick scale

Variable	Tandem gait steps (0-10)		Tandem gait grade (0-4)		JOA subscore (lower limb) (0-4)		Nurick scale (0-5)	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value
Velocity, cm/sec	0.612	<0.001	0.601	<0.001	0.621	<0.001	-0.738	<0.001
Cadence, steps/min	0.253	0.053	0.238	0.069	0.203	0.117	-0.104	0.448
Stride time, sec	-0.297	0.022	-0.255	0.051	-0.340	0.007	0.138	0.315
Stride length, cm	0.475	<0.001	0.479	<0.001	0.510	<0.001	-0.678	<0.001
Step widths, cm	-0.223	0.089	-0.190	0.149	-0.031	0.815	0.140	0.310
Swing phase, %	0.635	<0.001	0.620	<0.001	0.625	<0.001	-0.647	<0.001
Stance phase, %	-0.604	<0.001	-0.579	<0.001	-0.601	<0.001	0.618	<0.001
Double stance, %	-0.629	<0.001	-0.615	<0.001	-0.664	<0.001	0.661	<0.001
Single limb support, %	0.625	<0.001	0.611	<0.001	0.662	<0.001	-0.654	<0.001

Table 3. Results of correlation analyses between balance parameters of static and dynamic stability and tandem gait steps/grade, JOA subscore and Nurick scale

Category	Variable	Tandem gait steps, (0-10)		Tandem gait grade, (0-4)		JOA (lower limb) grade, (0-4)		Nurick score, (0-5)	
		rho	p-value	rho	rho	rho	p-value	rho	p-value
CTSIB	Firm, eye-opened	-0.510	<0.001	-0.545	<0.001	-0.346	0.006	0.459	<0.001
	Firm, eye-closed	-0.570	<0.001	-0.639	<0.001	-0.538	<0.001	0.471	<0.001
LOS	Reaction time, s	0.280	0.037	0.208	0.124	0.157	0.239	-0.394	0.004
	Speed, deg/s	0.281	0.031	0.262	0.045	0.160	0.217	-0.256	0.059
	end-point Excursion, %	0.513	<0.001	0.486	<0.001	0.335	0.008	-0.559	<0.001
	maximal Excursion, %	0.525	<0.001	0.487	<0.001	0.340	0.007	-0.551	<0.001
	Directional control, %	0.608	<0.001	0.588	<0.001	0.410	0.001	-0.669	<0.001
RWS	Mediolateral sway								
	Speed, deg/s	0.441	<0.001	0.379	0.003	0.327	0.010	-0.385	0.004
	Directional control, %	0.592	<0.001	0.561	<0.001	0.501	<0.001	-0.543	<0.001
	Anterioposterior sway								
	Speed, deg/s	0.466	<0.001	0.416	0.001	0.386	0.002	-0.469	<0.001
	Directional control, %	0.591	<0.001	0.678	<0.001	0.524	<0.001	-0.661	<0.001

Abbreviation: mCTSIB, modified clinical test of sensory integration and balance; LOS, limits of stability; RWS, rhythmic weight shift; JOA, Japanese Orthopedic Association

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Presentation #63

Defining Clinically Relevant Distal Failure In the Treatment of Adult Cervical Deformity: An Improved Definition Based on Functional Outcomes and Need for Reoperation

Sara Naessig, BS, *Peter Passias, MD, BS, Shengnan Huang, MS, Cheongeun Oh, PhD, Waleed Ahmad, MS, Katherine Pierce, BS, Virginie Lafage, PhD, Renaud Lafage, MS, Bassel Diebo, MD*

Introduction: The widely used definition for distal junctional kyphosis includes the change in kyphosis between the lower instrument vertebra (LIV) and LIV-2 to be >10°. However, this cut off has yet to be analyzed against other possible cut offs in terms of accuracy, sensitivity, and specificity for various clinically relevant outcomes.

Materials and Methods: Surgically treated CD pts were enrolled into a prospective, multi-center database and evaluated at a minimum of 1Y follow up for DJK. DJK was defined by the patient's DJK angle (DJKA) >10° change in kyphosis between LIV and LIV-2 and a>10° index angle. Sensitivity (true positive[TP]/TP+false negative[FN]), specificity (true negative[TN]/(TN+False Positive[FP]), and accuracy (TN+TP/TN+TP+FN+FP) metrics were calculated from different combinations of angular changes above and below the lower instrumented vertebrae (LIV) from pre- to postop. New cut-off point was obtained using decision tree. The ability of these angular changes to predict different types of DJK failure(DJKF) [1) reoperation for DJK 2) not meeting MCID for either NDI or Eq5D] and were compared against previously published definitions of DJK including absolute and ?DJKA>10° and ?DJKA>20°.

Results: 160 CD patients with follow-up were included (57yrs, 29.1 kg/m2, 51.8%F). 18% of these patients developed DJK post-op (33.4% 6M, 47.6% 1Y, 19% 2Y). The mean DJK angle prior to revision surgery was -1.7±7.4 (Minimum: -19.3, Maximum: 10.5). Baseline average pelvic parameters were: PT: 16.8±9.6, PI: 54.1±12.3, PI-LL:-2.0±13.5. The average cervical parameters were: TS-CL: 25.6±14.5, C2-C7: -0.9±14.4. Sensitivity, precision, and accuracy of previously used criteria of >10° to identify DJKF for outcome 1 demonstrated a sensitivity of 50%, specificity of 64.4% and an accuracy of 63.2%. For outcome two using this criteria resulted in a sensitivity of 55%, specificity 75.8%, and accuracy 67.3%. However, if the ?DJKA was increased to 15.3 the predicted sensitivity for DJKF defined by reoperation was 50%, specificity 86.6% and with an accuracy of 83.6%. When DKF was defined by HRQL's the sensitivity was 35%, specificity 96.5% and accuracy of 71.4%. This newly established cut off had greater ability to correctly identify true positives than the 20° cutoff (45.8% vs 27.1%), as well as for true negatives when compared to the 10° (39.2% vs 34.2%). A sub analysis identified 40.6% of patients with a DJKA>10° to be not clinically meaningful. When increasing the angle to the proposed 15.3° only 35.7% are not clinically meaningful.

Conclusion: The newly established cut off for DJK failure (?DJKA>15.3°) demonstrated greater sensitivity, specificity, and precision than the previously established criteria of 10° when analyzing distal junctional kyphosis failure as described by reoperations or clinical deterioration.

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #64

Clinical Application of a New Assessment Tool for Myelopathy Hand Using Virtual Reality

Quan Li, MD, *Hongxing Shen, MD*

Introduction: Clumsy fingers movement is a common symptom of cervical myelopathy patients. Evaluating the impaired hand function can provide a strong basis in assessing the severity of myelopathy. Currently, no objective evaluation method is widely accepted in clinical practice.

Materials and Methods: Myelopathy-hand Functional Evaluation System (MFES) was developed and mainly consisted of a pair of wise-gloves and a computer with software. 100 healthy individuals and 98 CSM patients were included. When performing the 10s G-R test, The movements of each finger were recorded by MFES and converted into waveforms. Relevant waveform parameters were measured and analyzed. The modified Japanese Orthopedics Association (mJOA) scores and the maximum spinal cord compression (MSCC) on midsagittal T2-weighted magnetic resonance imaging (MRI) were measured .

Results: Demographic factors affecting the average number of G-R cycles were gender and age. Male and younger age were significantly correlated with a higher number of G-R cycles. Myelopathy patients had a lower number of G-R cycles than healthy individuals. The number of cycles was significantly correlated with the mJOA scores (r =0.758) and negatively correlated with the MSCC (r = -0.591). There were significant differences in adduction and abduction time in patients with mJOA scores of more than 6, but not in healthy subjects and patients with mJOA scores of less than 6. The waveform of fingers in myelopathy patients was significantly lower and wider than those in healthy individuals. The average ratio value of wave height and wave width could quantitatively reflect such difference of waveform. According to the ROC curve analysis, the optimal threshold value of the normal average ratio was more than 1.92.

Conclusion: MFES is a new objective and quantitative assessment tool for patients with cervical myelopathy. Besides the number of G-R cycles, the waveform of finger movement was significantly different between healthy subjects and severe CSM patients. The average ratio value of wave height and wave width could describe the waveform of finger movement for this new device, and the optimal threshold value the normal average ratio was more than 1.92, namely fingers with average a/b ratio of less than 1.92 should be considered as symptomatic myelopathy hand. But this value was obtained according to a relatively small sample, and it still needed to be further verified in the subsequent study. In addition, our results about adduction and abduction time in G-R test suggested that finger flexor muscles were prior affected in mild (mJOA>12) and moderate (6

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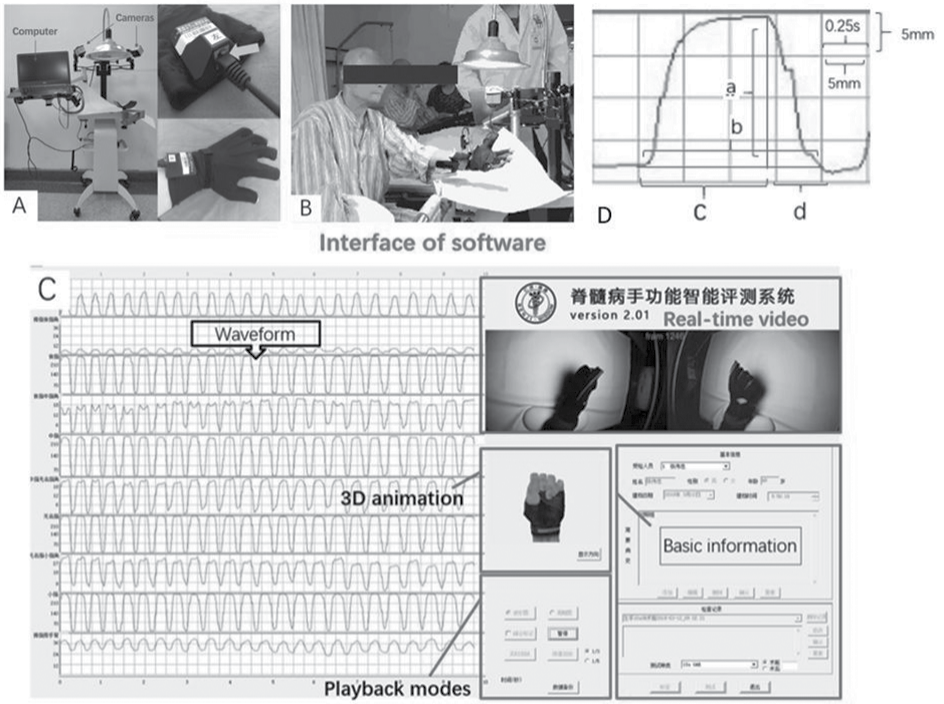

Fig 1. A). and B). The composition of Myelopathy-hand Functional Evaluation System (MFES) ; C). the interface of the software; D). parameters of the waveform shape

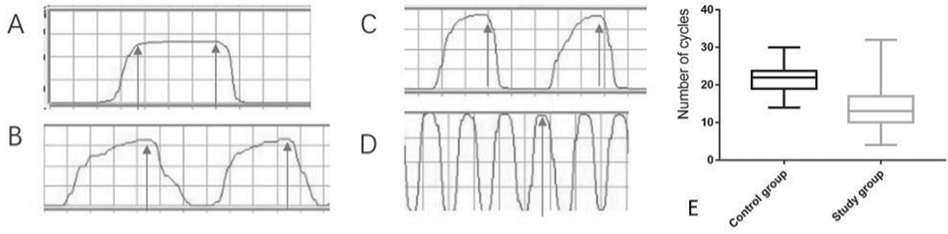

Fig 2. A) mJOA scores=5; B) mJOA scores=8; C) JOA scores=13; D) Healthy individual. The shape of waveforms were lower and wider in myelopathy patients than that in healthy individuals. There were significant differences in adduction and abduction time in patients with mJOA scores of more than 6, but not in healthy subjects and patients with mJOA scores of less than 6. And E) the number of G-R cycles of patients was significantly less than healthy subjects($p<0.0001$).

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Table 1: The average flexion time and extension time of the little finger in CSM patients

Subgroups / Variables	JOA scores ≤ 6	6 < JOA scores ≤ 12	JOA scores > 12
The flexion time	0.58±0.19s	0.43±0.12s	0.32±0.13s
The extension time	0.54±0.24s	0.28±0.08s	0.23±0.11s
P values	$P_1 > 0.05$	$P_2 < 0.01$	$P_3 < 0.01$

*JOA scores: Japanese Orthopedics Association scores.

Table 2: Comparison of the waveform parameters of five fingers between the study group and the control group.

		Control group	Study group	P value
Little finger	a (mm)	19.52±0.44	13.65±3.32	$P_1 < 0.0001$
	b (mm)	9.45±1.71	14.40±8.76	$P_2 < 0.0001$
	a/b	2.07±0.46	0.95±0.45	$P_3 < 0.0001$
Ring finger	a (mm)	19.70±0.08	15.29±0.40	$P_4 < 0.0001$
	b (mm)	7.64±0.37	14.05±1.55	$P_5=0.0003$
	a/b	2.70±0.14	1.22±0.07	$P_6 < 0.0001$
Middle finger	a (mm)	19.15±0.17	15.64±0.30	$P_7 < 0.0001$
	b (mm)	7.95±0.25	13.88±1.46	$P_8=0.0004$
	a/b	2.45±0.07	1.30±0.10	$P_9 < 0.0001$
Index finger	a (mm)	19.73±0.08	19.45±0.25	$P_{10}=0.29$
	b (mm)	7.57±0.21	14.15±1.78	$P_{11}=0.0008$
	a/b	2.64±0.07	1.63±0.12	$P_{12} < 0.0001$
Thumb	a (mm)	15.79±0.56	15.53±0.64	$P_{13}=0.76$
	b (mm)	8.79±0.32	14.35±1.67	$P_{14}=0.0024$
	a/b	1.83±0.07	1.27±0.11	$P_{15}=0.0002$

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Presentation #65

Deep learning-based radiomics using conventional MRI to predict clinically important improvement after laminoplasty in patients with degenerative cervical myelopathy

Satoshi Maki, MD, PhD, *Takeo Furuya, MD, PhD, Sho Okimatsu, MD, Takaki Inoue, MD, Atsushi Yunde, MD, Masataka Miura, MD, Seiji Ohtori, MD, PhD*

Introduction: Magnetic resonance imaging (MRI) is the criterion standard for evaluating spinal cord compression in degenerative cervical myelopathy (DCM). However, conventional MRI features of the cervical spine are limited in accurately estimating the possibility of neuronal recovery after decompression. Deep learning-based radiomics (DLR) was developed to quantify radiographic characteristics automatically using convolutional neural networks (CNN) and allow prognostic stratification of patients. There are two previous machine learning studies [1,2] using clinical data to predict surgical outcomes in DCM, but no image-based machine learning studies have been conducted to date. We sought to assess whether DLR can predict a minimum clinically important difference (MCID) after laminoplasty using conventional MRI in patients with DCM.

Materials and Methods: We enrolled 110 patients with DCM who had undergone laminoplasty and were followed up for more than one year. The clinical diagnoses included 77 patients with cervical spondylotic myelopathy and 33 with ossification of the posterior longitudinal ligament. Japanese Orthopaedic Association (JOA) score for cervical myelopathy was determined before and one year after surgery. Surgical outcomes were measured by the recovery rate of JOA score and were regarded as successful if achieving a minimum clinically important difference (MCID) [3], where the recovery rate of JOA score was 50% or more. The patients were examined using MRI before surgery. T2-weighted images (T2WI) of a midsagittal slice were used to train CNN. We implemented a CNN as a classification model using TensorFlow. The patients with DCM, who achieved MICD or not were randomly divided into 5 equally populated groups. Four groups of images were used to train CNN and classify patients as those who achieved MICD or not. The remaining group was used to validate the CNN classifier trained with the 4 groups. This cross-validation procedure was repeated 5 times. The predictive performance for

Results: JOA score was 9.0 preoperatively and 12.5 one year after surgery, showing significant improvement ($p<0.001$). The area under the ROC curve for prognostic precision for surgical outcomes evaluated by change and recovery rate of JOA score was 0.67 (95% confidence interval, 0.58–0.75), indicating that the DLR predictive model is good. At the optimal cutoff point, the sensitivity, specificity, and accuracy of the CNN classifier based on T2WI were 49%, 81%, and 75%.

Conclusion: Our results provide evidence that DLR may be used for prognostic stratification based on standard-of-care MR images from patients with DCM. DLR can be used as a biomarker for the surgical prognosis of DCM patients.

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Presentation #66

Significance of Cervical Spine Computed Tomography Hounsfield units to predict bone mineral density and the subsidence after anterior cervical discectomy and fusion

Ho Jin Lee, MD, PhD, *Il Sup Kim, MD, PhD, Soon-tae You, MD, PhD, Jae Taek Hong, MD, PhD*

Introduction: This study was a retrospective review. The purpose of this study was to investigate the correlation analysis between Hounsfield units (HU) and dual x-ray absorptiometry (DXA) based on the clinical results of patients who underwent anterior cervical discectomy and fusion (ACDF) surgery.There is no technique to directly measure bone mineral density (BMD) in the cervical spine. As computed tomography (CT) is a very popular preoperative planning modality, using the HU value from that analysis to predict osteoporosis is important for patient outcomes and applications in the clinical field.

Materials and Methods: We reviewed the records for 235 patients who underwent one- (n= 120) or two- (n= 115) level ACDF surgery. In the one-level ACDF group, the HU was measured from C3 to C6 vertebra, while that for the two-level ACDF group was measured from three surgical index vertebrae. The correlation patterns were analyzed with the corresponding DXA (T-score) for each patient. (Figure 1) Subsidence of fusion segment was defined as change in distance between plate-tip and endplate of the vertebra (index level) after four months of follow-up. In addition, to determine the relevant factors that influence fusion segment subsidence, other pre-operative (C2 slope, C7 slope, C2-7 angle, and C2-7 SVA) and post-operative parameters (coronal angle and segmental angle change) were measured.

Results: The correlation coefficient between HU and DXA ranged from 0.57 to 0.71 in the one-level ACDF group and from 0.59-0.66 in the two-level ACDF group. (Table 2, 3) The correlation between HU and DXA was statistically significant regardless of the degree of anterior osteophyte (r= -0.65-0.78). Total subsidence height was 3.8mm after ACDF, and both HU and DXA were statistically correlated with total subsidence (r= |0.26-0.28|). The high-subsidence group (= 4.5 mm) showed smaller HU values (284.1 vs. 316.0) and T-scores (-0.5 vs. 0.1) compared to the low-subsidence group (<4.5 mm). The Discrepancy group, defined as cases with excess plate shift on one side, also showed smaller HU values (260.4 vs. 312.4) and higher degrees of total subsidence than the Matched group.

Conclusion: The correlation between HU in cervical CT and lumbar DXA (T-score) was statistically significant in both one- and two- level ACDF. The level of BMD (HU or DXA) is a very important factor for clinically determining the amount and regularity of subsidence after ACDF. Therefore, HU can be a good alternative assessment to accurately reflect as much of the BMD degree as DXA in the cervical spine.

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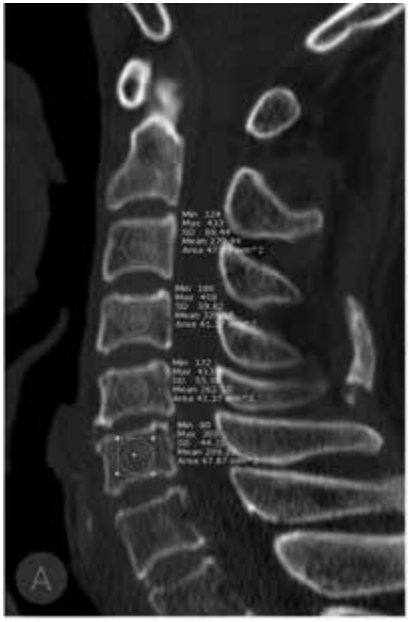

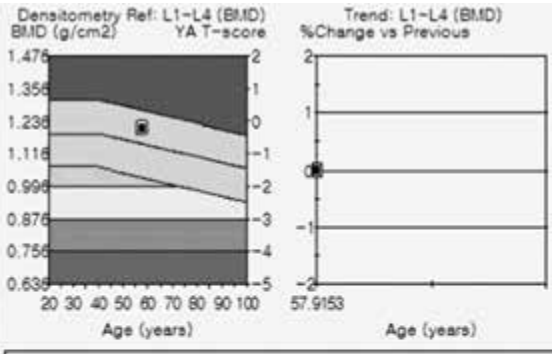

Region	BMD [1] (g/cm2)	Young-Adult [2] (%)	Young-Adult [2] T-score	Age-Matched [3] (%)	Age-Matched [3] Z-score
L1	1.024	88	-1.2	94	-0.5
L2	1.184	95	-0.5	101	0.1
L3	1.239	98	-0.2	105	0.5
L4	1.338	106	0.6	113	1.3
L1-L2	1.110	92	-0.8	98	-0.1
L1-L3	1.157	95	-0.5	102	0.1
L1-L4	1.208	98	-0.2	105	0.5
L2-L3	1.212	97	-0.3	103	0.3
L2-L4	1.257	100	0.0	107	0.7
L3-L4	1.290	102	0.2	110	0.9

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Table 2. Various measured values in two level ACDF patients

	Mean ± SD	Correlation with DXA	P-value
Age	55.6 ± 10.1		
Sex (M / F)	(61 / 54)		
Operation level (C3-5/ C4-6/ C5-7)	10 / 44 / 61		
Coronal angle (°)	2.6 ± 2.6		
Upper vertebrae (UV), HU	330.7 ± 83.3	r=0.66	<0.001
Middle vertebrae (MV), HU	305.9 ± 90.7	r=0.59	<0.001
Lower vertebrae (LV), HU	272.0 ± 82.7	r=0.59	<0.001
Mean value (UV+MV+LV), HU	302.9 ± 82.2	r=0.64	<0.001
Upper Plate vertebrae height (UPVH) (immediate state)	5.7 ± 1.9		
Lower Plate vertebrae height (LPVH) (immediate state)	5.1 ± 2.2		
Upper Plate vertebrae height (UPVH) (after F/U)	3.9 ± 2.3		
Lower Plate vertebrae height (LPVH) (after F/U)	3.1 ± 2.3		
Subsidence height (upper)	1.8 ± 1.9		
Subsidence height (lower)	2.0 ± 1.9		
Total subsidence height (upper + lower)	3.8 ± 3.1		
C2 slope (°)	-10.3 ± 10.0		
C7 slope (°)	-21.1 ± 7.6		
C2-7 angle (°)	10.8 ± 11.5		
C2-7 SVA (mm)	19.0 ± 13.3		
Segmental angle (Pre-OP) (°)	3.2 ± 6.8		
Segmental angle (Post-OP) (°)	8.6 ± 5.4		
Difference value of segmental angle (Pre-OP minus Post-OP) (°)	5.4 ± 7.4		
DXA	-0.1 ± 1.5		

DXA, dual X-ray absorptiometry; HU, Hounsfield units; SVA, sagittal vertical axis

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Table 3. Correlation analysis among multiple parameters

	Coronal angle	Global HU	C2 slope	C7 slope	C2-7 angle	C2-7 SVA	Segmental angle (Pre-OP)	Segmental angle (Post-OP)	Difference Segmental angle (Δ)	DXA	Total subsidence
Coronal angle	1										
Global HU	-0.02	1									
C2 slope	0.01	0.01	1								
C7 slope	0.04	-0.13	0.17	1							
C2-7angle	-0.02	0.10	0.75 **	-0.51 **	1						
C2-7 SVA	-0.02	-0.08	-0.75 **	0.37 **	-0.40 **	1					
Segmental angle (Pre-OP)	-0.18	0.08	0.47 **	-0.41 **	0.68 **	-0.36 **	1				
Segmental angle (Post-OP)	0.01	-0.04	0.13	-0.36 **	0.35 **	0.03	0.28*	1			
(Δ) Difference Segmental angle	0.18 **	-0.10	-0.33	0.11	-0.37 **	0.35 **	-0.81 **	0.47 **	1		
DXA (T-score)	-0.18	0.66 **	-0.17	-0.26 **	0.01	0.18	0.10	-0.06	-0.14	1	
Total Subsidence	0.02	-0.28 **	-0.01	0.08	-0.06	0.01	-0.12	0.05	0.15	-0.26 **	1

* P<0.05

DXA, dual X-ray absorptiometry; HU, Hounsfield units; SVA, sagital vertical axis

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Presentation #67

Risk Factors for Allograft Subsidence following ACDF

Zachariah Pinter, MD, *Anthony Mikula, MD, Matthew Shirley, MD, Ashley Xiong, MD, Brett Freedman, MD, Bradford Currier, MD, Benjamin Elder, MD, PhD, Mohamad Bydon, MD, Ian Kaye, MD, Christopher Kepler, MD, Scott Wagner, MD, Ahmad Nassr, MD, Arjun Sebastian, MD*

Introduction: Studies investigating the impact of interbody subsidence in ACDF suggest a correlation between subsidence and worse radiographic and patient-reported outcomes. Though some interbody subsidence is anticipated, a normal range of subsidence has yet to be defined. Furthermore, no study has investigated the variables influencing allograft subsidence in ACDF. The primary purpose of this study was to utilize computed tomography to characterize subsidence of allograft interbodies in ACDF. The secondary aim of this study was to determine the impact of patient- and graft-related variables on subsidence in ACDF.

Materials and Methods: We performed a retrospective review of a prospective cohort of patients undergoing 1 to 3 level ACDF with an allograft interbody and anterior plating at a single institution between the years of 2011-2017. We collected demographic information (Table 1), radiographic variables, and graft-related parameters (Table 2). Graft subsidence was assessed on CT scan performed at least 6 months postoperatively. We classified subsidence as none if <2mm, mild if 2-3mm, moderate if 3-4mm, and severe if >4mm. Student's t-test and ANOVA were used to compare all means between groups.

Results: We identified 98 patients (152 levels) for inclusion. On sagittal CT for the entire cohort, the mean superior endplate subsidence was 1.62mm+/-0.90 and the mean inferior endplate subsidence was 1.62mm+/-0.91. The number of levels that underwent <2mm, >2mm, and >4mm of subsidence was 73 (48.0%), 79 (51.9%), and 18 (11.8%), respectively. Of the 18 levels with severe subsidence, 14 occurred in multi-level constructs, 2 of which occurred in both levels of a two-level ACDF in one patient. Of the remaining 12 levels of severe subsidence, 11 (92%) occurred at the caudal level and to a significantly higher degree at the inferior end plate ($p<0.001$). On univariate analysis of levels with severe subsidence, both a decrease in the distance from the screw tip to the inferior endplate and in the screw tip height to vertebral body height ratio were associated with an increase in subsidence ($p<0.05$) (Table 3). Additionally, both mild and severe subsidence were significantly influenced by loss of vertebral body height on immediate postoperative x-rays ($p<0.005$) (Table 3). There was no significant difference in preoperative or postoperative VAS between groups ($p>0.05$). 16 patients (94.1%) with severe subsidence experienced pseudarthrosis compared to only 11 patients (13.6%) with <4mm subsidence ($p<0.001$). However, reoperation rate was not significantly different between the severe subsidence and non-severe subsidence groups (11.8% vs 17.3%, $p=0.44$).

Conclusion: The present study is the first to utilize advanced imaging to quantify and characterize allograft subsidence in ACDF. Univariate analysis of patients with severe subsidence demonstrated that inferior screw placement in the caudal instrumented vertebra was associated with increased subsidence, likely due to decreased buttress support and an increased working length with an associated decrease in construct rigidity. Furthermore, excessive endplate

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resection was associated with an increase in both mild and severe subsidence. Based upon our study, some allograft subsidence in ACDF is expected, but too inferior screw placement at the caudal vertebral level and excessive endplate resection should be avoided to prevent severe subsidence.

Table 1: Demographics

Variables	N=98
Age	55.5 ± 11.5
Sex	
Male	53 (54.1%)
Female	45 (45.9%)
BMI* (m/kg²)	29.5 ± 5.7
Obesity (BMI > 25)	74 (75.5%)
Smoking	16 (16.3%)
Diabetes	14 (14.3%)
Chronic steroid use	1 (1.0%)
Chronic kidney disease	3 (3.1%)
Inflammatory arthritis	2 (2.0%)
Number of levels fused	
One level	51 (52.0%)
Two level	40 (40.8%)
Three level	7 (7.1%)

*BMI: Body Mass Index

Table 2: Radiographic and Graft-related Parameters

Radiographic Parameters	N=152
Levels	
C3-4	8 (5.2%)
C4-5	28 (18.4%)
C5-6	66 (43.4%)
C6-7	46 (30.3%)
C7-T1	4 (2.6%)
HU* Superior VB*	
Cephalad	382.0 ± 122.8
Middle	383.0 ± 114.5
Caudal	408.3 ± 107.8
HU Inferior VB	
Cephalad	269.9 ± 78.2
Middle	270.1 ± 86.1
Caudal	278.2 ± 97.2
HU Vertebral body average	331.9 ± 84.8
Longus colli diameter	8.2 ± 2.5
Longus colli area	69.4 ± 36.9
HU paraspinal musculature	58.8 ± 20.2
Graft-related Parameters	N=152
Graft height (mm)	
5 mm	12
6 mm	29
7 mm	43
8 mm	36
>8 mm	32
Average	7.45 ± 1.5
Index disc space height (mm)	
Anterior	3.9 ± 1.2
Middle	4.6 ± 1.2
Posterior	3.5 ± 1.2
Average	4.0 ± 1.1
Graft : Index disc space height ratio	2.4 ± 5.6
Graft : Superior native disc height ratio	1.8 ± 0.6
Graft: Inferior native disc height ratio	1.8 ± 0.6
Graft length average (mm)	11.1 ± 2.6
Distance from Posterior VB* to Graft (mm)	4.0 ± 2.2
VB length	18.4 ± 3.4
Graft : VB length ratio	0.61 ± 0.16
Taillard index	21.5 ± 10.6%
Screw length (mm)	14.9 ± 1.7
Screw length : VB length ratio	0.83 ± 0.13
VB height (mm)	13.0 ± 2.3
Distance screw tip to endplate (mm)	5.1 ± 2.2
Screw height : VB height ratio	0.40 ± 0.16

*HU: Hounsfield Unit, VB: Vertebral Body

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TABLE 3: Univariate Analysis Severe Subsidence			
Variable	<4 mm subsidence	>4 mm subsidence	P value
Demographics			
Age	55.3	57.7	.281
Sex (Female)	68 (50.8%)	6 (33.3%)	.212
BMI* (m/kg^2)	29.1	28.6	.720
Smoking	23 (17.2%)	3 (16.7%)	.630
Diabetes	20 (14.9%)	3 (16.7%)	.738
Chronic steroid use	1 (0.75%)	0 (0.0%)	.882
Chronic kidney disease	3 (2.2%)	1 (5.6%)	.399
Inflammatory arthritis	4 (3.0%)	0 (0.0%)	.601
Number of levels fused			
One level	47 (35.1%)	4 (22.2%)	.534
Two level	69 (51.5%)	11 (61.1%)	
Three level	18 (13.4%)	3 (16.7%)	
Radiographic parameters			
HU* Superior VB*			
Cephalad	383.4	371.9	.724
Middle	385.8	361.7	.440
Caudal	410.1	394.4	.610
HU Inferior VB			
Cephalad	273.8	240.9	.130
Middle	272.7	250.9	.315
Caudal	282.8	243.7	.104
HU Vertebral body average	334.8	310.6	.285
Longus colli diameter (mm)	8.3	7.9	.526
Longus colli area (mm^2)	69.9	65.9	.658
HU paraspinal musculature	58.4	62.7	.518
Graft-related Parameters			
Graft height (mm)	7.41	7.62	.497
Index disc space height (mm)			
Anterior	3.91	4.27	.118
Middle	4.54	5.00	.080
Posterior	3.45	3.64	.515
Average	3.97	4.30	.115
Graft : Index disc space height ratio	2.51	1.81	.176
Graft : Superior native disc height ratio	1.77	1.88	.513
Graft: Inferior native disc height ratio	1.81	1.83	.869
Graft length average (mm)	11.0	11.5	.380
Distance from Posterior VB* to Graft (mm)	3.95	4.41	.383
VB length	18.4	18.6	.870
Graft : VB length ratio	.608	.655	.357
Taillard index	21.2%	24.2%	.264
Screw length (mm)	14.8	15.3	.214
Screw length : VB length ratio	.830	.806	.476
VB height (mm)	13.1	12.5	.339
Difference VB height anterior	**0.76**	**3.96**	**.004**
Difference VB height middle	**0.82**	**3.53**	**.005**
Difference VB height posterior	0.60	1.61	.190
Distance screw tip to endplate (mm)	**5.25**	**3.52**	**.030**
Screw height : VB height ratio	**.403**	**.298**	**.038**

*HU: Hounsfield, VB: vertebral body, BMI: body mass index

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Presentation #68

Quantitative Romberg using a Force Plate: An Objective Measure for Cervical Myelopathy

Jeffrey Gum, MD, *Steven Glassman, MD, Morgan Brown, MS, Christy Daniels, MS, Leah Carreon, MD, MSc*

Introduction: Surgical decision making for Cervical Spondylotic Myelopathy (CSM) relies on symptoms and physical examination. The Romberg test is a clinical exam used to identify balance issues with CSM, but has subjective interpretation and has a binary (positive or negative) result. Using a force plate, the area, frequency and speed of sway with eyes open and eyes closed can be quantified. This objective measurement has the potential for earlier intervention and/or to monitor treatment progress. Additionally, this measurement tool is more practical than a formal gait analysis in the clinical setting.

Materials and Methods: Patients with CSM requiring surgery and healthy normal volunteers were asked to perform the Romberg test while on a force plate measuring the center of pressure: standing up straight with arms extended for 30 seconds with eyes open, followed by 30 seconds with eyes closed. The change in total sway area (TSA), sway frequency and sway speed with eyes closed and eyes open were calculated.

Results: 27 of 48 CSM patients were age-matched to 27 healthy volunteers with a mean age of 54 years. The change in TSA (211.5mm2), frequency (365.4/s) and speed (7.0m/s) was statistically greater in the CSM group compared to normal TSA (87.8mm2, p=0.005), frequency (62.1/s, p=0.008) and speed (4.2m/s, p=0.085).

Conclusion: Poor standing balance can be quantified in patients with CSM. The Romberg test on a force plate may help diagnose and evaluate CSM. Further studies are needed to determine its utility to measure treatment effectiveness.

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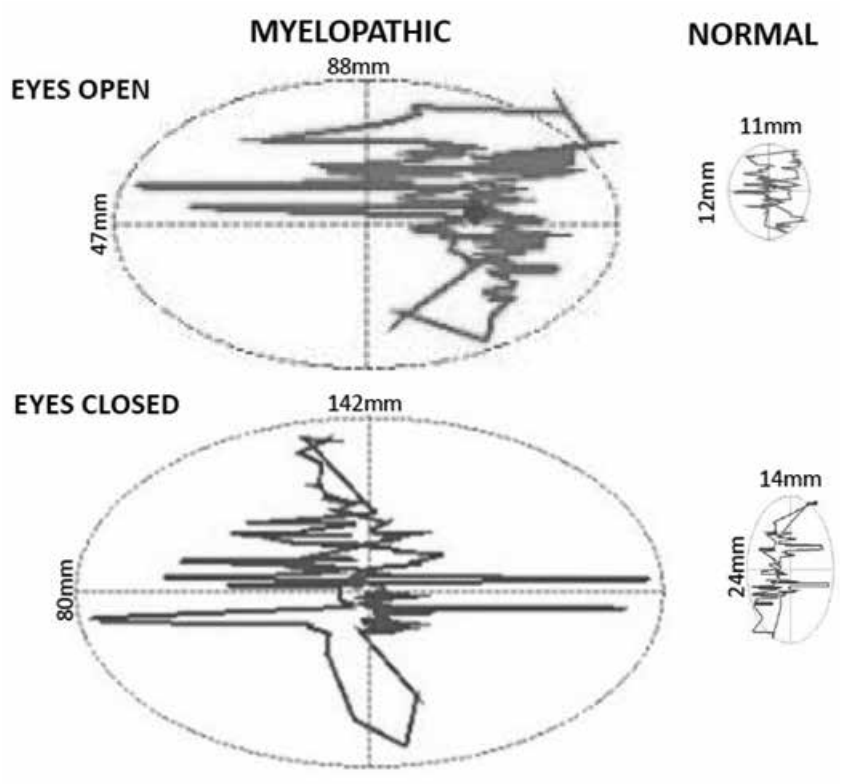

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Presentation #69

Functional Connectivity Changes of the Visual Cortex in the Cervical Spondylotic Myelopathy Patients- A Resting-State FMRI Study

Yuan Xue, MD, PhD

Introduction: To analyze altered functional connectivity (FC) in the visual cortex of cervical spondylotic myelopathy (CSM) patients using resting-state fMRI.We previously showed changes in visual cortex neural activity in CSM patients.

Materials and Methods: Thirty CSM patients and 20 healthy controls were recruited. MR data were collected using a 3.0 T MR. FC of the regions of interest (ROI) (Brodmann areas [BA] 17/18/19/7) were calculated in a voxel-wise manner and compared between groups. Correlation analyses were performed between preoperative Japanese Orthopaedic Association (JOA) scores and altered FC, as well as between preoperative best corrected visual acuity (BCVA) and altered FC. Furthermore, the FC where was compared between the preoperative and the postoperative CSM patients in an ROI-wise manner.

Results: Increased FC was found between BA19 and the cerebellum inferior lobe; between the left BA7 and bilateral calcarine, right lingual, right fusiform gyrus, and left precuneus (BA17); between the left BA7 and right fusiform gyrus and right inferior occipital gyrus (right BA19); and between the right BA7 and right superior lobe of cerebellum (right BA19) in CSM patients ($P<0.05$). A negative correlation was found between JOA score and FC of the left and right BA19, and a positive correlation was found between the BCVA and FC of the left and right BA7 ($P<0.05$). ROI analysis demonstrated statistically significant FC differences in between the preoperative and the postoperative CSM patients ($P<0.05$).

Conclusion: FC changes were present in the visual cortex of CSM patients, which negatively correlated with preoperative JOA scores and positively correlated with preoperative BCVA. Significant recovery of FC in the visual cortex was detected in CSM patients postoperatively.

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Presentation #70

Radiologic risk factors associated with myelopathy in patients with ossification of the posterior longitudinal ligament of the cervical spine.

Woo-Keun Kwon, MD, PhD, *Youn-Kwan Park, MD, PhD*

Introduction: Myelopathy following ossification of the posterior longitudinal ligament (OPLL) is one of the devastating clinical features in these patients, while we still know little about which factors are associated with development of myelopathy. We evaluated the difference of radiologic measurements between OPLL patients with or without myelopathy and searched for the clinical significance with emphasis on the impact of dynamic motion.

Materials and Methods: Patients with confirmed diagnosis of OPLL with more than 25% of central canal compromise (CC) were enrolled for retrospective review. They were divided into two groups according to the coexistence of radiographic evidence of myelopathy; increased signal intensities (ISIs) on T2 weighted magnetic resonance images (MRI). Demographic data as well as radiologic measures including the presence of disc degeneration (DD), anterior-posterior diameter (APD) of central canal, CC ratio, global and segmental range of motion (gROM and sROM), OPLL type (morphologic classification) and K-line were collected.

Results: Of the 305 patients enrolled, 151 were myelopathy positive (M+) while 154 were myelopathy negative (M-). Age, APD, CC ratio, sROM at the index level, laterality of OPLL and K-line positive were associated with the presence of myelopathy in the univariate analysis. Among these radiologic measures, the APD (odds ratio[OR]; 0.411, $p<0.001$), CC ratio ([OR]; 1.100, $p<0.001$) and sROM ([OR]; 1.371, $p<0.001$) were significantly associated with the presence of myelopathy in the multivariate analysis. When the subgroup analysis was done after dividing the enrolled cohort by CC ratio, the presence of DD, the APD and sROM were significantly associated with myelopathy in those with CC of 25~49%. On the other hand APD, CC ratio and sROM were significantly associated with myelopathy in those with CC ratio larger than 50%. Our result suggests that the presence of DDD plays as a key factor associated with myelopathy in OPLLs with smaller CC while the CC ratio itself had more significant effect in OPLLs with larger CC. APD and sROM were significantly associated with myelopathy in OPLL regardless of the CC ratio.

Conclusion: Unlike the general belief that morphologic classification of OPLL would have greater impact on the development of myelopathy, our results revealed that the APD, CC ratio and sROM had more significant association with myelopathy. And the presence of DDD had significant association with myelopathy in OPLLs with smaller CC. This new discovery of radiologic measures and its clinical significance regarding the presence of myelopathy might enhance our understanding of OPLL.

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Presentation #71

Clinical Outcomes and Prognostic Factors for Patients with Degenerative Cervical Myelopathy Managed Non-Operatively: An Ambispective Longitudinal Cohort Study in 117 Patients

Allan Martin, MD, PhD, FRCSC, *Sukhvinder Kalsi-Ryan, PhD, Eric Massicotte, MD, FRCSC, Michael Fehlings, MD, PhD, FRCSC, FACS*

Introduction: Degenerative cervical myelopathy (DCM) is the most common pathology causing spinal cord dysfunction, but its natural history and prognostic factors have not been well characterized. Surgery is recommended for moderate-severe DCM, based on the modified Japanese Orthopedic Association (mJOA) score, and also for mild patients that experience neurological deterioration [Fehlings et al., 2017]. A majority of previous studies have used mJOA as the sole measure for clinical deterioration, but its diagnostic accuracy for this purpose has not been established. This study investigates a battery of measurements to identify how to detect myelopathic deterioration, and to better characterize the natural history and prognostic factors for patients with DCM managed non-operatively.

Materials and Methods: Patients with newly diagnosed DCM or recurrent myelopathic symptoms after previous surgery who were initially managed non-operatively and had multiple clinical assessments were included. Clinical outcomes were obtained using prospective clinical assessments and post hoc chart reviews. Standard clinical assessments were used as the clinical case definition of neurological deterioration. Quantitative neurological assessments included mJOA, QuickDASH, GRASSP-myelopathy (motor, sensory, and dexterity), grip dynamometer, Berg Balance, and electronic gait analysis (including stability ratio and variability index); a deterioration of 10% was considered significant (e.g. 2-point decrease in mJOA). Anatomical MRI scans were assessed for worsening compression or increased spinal cord signal change.

Results: 117 DCM patients were included (95 newly diagnosed, 22 recurrent myelopathy), including 74 mild, 28 moderate, and 15 severe cases. Over a mean follow-up of 2.5 years, 57% (95% CI = 46-67%) of newly diagnosed and 73% (95% CI = 50-88%) of recurrent DCM patients deteriorated neurologically, including 50% of mild, 71% of moderate, and 73% of severe patients (Figure 1). The pattern of deterioration was steady in 38 patients, subtle in 27 patients, stepwise in 3 patients, and rapid in 1 patient. The detection of deterioration with individual quantitative measures had only modest diagnostic accuracy, including grip strength (sensitivity = 60%, specificity = 75%), gait variability index (sensitivity = 42%, specificity = 92%), Berg Balance score (sensitivity = 32%, specificity = 100%), mJOA (sensitivity = 33%, specificity = 92%), GRASSP dexterity (sensitivity = 60%, specificity = 62%), and gait stability ratio (sensitivity = 50%, specificity = 72%). However, a composite score of quantitative measures had sensitivity=81% and specificity=82%. In 83 patients, anatomical MRI had poor sensitivity (28%) for deterioration, while specificity was 70%. In multivariate analysis (N=117), deterioration was more common with lower baseline GRASSP-dexterity (p=0.01), lower mJOA (p=0.02), longer follow-up (p=0.02), and smoking (p=0.04).

Conclusion: DCM appears to have a poor natural history with a high rate of neurological

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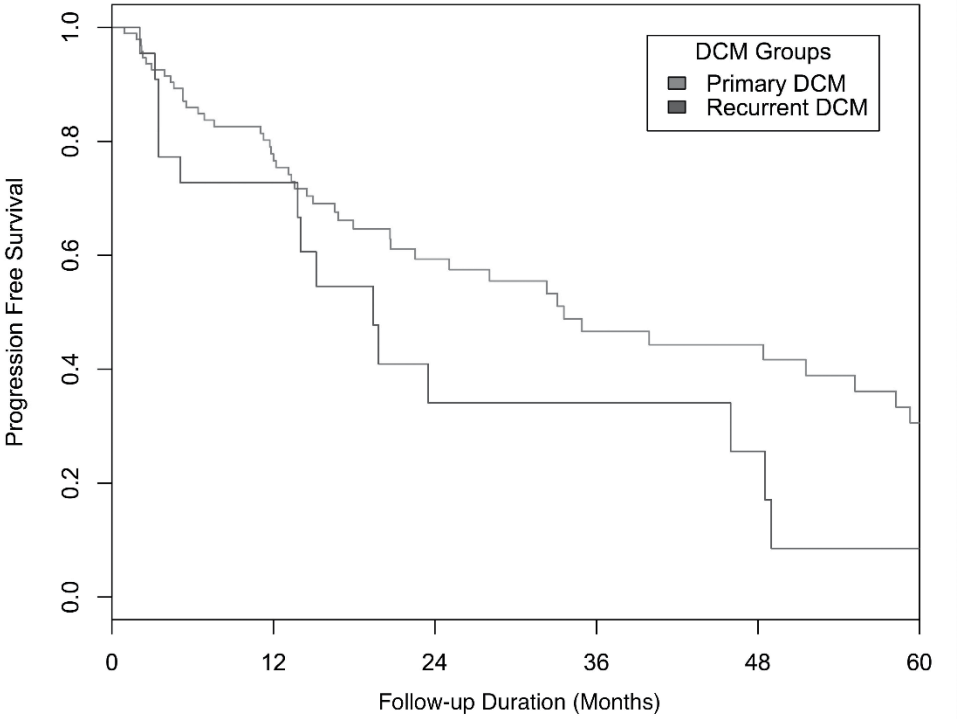
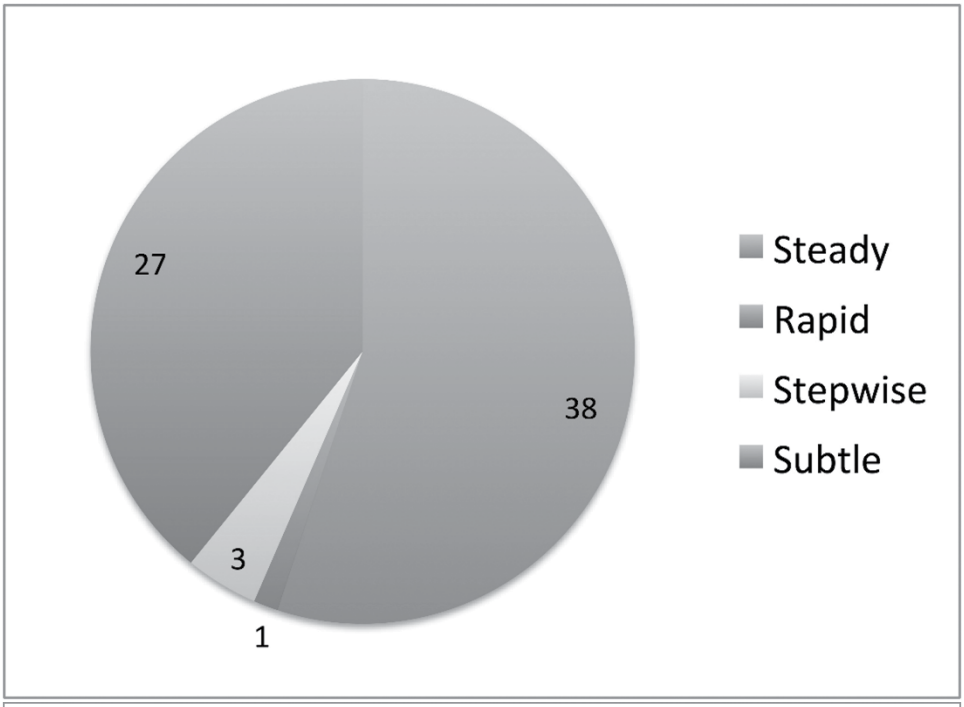
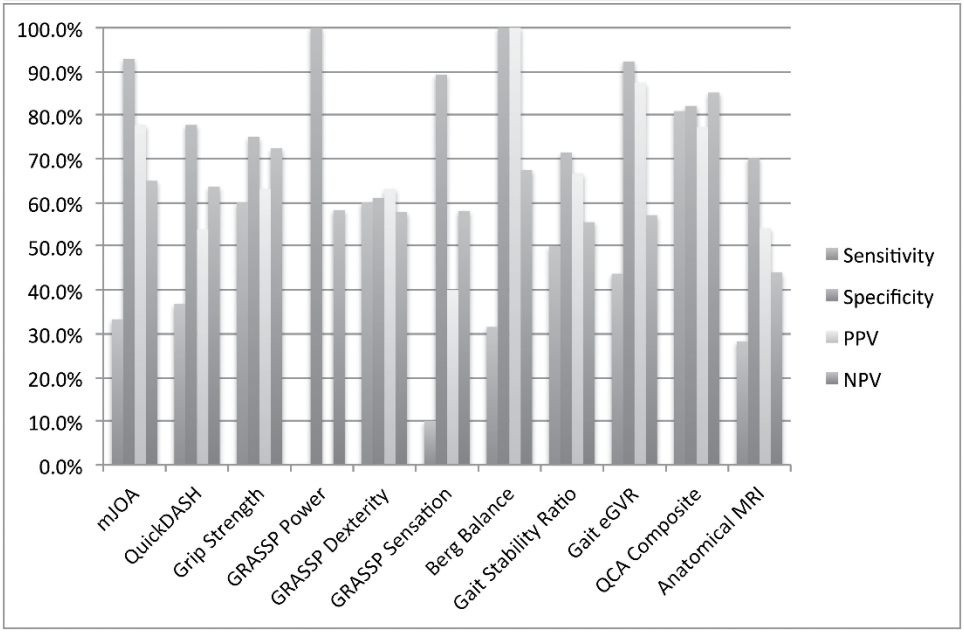
deterioration. mJOA is not sufficient as a standalone measure of neurological deterioration, and longitudinal monitoring should include a variety of clinical assessments, including grip strength, dexterity, balance, and gait analysis. Furthermore, the majority of patients that deteriorate do not show any changes on anatomical MRI, and this should not be considered evidence of clinical stability. Patients with greater baseline neurological dysfunction (lower mJOA or diminished dexterity), smoking, and longer follow-up appear more likely to deteriorate without surgery.







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Presentation #72

Risk factor analysis of implant failure and junctional failure after long level posterior cervical instrumentation

Jae Taek Hong, MD, PhD, Il Sup Kim, MD, PhD, Jung Woo Hur, MD, PhD, Ho Jin Lee, MD, PhD, ***Jong Beom Lee, MD, PhD***

Introduction: Posterior cervical instrumentation has become increasingly popular for stabilization in various pathologies of cervical spine. The aim of this study was to investigate the incidence of implant failure and junctional failure and to analyze the factors affecting the occurrence of mechanical failures after posterior cervical long-segment fusion surgery.

Materials and Methods: We retrospectively reviewed 142 cases of posterior cervical long segment fusion surgery (longer than three motion segment) that used pedicle screws, lateral mass screws, or laminar screws. The cranial end of the fusion was occiput or any level of cervical spine, and the caudal end was lower cervical or upper thoracic spine. All patients were observed with CT scans at least 12 months postoperatively. We evaluated the loosening and breakage of the implanted screws or rods. We also evaluated proximal and distal junctional failure. We also reviewed clinical records to evaluate clinical consequences of mechanical failure.

Results: Between 2009 and 2018, long level posterior cervical screws were placed in 142 patients with various conditions, including trauma, tumor, congenital anomaly, cerebral palsy (CP), cervical spondylotic myelopathy (CSM), deformity, infection or OPLL. Implant failure occurred in 26 cases (18.3%). Incidence of implant failure was significantly higher in deformity (45.5%) and CP patients (42.9%). Implant failure is lower in OPLL, tumor and infection patients (4%, 0%, 0% respectively). Age, sex and BMD t-score were not found to be risk factors of implant failure. Screw loosening was found in 17 cases (11.9%). Screw breakage occurred in 4 (2.8%) cases. Distal junctional failure (DJF) and rod fracture occurred in 4 patients (2.8%) and one patient (0.7%). The implant failures were observed in both ends of the construct. However, the incidence was higher in distal ends (4.2% vs 16.2%, $P<0.05$). When C6, C7, T1 and T2 was the end of the lower instrumented level, the percentage of patients requiring revision surgery for distal implant failure was 0%, 13.5%, 12.5% and 0% respectively.

Conclusion: The present study revealed that the incidence of implant failures of the screws in long-segment posterior cervical fusion surgery was not uncommon, especially in the caudal end of the fusion levels. Implant failure could be more common in CP and deformity patients compared to tumor, infection, CSM, OPLL and Trauma patients. DJF was higher than proximal junctional failure after long level posterior cervical instrumentation. When long level instrumentation is necessary around cervicothoracic junction, C7 and T1 should be avoided for the end of the lower instrumented level.

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Presentation #73

Association between significant disc degeneration at the level of maximal spinal stenosis and surgical outcomes of laminoplasty in patients with cervical spondylotic myelopathy

Koji Tamai, MD, *Akinoibu Suzuki, MD, Hidetomi Terai, MD, Masatoshi Hoshino, MD, Hiromitsu Toyoda, MD, Shinji Takahashi, MD, Hiroaki Nakamura, MD, PhD*

Introduction: Cervical laminoplasty, a motion-preserving procedure, is considered one of the standard surgeries for patients with cervical spondylotic myelopathy (CSM). We previously hypothesized that advanced cervical disc degeneration (CDD) could negatively affect surgical outcomes of laminoplasty. However, our study showed that overall, CDD severity was not associated with unfavorable surgical outcomes after laminoplasty (1). Therefore, we subsequently hypothesized that segments with severe CDD might show a smaller range of motion (ROM) resulting in rapid neurological improvement after laminoplasty, particularly at the level of maximal spinal stenosis. We compared the 2-year clinical outcomes of laminoplasty between patients with severe CDD and those with no, mild, or moderate CDD at the level of maximal spinal stenosis.

Materials and Methods: We investigated 144 Japanese patients who underwent open-door laminoplasty for CSM and were followed-up for >2 years. Using preoperative magnetic resonance imaging, cervical segments C2–3 to C7–T1 were individually evaluated for severity of disc degeneration (grade 0: none, grade 3: severest, Figure 1) and for severity of spinal stenosis (grade 0: none, grade 3: severest). The segmental ROM from C2–3 to C7–T1 was evaluated using preoperative dynamic radiography. The mean segmental ROM was compared between each CDD grade using Bonferroni adjustment after performing the one-way analysis of variance test. Patients were categorised into a Severe group (patients with grade 3 CDD at their most stenotic level) and a Control group (patients with grade 0, 1, or 2 CDD at their most stenotic level). Propensity score matching was performed to adjust for age, sex, and the preoperative Cervical Japanese Orthopaedic Association (cJOA) score. The preoperative and 2-year postoperative cJOA scores, visual analog scale (VAS) scores for neck and arm pain, and arm numbness, and the 36-Item Short-Form Health Survey (SF-36) scores were compared between the adjusted Severe and Control groups using the Mann–Whitney U test.

Results: We observed a significantly smaller ROM in segments with grade 3 CDD than in segments with grade 0, 1, and 2 CDD ($p<0.001$, Figure 2). Grade 3 CDD at the most stenotic level was observed in 32 patients who were categorised into the Severe group. After propensity score matching, 56 patients were assigned to the adjusted Severe and Control groups (n=28 respectively, Figure 3). No statistically significant intergroup differences were observed in age, sex, or preoperative clinical scores including cJOA score. However, the 2-year preoperative cJOA score was significantly higher in the adjusted Severe group than in the adjusted Control group (13.3 vs. 12.0, $p=0.034$). No significant intergroup differences were observed in the 2-year postoperative VAS and SF-36 scores.

Conclusion: Severe CDD at the level of maximal spinal stenosis may positively affect recovery of myelopathy after laminoplasty in patients with CSM. This finding can be attributed to the fact

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that increased stability of the cervical segments showing severe CDD may promote neurological recovery. CDD severity should not be considered a contraindication for surgical intervention (laminoplasty) in patients with CSM.

Figure 1 Representative magnetic resonance imaging scans showing different grades of disc degeneration

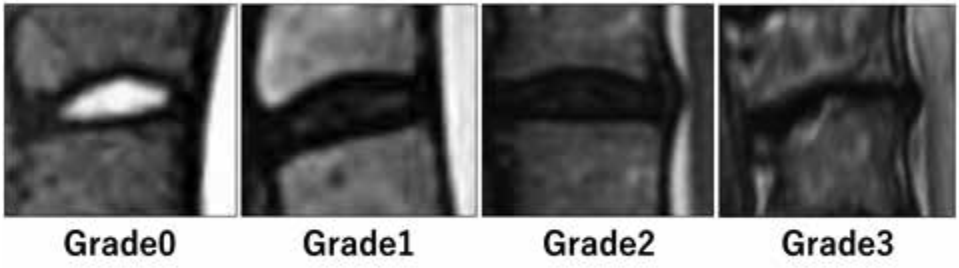

Figure 2 Association between cervical disc degeneration and range of motion

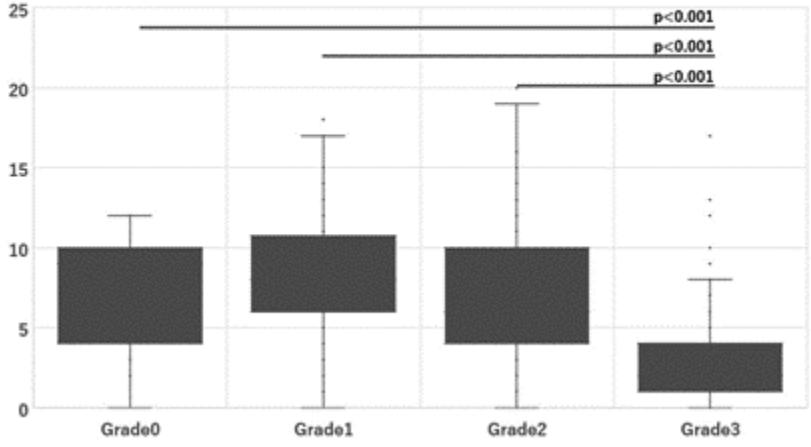

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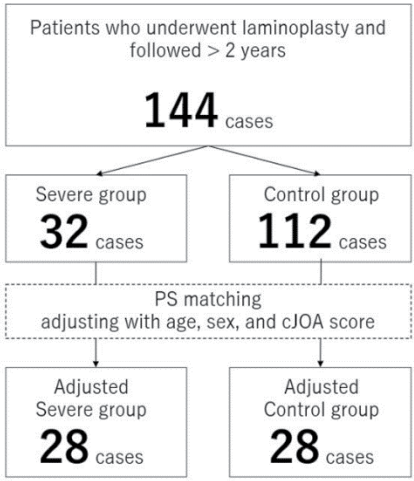
Figure 3 Summary of groups included in this study



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Presentation #74

Multimodal Analgesic Management for Cervical Spine Surgery in the Ambulatory Setting: Clinical Case Series and Review of the Literature

Nathaniel Jenkins, MS, James Parrish, MPH, Elliot Cha, MS, Conor Lynch, MS, Michael Nolte, MD, Caroline Jadczak, BS, Shruthi Mohan, BS, Cara Geoghegan, BS, Jeffrey Podnar, MD, Asokumar Buvanendran, MD, Kern Singh, MD, ***Elliot Cha, MS***

Introduction: Patient selection and new anesthetic techniques, such as the refined Multimodal Analgesic (MMA) protocol, aid in performing cervical spine surgery procedures in the ambulatory surgical center (ASC) setting. When compared to the inpatient hospital setting, ambulatory cervical spine surgery has been associated with better short term outcomes, fewer complications and lower direct costs related to the procedure [1–4]. This study aims to characterize patients who underwent cervical spine surgery anterior cervical discectomy and fusion (ACDF) and total cervical disc replacement (CDR), in the ASC setting with the use of an MMA protocol.

Materials and Methods: A prospectively maintained surgical registry was retrospectively reviewed for eligible patients of the senior author who performed all procedures and had extensive experience operating in an ASC. The ASC did not allow patient observation in excess of 23 hours. Consecutive patients were identified who underwent single or multilevel ACDF or CDR in the ASC between May 2013 until August 2019. Procedures were conducted using our MMA protocol (Table 1). Baseline demographics, comorbid diagnoses, spinal pathologies and operative characteristics were recorded (Table 2). Postoperative characteristics were recorded, including surgery center length of stay, patient-reported visual analogue scale (VAS) pain scores prior to discharge, neck disability index (NDI), and the quantity of narcotic medications administered to patients prior to discharge were converted into units of oral morphine equivalents (OME) and summed across all types of narcotic medications prescribed. Postoperative complications while in the surgical center were also recorded (Table 3).

Results: 178 patients met inclusion criteria with 125 single level, 52 two-level, and one three-level procedures. 127 patients underwent an ACDF and 51 patients underwent a CDR. (Table 2). 127 patients underwent an ACDF and 51 patients underwent a CDR. The longest case was 95 minutes with one outlier for length of stay at 23 hours (first cervical procedure performed at the ASC). The mean length of stay was 6.1 ± 2.5 hours, and two patients required admission. All other patients were discharged within 10 hours of the procedure. One of the two admitted patients in this series used illicit drugs prior to surgery and experienced a postoperative seizure of unknown origin that was later determined to be secondary to serotonin syndrome (Table 3). The second patient developed an anterior cervical hematoma noted five hours postoperatively during the observational period. The hematoma was immediately evacuated at the ASC and the patient was admitted to the hospital for 23-hour observation. The patient was uneventfully discharged the next day following surgery.

Conclusion: A safe and effective MMA protocol may help facilitate anterior cervical surgery in the outpatient setting. In our study, patients experienced considerable improvement in disability scores, with a low likelihood of postoperative complications. ACDF and CDR in the ASC setting

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appear to be feasible treatment options for the appropriate patient population.

Table 1: Multimodal Analgesic Regimen for Outpatient Spine Surgery

Prior to admission

Preoperative patient counseling regarding intraoperative and postoperative analgesia at spine surgeon's office.

Day of surgery

Preoperatively:

Oral medications given preoperatively in holding area about 1 hour prior to surgery:

1. Cyclobenzaprine 10mg
2. Pregabalin 150mg
3. Oxycodone controlled-release 10mg

Intraoperatively:

- Induction of anesthesia – propofol 2mg/kg plus ketamine 50mg
- Maintenance of anesthesia – sevoflurane with fentanyl 1-2 μg/kg titrated to clinical effect
- Additional medications administered intraoperatively:
    1. Bupivacaine 0.5% with epinephrine 1:200,000 injected at incision site
        a. 20ml per side if patient weight < 70kg
        b. 30ml per side if patient weight ≥ 70kg
    2. Acetaminophen 1000mg IV
    3. Dexamethasone 10mg IV
    4. Ondansetron 4mg IV
    5. Famotidine 20mg IV

Postoperatively in recovery room:

1. Cold compresses applied to surgical area
2. Pregabalin 75mg orally
3. Cyclobenzaprine 10mg orally for spasms
4. Hydrocodone 10mg plus acetaminophen 325mg
    a. 1 tablet as needed for pain (VAS Pain 1-5)
    b. 2 tablets as needed for pain (VAS Pain 6-10)
5. Tramadol 50mg
6. Oxycodone immediate release
    a. 5mg q4h as needed for pain (VAS Pain >3) for opioid naïve patients
    b. 10mg q4h as need for pain (VAS Pain >4) for opioid tolerant patients

VAS = Visual Analog Scale for pain (where 0 = no pain and 10 = worst possible pain

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Table 2. Patient Demographics and Baseline Characteristics

	Total (n=178)†	1 level (n=125)	2 level (n=52)	≥3 level (n=1)
Age (Mean ± SD, years)	46.7 ± 9.1	45 ± 8.9	52.2 ± 8.8	44.0
Gender				
Female	36.5% (65)	36% (45)	38.5% (20)	0.0% (0)
Male	63.5% (113)	64% (80)	61.5% (32)	100.0% (1)
Body Mass Index (n)	28.6 ± 4.4	29.0 ± 4.5	27.6 ± 4.2	29.8
Smoking Status (n)				
Non-Smoker	87.4% (153)	86.2% (106)	90.2% (46)	100.0% (1)
Smoker	12.6% (22)	13.8% (17)	9.8% (5)	0.0% (0)
Charlson Comorbidity Index (mean ± SD)	0.46 ± 0.8	0.47 ± 0.8	0.44 ± 0.6	0.0% (0)
ASA Score				
1	45.0% (49)	43.4% (32)	47.1% (16)	100.0% (1)
2	50.5% (55)	54.1% (40)	44.1% (15)	0.0% (0)
≥3	4.6% (5)	2.7% (2)	8.8% (3)	0.0% (0)
Preoperative Diagnoses				
Hypertension	16.6% (29)	14.6% (18)	21.6% (11)	0.0% (0)
Asthma	8.4% (15)	8.8% (11)	7.7% (4)	0.0% (0)
Arthritis	7.4 (13)	8.1 (10)	5.9% (3)	0.0% (0)
Hyperlipidemia	1.7% (3)	0.8% (1)	3.9% (2)	0.0% (0)
Cancer	1.1% (2)	1.6% (2)	0.0% (0)	0.0% (0)
Uncomplicated diabetes mellitus	4.6% (8)	3.3% (4)	7.8% (4)	0.0% (0)
Liver disease	0.6% (1)	0.8% (1)	0.0% (0)	0.0% (0)
Peripheral vascular disease	0.6% (1)	0.8% (1)	0.0% (0)	0.0% (0)

*There were no patients in our study with a recorded medical history of myocardial infarction, renal failure, chronic lung disease, or gastrointestinal bleeding.
† Percentages were based on total n of patients without missing data; those that had n<178 include: hypertension, arthritis, cancer, uncomplicated diabetes mellitus, liver disease (n=175), peripheral vascular disease (n=174)

Table 3. Postoperative complications

	Total (n=178)	1 level (n=125)	2 level (n=52)	≥3 level (n=1)
Complications	0	0	0	0
Acute renal failure	0	0	0	0
Airway Obstruction*	1	0	1	0
Altered mental status	0	0	0	0
Aspiration	0	0	0	0
Epidural hematoma	0	0	0	0
Ileus	0	0	0	0
Nausea and vomiting**	4	3	1	0
Postoperative anemia	0	0	0	0
Seizure of Unknown Origin†	1	1	0	0
Urinary retention	0	0	0	0
Urinary tract infection	0	0	0	0
Venous thromboembolism	0	0	0	0

* Single patient received immediate evacuation of cervical hematoma that developed at five hours postoperatively, transferred to inpatient hospital for observation and uneventfully discharged following morning
** All patients discharged in less than 23 hours; no admissions or further hospitalizations required.
†Single patient was emergently transferred with seizures postoperatively and diagnosed with serotonin surge secondary to illicit drug use prior to surgery

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Presentation #75

'To use or not use' intraoperative neuromonitoring: Utilization of neuromonitoring during spine surgeries and associated conflicts of interest

Jesse Bible, MD, *Madison Goss, BS*

Introduction: Intraoperative neuromonitoring (IONM) has become more commonplace, yet there is no standard, "one size fits all" technique used for all spine surgeries. However, courts have explicitly considered IONM as a legal standard of care. Conversely, given the controversial cost-benefit analysis, many payers consider it "not medically necessary", forcing a surgeon's hand into under or over utilizing IONM independent of its clinical value. Furthermore, the addition of IONM can add significant cost, causing its value to be questioned. The fees for similar IONM services can vary significantly and be billed independent of their hospital charges. The purpose of this study was to assess: 1) the use of certain IOMN modalities during common spine surgical scenarios, 2) surgeons' rationale for deciding to use IONM, and 3) IONM practices and potential conflicts of interest associated with its use via a survey of spinal surgeons.

Materials and Methods: Using a 3-part online survey, spine surgeons were first asked to select each IONM modality they used during 20 different surgical scenarios. Next, respondents rated the importance of several reasons when selecting to use IONM. Lastly, the occurrence of conflicts of interest, out-of-network billing, and cost were assessed. The survey was completed by 193 spine surgeons (60% neurosurgeons).

Results: Approximately one-half (47%) of respondents who perform ACDF/TDR for radiculopathy use IONM, opposed to 76% for myelopathy. (Table 1) The presence of cord compression and/or neurological symptoms increased IONM use by approximately 30% during trauma cases at cord level. However, cord symptoms (myelopathy or traumatic) did not lead to definite IONM use, as 18-27% of surgeons do not use for myelopathy cases and 18-19% do not use during cases with traumatic cord symptoms. For myelopathy, deformity, cord compression, and neurological symptoms scenarios at cord level in which SSEPs are used, 11% of the time concurrent MEPs are not used. Conversely, 16-52% of surgeons used IONM techniques during scenarios not routinely covered by payers. Medicolegal was the reason of highest importance when choosing to use IONM (7.4+/-2.9; mean+/-standard deviation), followed by surgeon reassurance (6.2+/-2.7; $p<0.0001$ vs. medicolegal) and belief if affects patient outcomes (5.2+/-3.0; $p=0.004$ vs. reassurance). (Figure A) Twenty-seven percent of surgeons were aware of conflicts of interest associated with IONM use within their geographical region, most commonly between surgeons and monitoring companies. A majority of surgeons felt IONM companies were frequently billing out-of-network. Of the surgeons aware of cost, 28% reported a cost of =$5000.

Conclusion: Although there is increasing use of IONM, this has not translated to an absolute requirement for every spine surgery. Surgeons are faced with opposing influences of the medicolegal system and insurance payers. Future guidelines on using IONM should not be absolute, but rather should consider the risks of each procedure, along with how patients and surgeons value these risks, in addition to the costs of not using IONM. The findings of this study should help to serve as a guide to surgeons, payers, and courts as contemporary, common

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practices for the use of IONM during spinal surgical scenarios.

Surgical Scenario	Percent of Spine Surgeons				
	Don't Perform Procedure	No Monitoring	EMG	SSEPs	MEPs
Cervical					
ACDF/TDR for Radiculopathy	2%	53%	40%	45%	35%
ACDF/TDR for Myelopathy	1%	24%	57%	75%	66%
Corpectomy for Radiculopathy	7%	46%	45%	52%	42%
Corpectomy for Myelopathy	2%	18%	59%	80%	72%
Laminoforaminotomy for Radiculopathy	4%	65%	31%	32%	21%
Laminectomy & Fusion / Laminoplasty for Myelopathy	3%	27%	57%	71%	60%
Deformity with or without Osteotomies	17%	13%	66%	86%	80%
Posterior Instrumented Fusion for Pseudarthrosis	6%	46%	45%	53%	39%
Posterior Instrumented Fusion for Trauma without Cord Compression or Neurological Symptoms	8%	37%	47%	62%	51%
Posterior Instrumented Fusion for Trauma with Cord Compression, but without Neurological Symptoms	8%	21%	69%	86%	72%
Posterior Instrumented Fusion for Trauma with Neurological Symptoms	8%	19%	61%	86%	73%
Thoracic					
Laminectomy for Myelopathy	3%	27%	45%	72%	63%
Thoracolumbar Deformity with or without Osteotomies	18%	10%	60%	89%	77%
Posterior Instrumented Fusion for Trauma without Cord Compression or Neurological Symptoms	13%	34%	45%	65%	54%
Posterior Instrumented Fusion for Trauma with Cord Compression, but without Neurological Symptoms	13%	20%	52%	80%	73%
Posterior Instrumented Fusion for Trauma with Neurological Symptoms	13%	18%	53%	81%	75%
Lumbar					
Laminectomy	2%	83%	16%	14%	9%
Laminectomy with Posterior Instrumented Fusion	3%	48%	51%	40%	17%
ALIF	13%	64%	31%	29%	8%
Lateral Lumbar Interbody Fusion (XLIF/OLIF/DLIF)	21%	19%	77%	47%	23%

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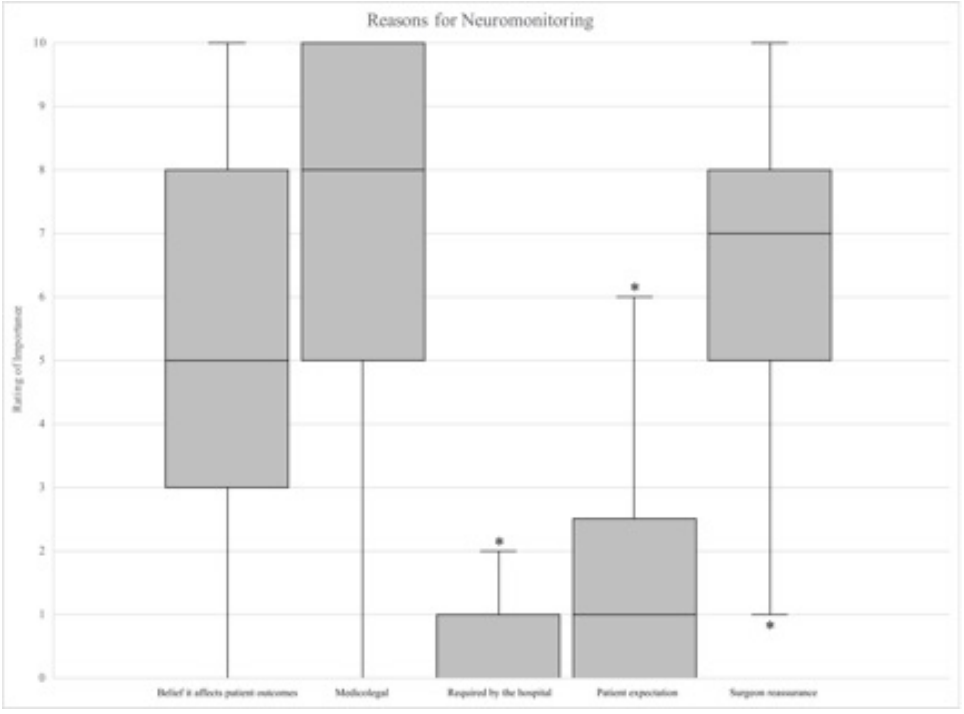

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Presentation #76

The HEAD Score: A Novel, Accurate, and Simple Clinical Score for Predicting 30-day Mortality after ACDF

Micheal Raad, MD, *Varun Puvanesarajah, MD, Andrew Harris, MD, Sang Hun Lee, MD*

Introduction: Degenerative disease of the cervical spine is exceedingly common within the adult population. Anterior cervical discectomy and fusion (ACDF) is the most common surgical procedure for patients who have a gradual progression of symptoms. Predicting postoperative mortality is an important issue because this patient population is well-known to be older and have other demographic and comorbid characteristics that present higher surgical risk and mortality compared to younger, healthier elective surgery cohorts. Many pre-existing systems that are used to predict post-operative mortality following other procedures are not widely used by spine surgeons for ACDF patients because of their non-specificity and complexity. The goal of this study was to create a novel, simple scoring system that improves upon existing methods to estimate post-operative mortality risk following ACDF.

Materials and Methods: Data from the National Surgical Quality Improvement Program database was utilized to create a logistic regression model predicting 30-day mortality following ACDF. A validation cohort of 4,810 patients (4,810/9,621 patients) was used to create a scoring system, which was then validated in an exclusive validation cohort (4,810/9,621 patients). Mortality association with various risk factors was analyzed and utilized to create a novel four-point scoring system based on a logistic regression model. Score was termed HEAD (Hypoalbuminemia (albumin < 3.5 mg/dl), Elderly (age>65 years), Anemia (Hgb < 8.5), Dependence for daily living). The HEAD score was compared to two different predictive scoring systems, American Society of Anesthesiologists (ASA) score and the modified 5 component frailty index (mF-I5) via comparisons of receiver operator area under the curve (AUC) values with fit assessed by the Lemeshow-Hosmer test.

Results: Of the 4,810 patients used to derive our model, 22 (0.5%) expired within the thirty days following ACDF. The probability of 30-day mortality associated with a HEAD score of 0 was <0.1%, and this increased to 26% with a HEAD score of 4 (Table 1). The AUC for the HEAD score for our outcome measure was 0.92, which was significantly more accurate than both ASA (0.82) and mF-I5 (0.75) ($p < 0.001$) (Figure 1). Notably a score of >=2 had a sensitivity of 76% and a specificity of 93% for our outcome measure.

Conclusion: The HEAD score provides a simple method for risk-stratifying pre-operative ACDF patients in terms of 30-day mortality. Though this score has not been analyzed to assess other post-operative outcomes, it can be used quickly and effectively to better educate patients and providers about the expected post-operative course. Future studies could be directed towards validating this tool in posterior or more complex cervical spine surgery, given the better accuracy and simplicity of the HEAD score.

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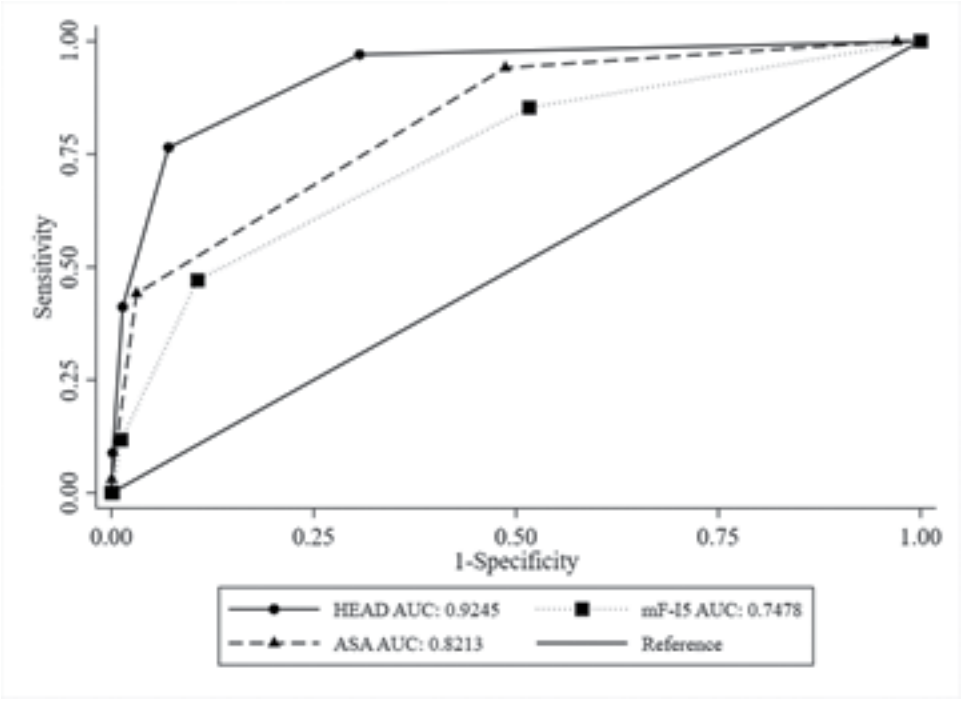

Table 1: Probability of 30-Day Mortality By HEAD Score

HEAD Score	Estimated 30-Day Mortality
0	< 0.1%
1	0.3%
2	2%
3	8%
4	26%

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Presentation #77

Impact of Frailty and Sarcopenia on Postoperative Outcomes Following Elective Cervical Spine Surgery

John Wanner, MD, *Michael Benvenuti, MD, Inam Khan, MD, Kristin Archer, PhD, Byron Stephens, MD, Amir Abtahi, MD*

Introduction: Frailty is defined as an age-related decline in physiologic reserve and has been shown to be predictive of perioperative complications across numerus specialties including spine surgery. Multiple clinical, biochemical, and radiologic surrogates have been used in an attempt to quantify frailty including the modified 5-item frailty index (mFI-5) as well as sarcopenia. , , The aim of this study was to assess the impact of the mFI-5, as well as frailty surrogates including sarcopenia and dentition on patient reported outcomes (PROs) after elective cervical spine surgery.

Materials and Methods: A retrospective review was conducted of 163 consecutive patients at a single institution who underwent elective primary cervical spine surgery. The mFI-5 was calculated for each patient and sarcopenia was measured utilizing the normalized total psoas area (NTPA) as well as MRI-based morphometrics of the superficial and deep cervical paraspinal muscles in a subset of 45 patients for which this imaging was available. Dentition scores were also calculated, as a surrogate for frailty, using a numerical system (0-2) if no teeth, some teeth, or most teeth were present on cervical radiographs. Univariate linear regression models were utilized to identify the impact of mFI-5 on 12-month PROs, sarcopenia, and dentition. The correlation and interobserver reliability were evaluated between the various sarcopenia definitions using Pearson correlation and Kappa statistics.

Results: After adjusting for baseline PROs, higher levels of frailty - defined by the mFI-5 - were found to be predictive of lower EQ-5D at 12 months (coefficient: -0.092, p=0.006) as well as higher NRS neck pain scores at 12 months (1.301, p=0.039) and NDI scores (3.488, p=0.02). However, the mFI-5 was not found to be predictive of a higher rate of complications, readmissions, or mortality. Cervical or lumbar sarcopenia and poor dentition were not found to be correlated with patient reported outcomes or perioperative complications, readmissions, or mortality at 12-months. Neither sarcopenia nor dentition were found to be correlated with frailty as defined by the mFI-5.

Conclusion: Frailty as defined by the mFI-5 was found to be predictive of worse 12-month PROs including EQ-5D, NRS neck pain, and NDI after adjusting for baseline PROs. These findings indicate that functional assessments of frailty may be predictive of patient reported outcomes after cervical spine surgery. Neither sarcopenia nor poor dentition were associated with complications, readmissions, mortality, or PROs following elective cervical spine surgery in our cohort. These results indicate that quantitative measurements of frailty (mFI-5) should be considered in assessing a patient's likelihood of functional improvement after cervical spine surgery. These results also suggest that neither sarcopenia nor dentition should be utilized as surrogates for frailty in a cervical spine population.

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Presentation #78

Patient-Reported Mental Health Status Improves After Anterior Cervical Discectomy and Fusion

Scott Wagner, MD, *Mohamad Bydon, MD, Brett Freedman, MD, Benjamin Elder, MD, PhD, Ahmad Nassr, MD, Melvin Helgeson, MD, Christopher Kepler, MD, MBA, Arjun Sebastian, MD*

Introduction: The effect of preoperative depression and anxiety on outcomes after anterior cervical discectomy and fusion (ACDF) has been increasingly evaluated in the literature. However, no study has examined the role of surgical intervention in improving patient-reported mental health status. The purpose of this study was to utilize detailed mental health domains within legacy patient reported outcomes measures (PROMs) to compare changes in depression and anxiety after ACDF. We hypothesized that surgical intervention would improve patient reported mental health.

Materials and Methods: Patients undergoing ACDF for degenerative cervical spondylosis were included, with at least 12 months of follow up. All non-binary RAND-36 mental health domains were combined to yield an average, continuous score from zero to 100. Patients scoring less than or equal to 60.0 were classified as depressed. Changes in the mental health domains of the RAND and EuroQual-5D (EQ-5D, range: 1 = not depressed/anxious, 5 = extremely depressed/anxious) were assessed and compared pre-operatively and at final follow up.

Results: Seventy-one patients with complete follow up information were included in the study. Average age was 50.8 years, and the cohort was 49.6% female. The baseline RAND composite mental health domain average was 68.79, which improved significantly to 77.49 after ACDF ($p=0.0001$). Twenty-three patients (32.4%) were categorized as depressed preoperatively, which decreased significantly to 19.9% postoperatively ($p=0.03$). Similarly, the average anxiety/depression domain of the EQ-5D significantly improved from pre- and post-operatively after ACDF (1.73 vs 1.45, $p=0.011$).

Conclusion: This study is the first to assess the effect of ACDF on patient reported mental health status, utilizing multiple granular mental health composite instruments. We found a relatively high prevalence of depression and anxiety within the population undergoing ACDF, but this percentage decreased significantly after surgery. Additionally, ACDF yielded significant improvements in average mental health scores across multiple PROMs.

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Presentation #79

Association Between Surgical Fixation and In-Hospital Mortality for Fracture of the C2 Odontoid Process in Geriatric Patients

Zamir Merali, MD, *Christopher Witiw, MD, MS*

Introduction: Fractures of the odontoid process of C2 have become increasingly prevalent in the aging population and are typically associated with high morbidity and mortality1. Although recent evidence has indicated that surgical treatment of Type 2 odontoid fractures in elderly patients is associated with improvements in mortality, there exists controversy regarding the optimal management2. We evaluated the association between surgical management of odontoid fractures and mortality in centers participating in the American College of Surgeons Trauma Quality Improvement Program (TQIP).

Materials and Methods: We collected data on 11333 patients with an Abbreviated Injury Scale (AIS) code corresponding to an odontoid fracture presenting in 2015 and 2016 across 410 centers. We included patients over the age of 64 and excluded patients with severe injuries (AIS>2) in another body region, who were dead on arrival, with prior advance directives, and with significant thoraco-lumbar fractures, which left a cohort of 5019 patients. Multiple logistic regression modeling was used to evaluate the association between surgical intervention and in-hospital mortality at the patient level and institutional level after adjusting for cofounders.

Results: Patients who received surgery were more likely to be male, had younger age (median 80 vs. 78 yrs), and were more likely to be treated in a teaching hospital. Overall in-hospital mortality (n=260) was 5.1%. 673 patients underwent surgical fixation, with a mortality of 3.71%. The adjusted odds ratio (OR) for mortality was 0.55 [95% confidence interval (CI), 0.35-0.87], when comparing patients who underwent surgical intervention to those who did not. Higher age, higher injury severity scale (ISS), and male gender were associated with higher in-hospital mortality (Table a). We grouped facilities into quartiles based on how frequently they offered surgical intervention and found significant variability in rates of surgical intervention (Table b). 30.69% vs 0.90% of patients received surgery in the highest quartile vs. the lowest. In addition, hospitals with higher rates of surgical intervention were associated with lower mortality but this relationship did not meet statistical significance (p=0.14). The adjusted OR of death was 0.73 [95% CI 0.47-1.11] in the quartile of hospitals with highest rates of surgical intervention compared to the lowest.

Conclusion: Substantial variability in rates of surgical intervention for odontoid fractures in elderly patients exists between hospitals. These results support previous studies and indicate that surgical intervention is associated with improved outcomes for elderly patients with odontoid fractures. To our knowledge this is the largest analysis demonstrating benefit of surgical intervention for odontoid fractures in elderly patients in the literature.

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Table a – Relationship between surgical fixation and in-hospital mortality (patient-level analysis).

Covariate	Adjusted OR	95% CI	P value
Surgery (yes)	0.55	0.35 - 0.87	0.006 *
Age (years)			
65-69	Ref		
70-74	1.73	0.88 - 3.42	0.113
75-79	2.59	1.38 - 4.88	0.003 *
80-84	3.74	2.03 - 6.89	< 0.001 *
> 85	4.64	2.52 - 8.54	< 0.001 *
Gender (male)	2.43	1.85 - 3.19	< 0.001 *
Comorbid illness (presence)			
Hypertension	0.98	0.73 - 1.3	0.868
Diabetes	1.38	1.02 - 1.88	0.042 *
On dialysis	1.44	1.19 - 4.07	0.018 *
CVA with residual deficit	1.06	0.76 - 2.74	0.281
Bleeding disorder	0.71	0.5 - 1.0	0.043 *
Chronic respiratory failure	1.37	0.96 - 1.98	0.095
Functionally dependent	0.96	0.65 - 1.42	0.826
Dementia	1.72	1.24 - 2.38	0.002 *
Injury severity score	1.07	1.05 - 1.1	< 0.001 *
Hospital teaching status			
Community	Ref		
University	1.45	1.07 - 1.97	0.017
Nonteaching	0.93	0.59 - 1.48	0.758
Hospital No. of beds, no. (%)			
<= 200	Ref		
201-400	1.5	0.60 - 3.71	0.406
401-600	1.55	0.62 - 3.84	0.427
>600	1.43	0.58 - 3.52	0.565
Trauma center level, no. (%)			
Level 1	Ref		
Level 2	0.9	0.35 - 2.26	0.816
Level 3	-	-	-
N/A	0.92	0.36 - 2.32	0.854

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Table b – Comparison of rates of surgical intervention and patient mortality across hospitals grouped into quartiles based on rate of surgical intervention.

Facility quartile (# of facilities)	Rate of surgery (%)	In hospital mortality (%), mean	Adjusted OR	95% CI	P value
Quartile 1 (n = 51)	0.90	5.72	ref	ref	ref
Quartile 2 (n = 51)	7.18	4.96	0.92	0.6 – 1.39	0.68
Quartile 3 (n = 49)	14.30	4.45	0.74	0.49 – 1.13	0.16
Quartile 4 (n = 50)	30.69	4.40	0.73	0.47 – 1.11	0.14

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Presentation #80

Workers' Compensation Status May Negatively Impact Post-Operative Dysphagia And Dysphonia Following Anterior Cervical Fusion

Marie-Jacqueline Reisener, MD, *Ichiro Okano, MD, Jiaqi Zhu, MA, Courtney Ortiz Miller, BA, Jennifer Shue, MS, Andrew A Sama, MD, Frank Cammisa, MD, Federico Girardi, MD, Alexander Hughes, MD*

Introduction: Anterior cervical discectomy and fusion (ACDF) is an increasingly used procedure to treat various cervical spine conditions. ACDF is a safe and effective procedure but has approach-related complications, such as postoperative dysphagia and dysphonia (PDD). Patient reported outcome measures (PROMs), including the Hospital for Special Surgery Dysphagia and Dysphonia Inventory (HSS-DDI), have been used for the assessment of PDD. Various patients' factors have previously been described to influence the outcomes after ACDF including the patients' psychosocial status. However, it remains unclear how workers' compensation status negatively impacts patient reported PDD. The aim of this study was to evaluate the impact of Workers' Compensation (WC) status on postoperative PDD after ACDF.

Materials and Methods: We utilized a prospectively maintained surgical database which includes patients undergoing ACDF from 2015 to 2018 at a single academic institution. The patient cohort was stratified according to the insurance status: WC and non-workers compensation. Postoperative dysphagia and dysphonia were assessed utilizing the HSS-DDI score 4 weeks after surgery. We set the number of the patients who had HSS-DDI total and subdomain scores with clinically meaningful dysphagia and dysphonia (100 minus previously published MCIDs) as the outcome variables and conduced logistic regression analyses adjusted with the calculated propensity score (PS) for insurance status. Since WC status can negatively affect pain scores in addition to preoperative pain negatively impacting postoperative dysphagia, additional analysis was conducted adjusting with the preoperative Neck Disability Index (NDI) score.

Results: We included 287 ACDF patients in the analysis, of which 44 (15.3%) had WC insurance and 243 (84.7%) had non-WC insurance. A PS adjusted comparison of the HSS-DDI between patients with WC and non-WC patients revealed significant differences in the HSS-DDI total score and both subdomains (total score: odds ratio (95% CI) 0.32 (0.13, 0.80), p=0.014; dysphagia: odds ratio (95% CI) 0.37 (0.16, 0.86), p=0.021; dysphonia: odds ratio (95% CI) 0.31 (0.15, 0.65), p=0.001). Additional logistic regression analysis with preoperative NDI scores resulted in no statistical significant difference in the HSS-DDI total score and both subdomains (total score: odds ratio (95% CI) 0.66 (0.24, 1.82), p=0.420; dysphagia: odds ratio (95% CI) 0.74 (0.29, 1.90), p=0.531; dysphonia: odds ratio (95% CI) 0.65 (0.29, 1.48), p=0.315) between patients with WC and non-WC patients.

Conclusion: WC status was related to a worse HSS-DDI score, but the difference was not independent of the preoperatively NDI score. This suggests that common psychosocial factors that are related to both WC status and worse NDI scores play a significant role in worse PDD scores.

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Presentation #81

The Single Assessment Numeric Evaluation (SANE) Is a Reliable Metric to Measure Clinically Significant Improvements after Anterior Cervical Discectomy and Fusion

Scott Wagner, MD, *Ahmad Nassr, MD, Brett Freedman, MD, Benjamin Elder, MD, PhD, Mohamad Bydon, MD, Arjun Sebastian, MD*

Introduction: Patient reported outcome measures (PROMs) have been increasingly utilized to objectively measure outcomes after spinal surgery. Many of these PROM surveys are limited by a patient-perceived burden of completion. The single assessment numerical evaluation (SANE) score, a single-question PROM, has been generating interest throughout other orthopaedic subspecialties. We set out to compare the SANE score to commonly utilized multi-question PROMs among patients undergoing anterior cervical discectomy and fusion (ACDF). We hypothesized that the SANE score would perform similarly to standard PROMs used in spine surgery, and provide clinically significant information.

Materials and Methods: Patients undergoing ACDF completed the Neck Disability Index (NDI) questionnaire, the RAND-36 survey and the EuroQual Five Dimension (EQ-5D) scale, as well as the one-question SANE score, pre- and post-operatively. The SANE question consists of a subjective overall functional assessment on a scale from 0 to 100, with 100 being the best possible score, and representing optimal function of the affected area. Validity of SANE compared with other PROMs was determined by Spearman's rank coefficient and linear correlation. Ceiling and floor effects of each PROM were calculated. The standardized responsiveness mean (SRM), to assess the ability of SANE to accurately determine changes in health state, was compared across PRMs. A score for a minimally important clinical difference (MCID) was calculated for each PROM and compared.

Results: Sixty-nine patients undergoing ACDF with at least 1-year follow-up were reviewed. The average SANE score improved from 67.4 preoperatively to 77.8 at one year postoperatively ($p<0.0001$). There were moderate to strong correlations at one-year follow-up between the SANE and NDI ($\rho = -0.69$, $P < 0.0001$), RAND ($\rho = 0.78$, $P < 0.0001$), and EQ-5D ($\rho = -0.66$, $P < 0.0001$). The change in pre- to post-operative NDI and SANE exhibited a near-perfect correlation ($\rho = -0.98$, $P < 0.00001$, $R2 = 0.96$) (Figure 1a). These findings were also statistically significant for the change in RAND ($\rho = -0.71$, $P < 0.0001$) and EQ-5D scores ($\rho = -0.67$, $P < 0.0001$), respectively. Weaker, but still statistically significant, correlations were found for pre-operative NDI ($\rho = -0.32$, $P = 0.006$), RAND ($\rho = 0.48$, $P < 0.0001$), and EQ-5D ($\rho = -0.66$, $P = 0.001$). The SANE demonstrated ceiling and floor effects of 4.3% and 0%, respectively. The SRM for SANE (1.05) was statistically comparable to all other PROMs. The minimal clinically significant difference for SANE after ACDF was calculated to be 7.5, which was statistically similar to all other PROMs in the study.

Conclusion: This study is the first to assess the one-question SANE score after ACDF. We found the SANE score provides reliable patient outcomes data and performs comparably to other widely-utilized but more burdensome health questionnaires. Pre- and post-operative changes in NDI and SANE exhibited an almost perfect correlation. Additionally, this is the first study to

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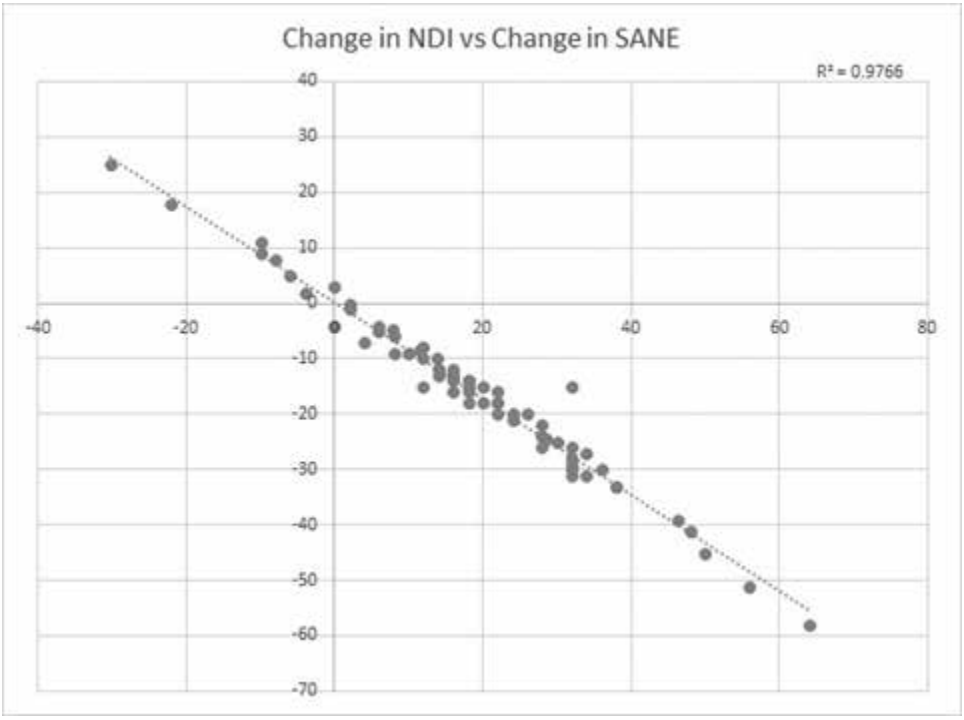
determine a minimal clinically important difference threshold for SANE after any spine surgery. Our findings suggest that SANE may be a viable alternative to NDI for assessing post-operative outcomes.



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Presentation #82

A Clinical Model to Predict Postoperative Improvement in Sub-Domains of the Modified Japanese Orthopedic Association Score for Degenerative Cervical Myelopathy

Byron Stephens, MD, *Inamullah Khan, MBBS, Clinton Devin, MD, Mohamad Bydon, MD, Anthony Asher, MD, Amir Abtahi, MD, Kristin Archer, PhD*

Introduction: Longstanding and progressive compression of the cervical spinal cord can lead to irreversible loss of neurologic function due to demyelination and apoptosis of oligodendrocytes. A commonly used metric to quantify the severity of cervical myelopathy is the modified Japanese Orthopedic Association (mJOA) score(1-2). The mJOA score comprises six items to assess the impact of spinal cord compression on: 1) Ability to feed oneself, 2) Ability to walk, 3) Loss of feeling or numbness in arms, 4) Loss of feeling or numbness in legs, 5) Loss of feeling or numbness in body and 6) Ability to urinate. In the present study, the primary objective was to construct a clinical prediction model for improvement of mJOA sub-domains at 12-months following surgery utilizing data from a longitudinal, multi-center clinical spine registry(3-6).

Materials and Methods: This study was conducted using data from the cervical module of the Quality Outcomes Database (QOD). The outcomes of interest were the sub-domains or items of the mJOA at 12-months following surgery. A multivariate-multivariable proportional odds ordinal regression model was developed for patients with cervical myelopathy. Patient demographic, clinical, and surgery covariates as well as baseline sub-domain scores were included in the model. The model was internally validated using bootstrap resampling to estimate the likely performance on a new sample of patients.

Results: A total of 5,000 patients who underwent elective surgery for cervical myelopathy were enrolled into the registry and had complete 12-month follow-up. The mean age for the patients was 60.9(±11.4) years and comprised of 47%(n=2,339) females. Patients had statistically significant improvement from baseline to 12-months post-surgery on all the mJOA sub-domains($p<0.001$). The multivariable analysis identified that the baseline sub-domains of the mJOA were the strongest predictors of 12-month scores, with numbness in legs and ability to walk predicting 5 of the 6 mJOA items. Additional covariates that predicted 3 or more of the sub-domain mJOA scores at 12-months included age, preoperative anxiety or depression, gender, race, employment status, duration of symptoms, smoking status, and presence of listhesis on radiology. Surgical approach, the presence of motor deficits, number of surgical levels involved, history of diabetes mellitus, worker's compensation claim and a patient's insurance had no impact on the 12-month scores of the mJOA. The discriminative ability of the model regarding joint probabilities measured by unweighted generalized C-index was 0.753.

Conclusion: In conclusion, our study has developed and validated a clinical prediction model for improvement in mJOA scores at 12-months following surgery. Results highlight the importance of assessing preoperative numbness symptoms and walking ability as well as the modifiable variables of anxiety/depression and smoking status prior to surgery. Additional patient demographic variables to consider are age, gender, race, employment status, duration of symptoms, and presence of listhesis when counseling patients prior to surgery. This prediction

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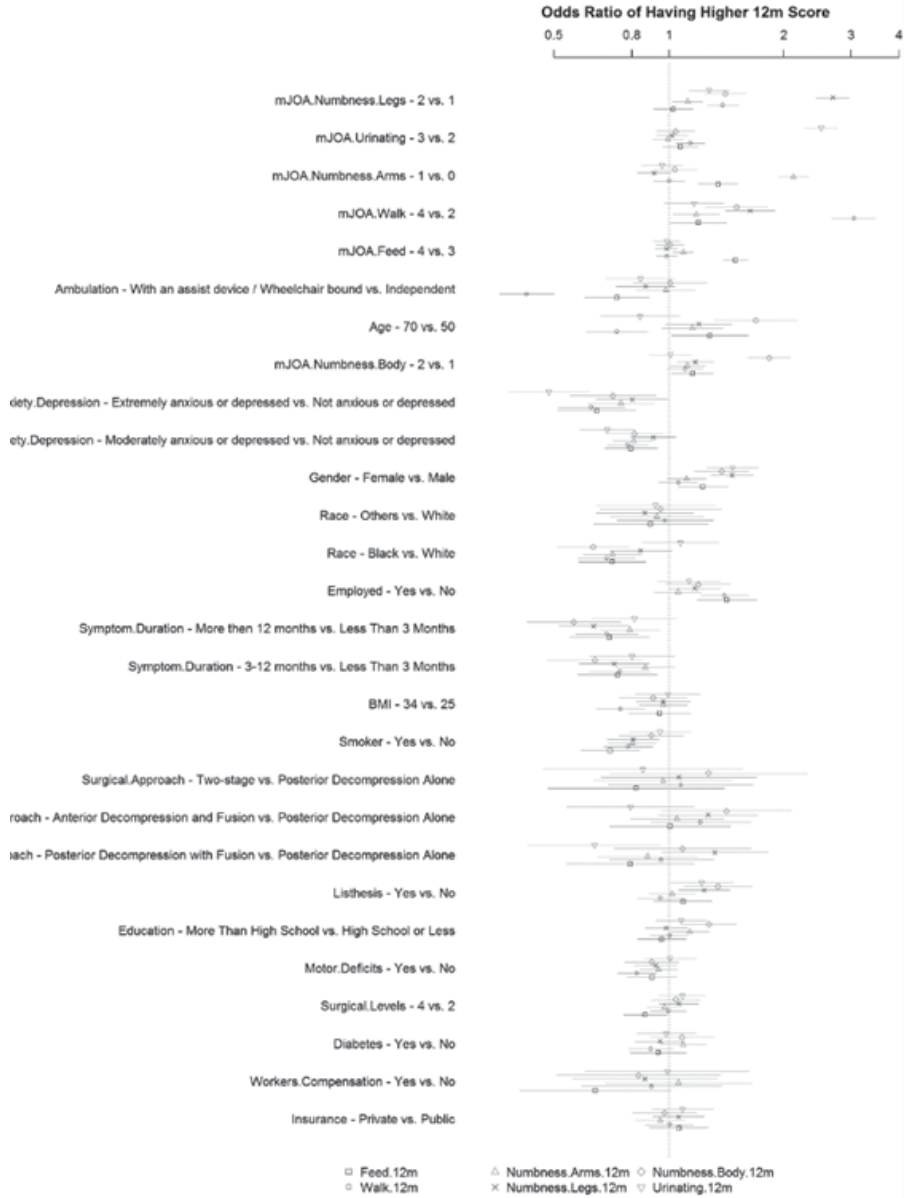
model has the potential to assist surgeons, patients and families when considering surgery for cervical myelopathy and provides clinically useful information in the preoperative setting. Future steps include prospective, external validation of the predictive model in order to assess the reproducibility and clinical utility of this work.



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Presentation #83

Characteristics of Upper Limb Impairment Related to Degenerative Cervical Myelopathy: Development of a Sensitive Hand Assessment (Graded Redefined Assessment of Strength, Sensibility, and Prehension Version Myelopathy).

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Introduction: Degenerative cervical myelopathy (DCM) involves spinal cord compression, which causes neurological decline. Neurological impairment in DCM is variable and can involve complex upper limb dysfunction including loss of manual dexterity, hyper-reflexia, focal weakness, and sensory impairment. The modified Japanese Orthopaedic Association (mJOA) score relies on the patients' subjective perceptions, while existing objective measures such as strength and sensory testing do not capture subtle changes in dexterity and function.Objectives: 1) Characterize hand function in DCM; 2) Develop and validate GRASSP V-Myelopathy (GRASSP-M), a clinical assessment that quantifies upper limb impairment in all severities of DCM.

Materials and Methods: Methods: 148 DCM patients (categorized into mild, moderate and severe based on mJOA grade) and 21 healthy subjects were enrolled. A complete neurological exam, the mJOA, the QuickDASH, grip dynamometry, and the GRASSP-M were administered.

Results: Results: Strength, sensation, and manual dexterity significantly declined with increasing DCM severity ($p=0.05$). Impairment in hand dexterity showed better discrimination between mild, moderate, and severe DCM categories than strength or sensation. The GRASSP-M was found to be both a reliable (ICC > 0.75 for intra- and inter-rater reliability) and valid (with both concurrent and construct validity) tool.

Conclusion: Conclusions: These results demonstrate that patients' subjective reporting of functional status, especially in the mild DCM category, may underrepresent the extent of functional impairment. The GRASSP-M is an objective tool designed to characterize patients' functional impairment related to the upper limb, which proves useful to diagnose and quantify mild dysfunction, monitor patients for deterioration, and help determine when patients should be treated surgically.

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Presentation #84

New Chronic Opioid Prescription-Filling Behavior within One Year After Cervical Spine Surgery

Inamullah Khan, MBBS, Jeffrey Hills, MD, Jacquelyn Pennings, MD, Kristin Archer, PhD, Byron Stephens, MD, ***Amir Abtahi, MD***

Introduction: Over the last two decades, the opioid epidemic has caused more than 400,000 overdose-related deaths in the United States. Despite the well-documented clinical benefits of spine surgery, recent evidence suggests a high incidence of new chronic opioid use following spine surgery (1). With the opioid epidemic front and center, increased emphasis will be placed on demonstrating that spine surgery patients remain opioid-free in the long-term after elective spine surgery (2-3). In the present study, we aim to identify the proportion of patients who developed new chronic opioid prescribing behavior after elective spine surgery.

Materials and Methods: All patients undergoing elective spine surgery for degenerative spinal conditions at our institution are enrolled in a longitudinal registry. In this analysis, patients were included if they underwent elective cervical spine surgery for a degenerative condition and had an identifiable record in our states prescription drug monitoring program (PDMP). Opioid data obtained from our state's prescription drug database was linked to our institution's prospective clinical spine registry to analyze opioid dispensing between 2010 and 2017. Patients were categorized as chronic opioid users based on the CDC definition, which defines chronic opioid use as opioid intake for at least 50% of days in a three-month window (we used three months immediately preceding surgery for preoperative chronic use) (2). New chronic opioid prescribing behavior at one-year was defined as patients who had no chronic opioid use in the three-months immediately prior to surgery, but who had chronic opioid use during the 9-12 months window after surgery.

Results: A total of 667 patients who underwent elective surgery for degenerative cervical spinal conditions; of these patients, 542 had no history of chronic preoperative opioid use and were the study population. The average age of the patients was 55.62 (±10.97) years, and 47.6% (n=258) were females. Of these, 51 (9.4%) developed new chronic opioid use at one-year after elective cervical spine surgery (Table 1). Patients undergoing revision spine surgery had a higher rate of new chronic opioid prescriptions (17.07%) compared to patients undergoing primary surgery (8.04%) ($p<.001$) (Figure 1). Patients undergoing two-stage surgeries (18.2%) had a higher proportion with new chronic opioid use when compared to single stage surgeries. In addition, the adjusted analysis identified that the major risk factors for the development of new chronic opioid prescription included number of days of preoperative opioid use and insurance other than private.

Conclusion: These results suggest that utilizing the CDC recommended definition of chronic opioid-use, we identified near 10% of patients who develop new-chronic opioid prescribing behavior at one year after elective cervical spine surgery. The results of this study will aid providers in clinical decision making – allowing them to identify risk factors for new chronic prescription opioid use including higher number of days of preoperative opioid use. However, further studies are required to assess the clinical impact of interventions directed at individual

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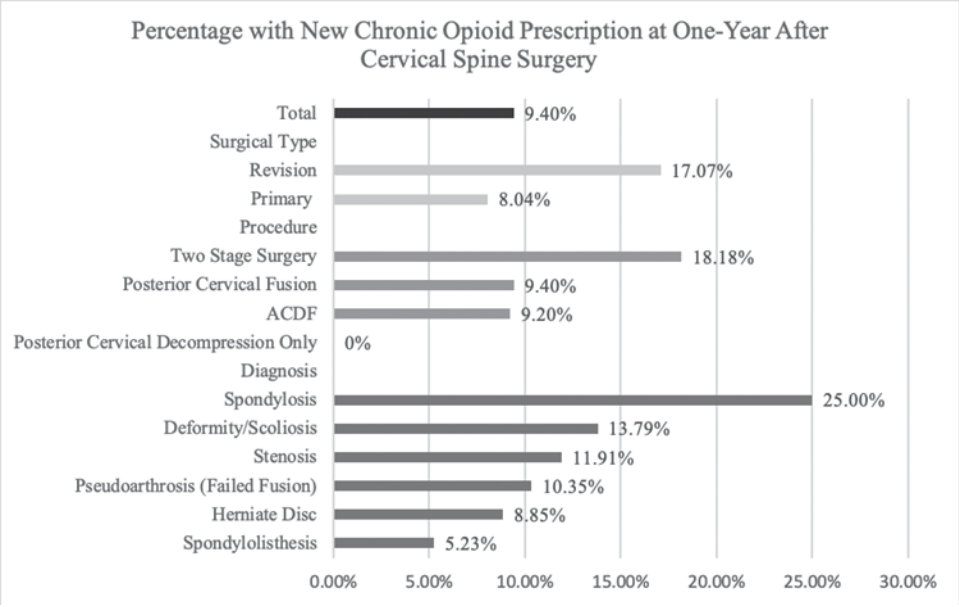
patient to effectively minimize the risk of new chronic opioid prescribing behavior after cervical spine surgery.



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Presentation #85

A Prospective Observational Study Comparing the Dysphagia Short Questionnaire and the Bazaz Dysphagia Score

Susan Odum, PhD, *Claes Olerud, MD, Alden Milam, MD, Todd Chapman, MD, Eric Laxer, MD, Leo Spector, PhD, Alfred Rhyne, MD, James Stokman, MD, Kirk Thompson, MD, Brad Segebarth, MD, Bruce Darden, MD*

Introduction: Dysphagia is a common complication following anterior cervical spine surgery (ACSS). There is no consensus on a subjective, patient reported outcome measure (PROM) for assessing dysphagia. The Bazaz Dysphagia Score (BDS) and the Dysphagia Short Questionnaire (DSQ) have been developed as simple, easy to understand PROMs to assess dysphagia following ACSS. The validated DSQ consists of five questions measuring different aspects of dysphagia. Weighted DSQ scores range from 0-18 with higher scores indicating increased severity. The Bazaz score is not validated and consists of 1 question about swallowing liquids and 1 about swallowing solids. There are four categorical response levels: none, mild, moderate and severe. Prior research indicates that the DSQ is a valid and reliable PROM that also measures change over time. The purpose of this study was to compare the responsiveness of the DSQ and the BDS scores in ACSS patients.

Materials and Methods: After Institutional Review Board approval and informed consent, 131 ACSS patients were enrolled at two institutions. Patients were excluded for history of cervical spine surgery, traumatic injury, inflammatory disease, history of cognitive issues and addiction. Patients completed the BDS and the DSQ preoperatively as well as 6 weeks and 3 months postoperatively. Patient demographics and medical history were recorded. Of the 131 enrolled, 128 completed all DSQ and BDS questions; 65 (51%) were male and the average age was 51 (range 32-66 yrs). Median and interquartile ranges of the DSQ were calculated within Bazaz scoring categories at each time point. Kruskal-Wallis Tests were used to statistically compare. Responsiveness was evaluated by defining a categorical change between each time point for both BDS and DSQ: no dysphagia-no change; dysphagia-no change, dysphagia-improved, dysphagia-worsened. For the DSQ, no dysphagia was defined as a score of 0 and any score >0 was defined as dysphagia. If the score was >0 and decreased longitudinally then the responsiveness category was dysphagia-improved. If the score was >0 and increased longitudinally then the responsiveness category was dysphagia-improved. Responsiveness categories were similarly defined for the BDS and moderate or severe responses were combined. Bowkers Test of Symmetry was used to statistically compare responsiveness categories between the BDS and DSQ.

Results: There were significant differences in DSQ scores within the Bazaz difficulty swallowing liquids and solids categories at all time points except liquids at 6-weeks (Table 1) indicating that the median DSQ score differentiates between the Bazaz severity categories. However, the variance between categories is similar. As indicated by significant p-values on the Bowkers Test of Symmetry, there is no agreement between the responsiveness of DSQ and Bazaz solids (Table 2) and liquids (Table 3). Therefore, each PROM will yield a different assessment of clinical symptoms over time.

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Conclusion: We found no agreement in responsiveness between the DSQ and BDS. The study sample is homogenous and the incidence of dysphagia in this study cohort was very low. At 3-months, the maximum DSQ score was 11, and 16 patients reported moderate or severe dysphagia. This lack of variability in symptom severity may have contributed to the lack of agreement.

Table 1. Association of Dysphagia Short Questionnaire Scores within Bazaz Dysphagia Scores

	Minimum	Lower Quartile	Median	Upper Quartile	Maximum	Pvalue
	Bazaz Liquids: Preop					
None (n=12)	0	0	0	2	8	<.0001
Mild (n=9)	1	3	3	4	5	
Moderate/Severe (n=7)	0	1	4	6	9	
	Bazaz Liquids: 6 Week					
None (n=84)	0	0	1	3	8	0.103
Mild (n=26)	0	2	4	6	9	
Moderate/Severe (n=11)	4	5	6	9	11	
	Bazaz Liquids: 3 Month					
None (n=97)	0	0	0	2	11	0.0038
Mild (n=19)	0	3	3	5	9	
Moderate/Severe (n=7)	2	5	7	9	10	
	Bazaz Solids: Preop					
None (n=100)	0	0	0	1	8	<.0001
Mild (n=15)	0	2	3	4	6	
Moderate/Severe (n=13)	1	3	4	5	9	
	Bazaz Solids: 6 Week					
None (n=64)	0	0	0	2	8	0.0285
Mild (n=21)	0	2	3	4	8	
Moderate/Severe (n=36)	1	4	5	7	11	
	Bazaz Solids: 3 Month					
None (n=78)	0	0	0	1	6	0.0008
Mild (n=29)	0	2	3	3.5	7	
Moderate/Severe (n=16)	1	3	5	9	11	

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Table 2. Responsivess of DSQ and Bazaz Solids

	None-same	Dysphagia-Same	Improved	Worse	Pvalue
DSQ: Change from Pre to 6 wks	Bazaz Solid: Change from Pre to 6 wks				
None-same	23 (92%)	0 (0%)	1 (4%)	1 (4%)	0.0022
Dysphagia-same	3 (30%)	3 (30%)	1 (10%)	3 (30%)	
Improved	3 (12%)	5 (19%)	2 (8%)	16 (62%)	
Worse	11 (52%)	1 (5%)	6 (29%)	3 (14%)	
DSQ: Change from Pre to 3 mos	Bazaz Solid: Change from Pre to 3 mos				
None-same	31 (91%)	0 (0%)	1 (3%)	2 (6%)	0.0025
Dysphagia-same	2 (25%)	2 (25%)	2 (25%)	2 (25%)	
Improved	3 (17%)	3 (17%)	2 (11%)	10 (56%)	
Worse	16 (52%)	8 (26%)	4 (13%)	3 (10%)	
DSQ: Change from 6 Wk to 3 mos	Bazaz Solid: Change from 6 Wk to 3 mos				
None-same	26 (96%)	0 (0%)	1 (4%)	0 (0%)	<.0001
Dysphagia-same	1 (5%)	8 (42%)	7 (37%)	3 (16%)	
Improved	4 (36%)	3 (27%)	1 (9%)	3 (27%)	
Worse	20 (37%)	9 (17%)	24 (44%)	1 (2%)	

Table 3. Responsivess of DSQ and Bazaz Liquids

	None-same	Dysphagia-Same	Improved	Worse	Pvalue
DSQ: Change from Pre to 6 wks	Bazaz Liquids: Change from Pre to 6 wks				
None-same	24 (96%)	0 (0%)	0 (0%)	1 (4%)	<.0001
Dysphagia-same	7 (70%)	1 (10%)	2 (20%)	0 (0%)	
Improved	10 (38%)	3 (12%)	0 (0%)	13 (50%)	
Worse	13 (62%)	0 (0%)	4 (19%)	4 (19%)	
DSQ: Change from Pre to 3 mos	Bazaz Liquids: Change from Pre to 3 mos				
None-same	31 (91%)	0 (0%)	1 (3%)	2 (6%)	0.0025
Dysphagia-same	2 (25%)	2 (25%)	2 (25%)	2 (25%)	
Improved	3 (17%)	3 (17%)	2 (11%)	10 (56%)	
Worse	16 (52%)	8 (26%)	4 (13%)	3 (10%)	
DSQ: Change from 6 Wk to 3 mos	Bazaz Liquids: Change from 6 Wk to 3 mos				
None-same	25 (93%)	0 (0%)	1 (4%)	1 (4%)	<.0001
Dysphagia-same	7 (37%)	8 (42%)	3 (16%)	1 (5%)	
Improved	3 (27%)	3 (27%)	2 (18%)	3 (27%)	
Worse	34 (63%)	6 (11%)	13 (24%)	1 (2%)	

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Presentation #86

Long-term follow-up of cervical artificial disc replacement versus anterior fusion: patient reported outcomes, secondary surgeries and incidence of adjacent segment pathology.

Michail Kontakis, MD, *Anna MacDowall, MD, PhD, Claes Olerud, MD*

Introduction: Artificial disk replacement (ADR) preserves motion after anterior discectomy and is an alternative treatment to fusion in patients with cervical radiculopathy. This study of 153 patients randomized to either ADR or fusion has previously been reported with 2- and 5-years of follow-up presenting no superiority of either procedure.

Materials and Methods: In this 10-12 year follow-up of the 153 RCT patients Neck disability index (NDI), European quality of life five dimensions (EQ-5D), Visual analog scale (VAS) -neck and VAS-arm were obtained from the Swedish Spine Registry. Information about secondary surgeries was collected and MRI as well as flexion-extension radiographs were performed;

Results: Remaining patients in the study were 143 (79 ADR and 64 ACDF); two patients did not receive the allocated treatment, two had left the study by their own request and six patients have deceased. In the intention to treat analysis (ITT) the mean NDI in the ADR group was 12, versus 10 in the fusion group (p=0.32). Mean VAS-neck was 30 for the ADR group and 29 for the fusion group (p=0.72) while VAS-arm was 27 for the ADR and 21 for the fusion group (p=0.26). Since the initial operation, there were 23 secondary surgeries in the ADR group (11 cases of subsidence/loosening, 3 cases of loosening with simultaneous adjacent segment pathology (ASP), 8 cases of ASP, one case of residual root-canal stenosis), while in the ACDF group there were 11 reoperations (eight cases of ASP, two cases of pseudarthrosis and one case of residual foraminal stenosis), OR=1.97, p=0.09. In the per protocol analysis (PP), since their last 5-year follow-up, 64 patients remained in the ADR group with similar NDI (10.49 vs 10.42, p= 0.96), VAS-neck scores (28 vs 29, p=0.88) and, VAS-arm scores (25 versus 21, p=0.47) compared with the fusion group.

Conclusion: The ADR group in the ITT analysis had a tendency towards higher NDI and VAS scores, and more secondary surgeries compared with the fusion group. The difference however was not statistically significant and did not reach the minimum clinically important difference. Our findings show no superiority of either treatment method 10-12 years after the primary surgery.

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Presentation #87

A Validation of the Patient Health Questionnaire-9 for Cervical Spine Surgery

Nathaniel Jenkins, MS, James Parrish, MPH, ***Conor Lynch, MS,*** *Elliot Cha, MS, Dustin Massel, MD, Augustus Rush, MD, Shruthi Mohan, BS, Cara Geoghegan, BS, Caroline Jadczak, BS, Nadia Hrynewycz, BS, Kern Singh, MD[1]*

Introduction: As the number of elective cervical spine surgeries continues to rise and current research indicates depression may influence postsurgical outcomes,[1] it is increasingly important to screen patients for preoperative depressive symptoms. The Patient Health Questionnaire-9 (PHQ-9) is a screening instrument used to evaluate patient depressive symptoms and has been validated in numerous patient populations [2–6]. While the PHQ-9 has favorable operating characteristics as a depressive symptom screening instrument, it has not been evaluated within cervical spine surgery. A rigorous history of mental health evaluation has been demonstrated with the Short Form-12 (SF-12) and Veterans RAND-12 (VR-12). The purpose of this study is to evaluate depressive symptoms as measured by the PHQ-9 survey and correlated them with scores from the SF-12 and VR-12 Mental Component Summary (MCS).

Materials and Methods: A prospective maintained surgical registry was retrospectively reviewed for patients undergoing single or multilevel ACDF or CDR procedures from March 2016 until May 2019. Patients were included if they underwent an elective cervical surgery for degenerative spinal pathology. Patients were excluded for not having completed a preoperative PHQ-9, SF-12, or VR-12 preoperative survey. Cases were excluded if surgery was indicated due to trauma, malignancy or infection. Demographic and baseline perioperative variables were collected, including age, gender, smoking status, body mass index (BMI) category (<30 kg/m2 or >30 kg/m2), Charlson comorbidity index (CCI), type of cervical procedure, number of operative levels, operative duration (time from skin incision to closure), estimated blood loss (EBL), and hospital length of stay (Table 1). The mean scores for postoperative PHQ-9, SF-12 and VR-12 surveys were calculated. We then calculated an average change (delta value) between preoperative scores to each postoperative timepoint (Table 2). We evaluated the relationship of PHQ-9 with SF-12 MCS and VR-12 MCS scores by calculating a Pearson's correlation coefficient and time-independent partial correlation coefficient (Table 3). Correlation strength was assessed using subcategories: $0.1 \leq |r| < 0.3$ = low; $0.3 \leq |r| < 0.5$ = moderate; $|r| \geq 0.5$ = strong.

Results: A total of 152 patients underwent single or multilevel level cervical spine surgery (ACDF: 73% [n=111] and CDR: 27% [n=41], Table 1). The cohort was 39% female with an average age of 42.4 years. 61% were obese. Compared to preoperative scores, statistically significant increases were observed among postoperative PHQ-9, SF-12 MCS, and VR-12 MCS surveys ($p \leq 0.001$, Table 2). We observed strong correlations between SF-12 MCS and VR-12 MCS with PHQ-9 scores for both the Pearson's and time-controlled partial correlations (Table 3).

Conclusion: We observed PHQ-9, SF-12 MCS and VR-12 MCS scores had significant improvement in patients undergoing ACDF or CDR. PHQ-9 scores were strongly correlated with SF-12 MCS and VR-12 MCS scores when evaluated with both Pearson's and partial correlation coefficients. Our findings indicate PHQ-9 is a valid tool to evaluate pre and postsurgical

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symptoms of depression.

Table 1. Baseline characteristics of study population

	Total %, (n) n=152
Age (Mean ± SD, years)	47.3 ± 10.6
Gender	
Female	38.8% (59)
Male	61.2% (93)
Smoking Status (n)	
Non-Smoker	88.8% (135)
Smoker	11.2% (17)
Body Mass Index (BMI)	
<30 kg/m2 – Non-obese	59.9% (91)
>30 kg/m2 – Obese	40.1% (61)
Charlson Comorbidity Index	1.1 ± 1.2
Cervical Procedure	
ACDF	73.0% (111)
CDR	27.0% (41)
Operative Levels	
1-level	62.5% (95)
2-level	30.3% (46)
3-level	5.9% (9)
4-level	1.3% (2)
Operative Time (Mean ± SD, min)	41.2 ± 11.8
Estimated Blood Loss (Mean ± SD, mL)	25.8 ± 5.3
Hospital Length of Stay (Mean ± SD, hours)	5.3 ± 7.0

ACDF= Anterior Cervical Discectomy and Fusion; CDR = Cervical Disc Replacement; SD = Standard Deviation; CCI = Charlson Comorbidity Index

Table 2. Postoperative Changes in Survey Scores

	Score Mean ± SD (n)	Change Mean ± SD (n)	†p-value*
PHQ-9			
Preoperative	7.1 ± 6.2 (123)		
6 week	5.0 ± 5.5 (123)	2.1 ± 5.3 (123)	0.000
12 week	4.4 ± 5.7 (99)	2.9 ± 5.2 (99)	0.000
6 month	4.9 ± 5.7 (78)	2.2 ± 6.4 (78)	0.004
1 year	4.0 ± 5.3 (42)	2.7 ± 6.2 (42)	0.008
SF-12 MCS			
Preoperative	47.0 ± 12.7 (114)		
6 week	51.1 ± 10.8 (114)	-4.2 ± 10.0 (114)	<0.001
12 week	51.0 ± 11.8 (89)	-4.9 ± 10.4 (89)	<0.001
6 month	50.4 ± 11.8 (65)	-3.1 ± 12.0 (65)	0.042
1 year	52.3 ± 11.9 (39)	-6.3 ± 12.9 (39)	0.004
VR-12 MCS			
Preoperative	50.0 ± 13.7 (114)		
6 week	53.6 ± 11.0 (114)	-3.6 ± 10.1 (114)	<0.001
12 week	54.1 ± 11.8 (89)	-5.5 ± 10.0 (89)	<0.001
6 month	53.7 ± 11.9 (65)	-4.2 ± 11.2 (65)	0.004
1 year	56.6 ± 11.0 (39)	-7.8 ± 13.9 (39)	0.001

*Boldface indicates statistical significance
†p-value calculated using paired t-test comparing scores at each timepoint to preoperative values
PHQ-9 = Patient Health Questionnaire-9; SF = Short Form 12-Item Survey; VR = Veterans RAND 12-Item Health Survey

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Table 3. Correlation of PHQ-9 with SF-12 and VR-12 MCS for Cervical Surgery

	Pearson, r	†Strength	‡p-value*	Partial, r	†Strength	‡p-value*
PHQ-9 vs. SF-12 MCS						
Preoperative	-0.741	Strong	<0.001	-0.740	Strong	<0.001
6 week	-0.779	Strong	<0.001	-0.773	Strong	<0.001
12 week	-0.823	Strong	<0.001	-0.825	Strong	<0.001
6 month	-0.827	Strong	<0.001	-0.837	Strong	<0.001
1 year	-0.779	Strong	<0.001	-0.776	Strong	<0.001
PHQ-9 vs. VR-12 MCS						
Preoperative	-0.743	Strong	<0.001	-0.741	Strong	<0.001
6 week	-0.800	Strong	<0.001	-0.796	Strong	<0.001
12 week	-0.870	Strong	<0.001	-0.868	Strong	<0.001
6 month	-0.861	Strong	<0.001	-0.866	Strong	<0.001
1 year	-0.878	Strong	<0.001	-0.878	Strong	<0.001

*Boldface indicates statistical significance
†Correlation strength was assessed using subcategories: $0.1 \leq |r| < 0.3$ = low; $0.3 \leq |r| < 0.5$ = moderate; $|r| \geq 0.5$ = strong
‡p-value calculated testing significance of correlation coefficient
PHQ-9 = Patient Health Questionnaire-9; SF = Short Form 12-Item Survey; VR = Veterans RAND 12-Item Health Survey

Presentation #88

Ultrasonography for the Evaluation of Neck Hematoma Before and After Anterior Cervical Spine Surgery

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Introduction: With more anterior cervical surgeries in outpatient settings, evaluation of postoperative hematoma and soft tissue swelling are crucial. Magnetic resonance imaging is the most common imaging modality to evaluate these features following surgery, but can be costly, unavailable, or may include longer wait times. Ultrasonography (US) is a cheaper, mobile, and more widespread imaging modality that has shown efficacy to evaluate fluid collections and soft-tissue morphology in several regions of the body; easily performed immediately outpatient. Our goal is to assess the reproducibility and reliability of ultrasonography as a method to evaluate hematoma volume and the surrounding structures of the neck before and after anterior cervical spine surgery. Secondarily, we hope to develop a range of baseline hematoma formation and soft-tissue morphologic changes following anterior neck surgery in this patient population.

Materials and Methods: This is an IRB-approved prospective study from a single-center. All patients scheduled to undergo a 1-3 level anterior cervical discectomy fusion (ACDF) or cervical disc replacement (CDR) by one of 6 fellowship-trained spine surgeons with no drain placement. Prior to surgery, patients obtained a neck US and filled out an EAT-10 dysphagia questionnaire at this time. The morning after surgery, a neck US and standard antero-posterior/lateral cervical spine plain radiographs was obtained and another EAT-10 dysphagia questionnaire at the time of the neck US. The neck US was evaluated by a radiologist for: presence of hematoma (and dimensions), vertebral bodies visualized, thickness of bilateral longus colli ("AP-lateral", "AP transverse," and "Med-Lat transverse"), and ability to visualize the esophagus and trachea. The plain radiographs were evaluated for retropharyngeal soft-tissue swelling.

Results: To date,12 patients have completed the study. Mean age was 54.42+9.71 years and the majority were male 8 (66.7%). Six patients underwent a single-level, 5 patients underwent a 2-level, and 1 patient underwent a 3-level anterior cervical surgery; all through a left-sided approach. No patients reported a clinically-significant hematoma. On US neck, there were 3 hematomas that were observed, all in 2-level procedures. There were no significant differences in the thickness of the left-sided longus colli from pre-op to post-op evaluation in all 3 measurements (Table 1). Right-sided longus thickness showed significant increases in the "AP-lateral" (7.89+1.70mm to 7.89+1.70mm; p=0.04 and "AP-transverse" (9.40+2.37 to 9.40 + 2.37mm; p=0.010). There are currently no significant differences in US neck findings between single- and 2-level procedures. EAT-10 scores showed significant worsening from pre-operative assessment to post-operative day 1 evaluations, performed at the time of neck US (0.14+0.38 to 11.57+8.18; p=0.01). Similarly, retropharyngeal swelling distance at the surgical level, based on lateral cervical plain radiographs increased from 10.95+5.37mm to 13.00+4.64mm on post-operative day 1.

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Conclusion: In early stages of this study, neck ultrasound appears to be an effective method to evaluate hematoma and soft-tissue structures in the neck, before and after anterior cervical surgery. As the study progresses, we will be able to further describe the safety of performing these surgeries without drain placement, and correlate US neck findings to clinical outcomes.

Table 1. Preoperative vs. Postoperative

	Pre-operative	Post-operative	*p value*
EAT10 scores	0.14 ± 0.38	11.57 ± 8.18	**.010**
Cervical XR retropharyngeal swelling distance at surgical level (mm)	10.95 ± 5.37	13.00 ± 4.64	**.010**
Longus colli thickness, Left (mm)			
• AP lateral	8.68 ± 2.94	9.27 ± 3.00	.306
• AP transverse	10.04 ± 3.23	10.90 ± 2.18	.309
• Med-Lat transverse	14.07 ± 3.18	12.61 ± 2.60	.153
Longus colli thickness, Right (mm)			
• AP lateral	7.89 ± 1.70	9.58 ± 2.62	**.046**
• AP transverse	9.40 ± 2.37	c	**.010**
• Med-Lat transverse	13.83 ± 3.57	14.23 ± 2.13	.703
Total number of visible vertebral bodies	3.83 ± 0.39	4.17 ± 0.39	**.039**
Individual visible vertebral bodies			
• C2	0	0	
• C3	7 (58.33%)	8 (66.67%)	1.000
• C4	12 (100%)	12 (100%)	
• C5	12 (100%)	12 (100%)	
• C6	12 (100%)	12 (100%)	
• C7	3 (25%)	6 (50%)	.375
Trachea visibility			
• Right-sided	10 (83.33%)	12 (100%)	
• Left-sided	10 (83.33%)	12 (100%)	
Esophagus visibility			
• Right-sided	6 (50%)	4 (33.33%)	.500
• Left-sided	9 (75%)	2 (16.67%)	**.016**
Postoperative hematoma (N)		3 (25%)	
Hematoma dimensions			
• Long axis		31.77 ± 19.52	
• Short axis		5.63 ± 1.85	
Hardware visibility		12 (100%)	

* Statistics are summarized as mean ± SD. All categorical variables reported as N (%).

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Presentation #89

Significance of Vertebral Body Sliding Osteotomy in Surgical Strategy for the Treatment of Cervical Myelopathy due to Ossification of Posterior Longitudinal Ligaments: Results of Comparison with Laminoplasty

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Introduction: Vertebral body sliding osteotomy (VBSO) has been reported as a decompression technique for ossification of posterior longitudinal ligament (OPLL) that anteriorly translates the vertebral body without direct removal of OPLL mass (Figure 1). Although VBSO has fewer complications than does anterior cervical corpectomy and fusion, little is known regarding its clinical efficacy and surgical indication. Furthermore, the advantages of VBSO over posterior approach procedures such as laminoplasty have not been evaluated. This study aimed to evaluate the efficacy of VBSO versus laminoplasty for treating OPLL-induced cervical myelopathy.

Materials and Methods: We retrospectively reviewed 97 patients with symptomatic OPLL-induced cervical myelopathy who were treated with VBSO (VBSO group; n = 40) or laminoplasty (LMP group; n = 57) and were followed-up for >2 years. Cervical alignment, range of motion, fusion, modified Kyphosis-line (mK-line) status, minimum interval between ossified mass and mK-line (INT(min)), Japanese Orthopaedic Association (JOA) score, and JOA recovery ratio were assessed. In addition, complications such as dural tear, neurological deterioration, and infection were recorded.

Results: Compared with the LMP group, the VBSO group demonstrated a greater canal occupying ratio ($p < 0.01$) and more kyphotic alignment ($p = 0.02$) preoperatively (Table 1). Cervical lordosis and INT(min) significantly increased in the VBSO group ($p < 0.01$, $p < 0.01$, respectively) and were significantly greater in the VBSO group than in the LMP group at the final follow-up ($p < 0.01$, $p < 0.01$, respectively). Range of motion significantly decreased in both the groups with no significant difference at the final follow-up ($p = 0.14$) (Table 2). All the patients who were assessed as mK-line status (-) preoperatively were assessed as mK-line status (+) postoperatively. However, in the LMP group, the mK-line status changed from (+) preoperatively to (–) postoperatively in 3 patients (Table 1). The final JOA score ($p = 0.02$), JOA score improvement at the final follow-up ($p = 0.01$), JOA recovery ratio ($p = 0.03$), and proportion of patients with >50% recovery rate ($p < 0.01$) were significantly higher in the VBSO group than in the LMP group (Table 2). One case (2.5%) of dural tear was identified in the VBSO group and 1 patient (1.7%) in the LMP group had superficial infection (Table 1). The fusion rate in the VBSO group was 92.5%. Logistic regression analysis revealed that the change in mK-line status from (–) to (+) was significantly associated with >50% JOA recovery rate ($p < 0.01$).

Conclusion: Compared with laminoplasty, VBSO demonstrated better lordosis restoration, better separation of ossified mass from the spinal cord, and conversion of the mK-line status from (–) to (+). Hence, VBSO results in better neurological recovery despite preoperative kyphotic alignment and higher canal occupying ratio. Furthermore, complication rates did not significantly differ between the two procedures. Therefore, VBSO, a surgical option for OPLL-induced myelopathy, is

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effective, both, for sagittal alignment restoration and neurological recovery, and is best indicated for kyphotic alignment and OPLL with a high canal occupying ratio.

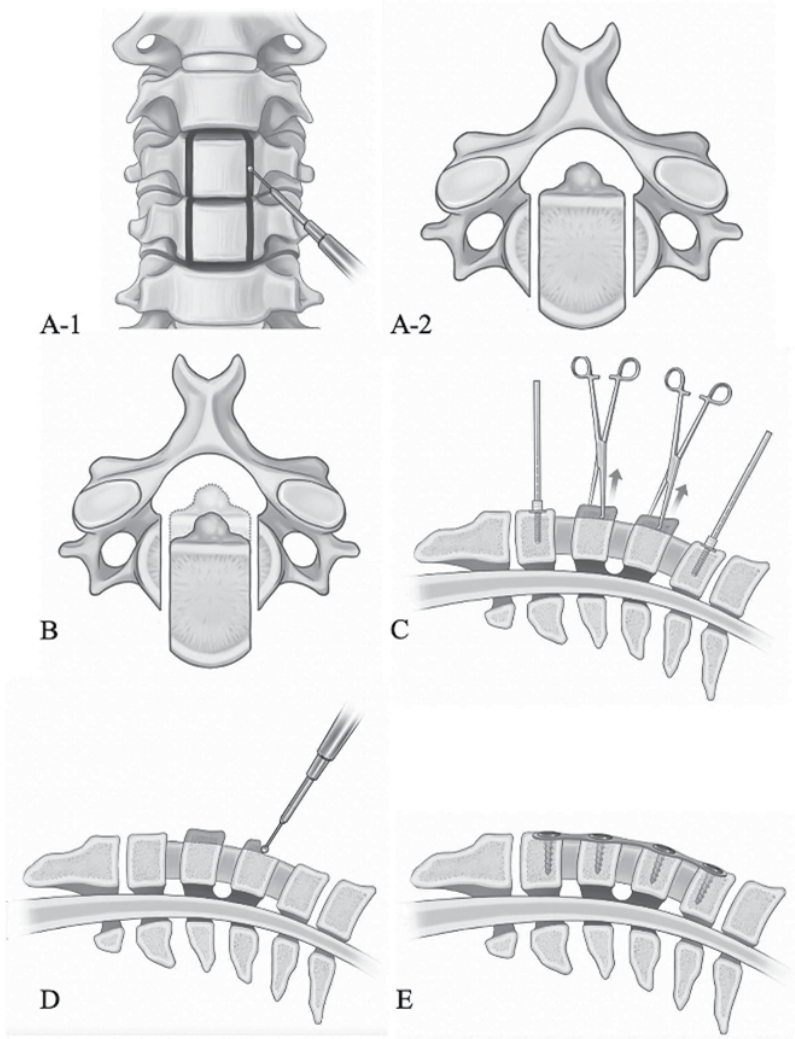

Figure 1. Technical description of vertebral body sliding osteotomy. (A) Two lateral slits are made using a high-speed burr at the base of the uncinate process. (B) Anterior translation of the vertebral body with ossification of the posterior longitudinal ligament mass with gentle traction. (C) While holding the vertebral body in an anteriorly translated position, interbody cages are inserted. A slight distraction force was applied with a Casper pin distractor to allow control of the vertebral body position. (D) A burr is used to remove the anterior part of the translated vertebral body. (E) The anterior plate is applied for additional stability.

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Table 1. Patient characteristics and mK-line state comparison between the two groups

	VBSO	LMP	P value
Number	40	57	
Age	58.6±10.9	62.2±9.9	0.10
Sex			
Male	29 (72.5%)	44 (77.2%)	0.64
Female	11 (27.5%)	13 (28.8%)	
DM	8 (20.0%)	11 (19.3%)	1.00
HTN	13 (32.5%)	19 (33.3%)	1.00
Malignancy	2 (5.0%)	0 (0%)	0.17
BMI	25.9±6.9	25.6±2.7	0.70
Current smokers	7 (17.5%)	7 (12.3%)	0.56
Operative factors			
Operation time	212.4±34.7	157.7±28.7	<0.01*
Number of OPLL involved level	2.6±0.7	3.9±1.3	<0.01*
Canal occupying ratio (%)	46.6±11.3	40.6±0.12	0.01*
Complications			
Dural tear	1 (2.5%)	0 (0%)	0.35
Neurologic deterioration	0 (0%)	0 (0%)	-
Infection	0 (0%)	1 (1.7%)	1.00
Readmission	0 (0%)	1 (1.7%)	1.00
Reoperation	0 (0%)	0 (0%)	-
Preoperative mK-line state			
(+)	16 (40.0%)	51 (89.5%)	<0.01*
(-)	24 (60.0%)	6 (10.5%)	
Postoperative mK-line state			
(+)	40 (100.0%)	48 (84.2%)	0.01*
(-)	0 (0.0%)	6 (10.5%)	

VBSO = Vertebral body sliding osteotomy; LMP = laminoplasty; DM = diabetes mellitus; HTN = hypertension; BMI = body mass index; OPLL = ossification of posterior longitudinal ligament; mK-line = modified kyphosis line;

Age, BMI, operative factors were analyzed by student's t-test;

DM, HTN, malignancy, current smokers, complications, and mK-line status were analyzed by chi-square test

* P value <0.05

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Table 2. Comparison between VBSO group and LMP group

		VBSO	LMP	P value†
Cervical lordosis	Preoperative			
	Degrees	5.7 ± 13.8	11.2 ± 8.0	0.02*
	Post op 12M			
	Degrees	12.0 + 8.3	6.9 + 8.5	<0.01*
	Change	6.3 ± 10.3	-4.2 ± 7.2	<0.01*
	P value‡	<0.01*	<0.01*	
	Final follow-up			
	Degrees	11.6 ± 9.0	7.0 ± 7.4	<0.01*
	Change	5.6 ± 10.5	-4.2 ± 7.9	<0.01*
	P value‡	<0.01*	<0.01*	
Range of motion	Preoperative			
	Degrees	38.5 ± 10.7	35.7 ± 14.2	0.29
	Post op 12M			
	Degrees	19.9 + 7.8	25.5 + 12.2	0.01*
	Change	-18.6±7.8	-10.2±9.8	<0.01*
	P value‡	<0.01*	<0.01*	
	Final follow-up			
	Degrees	20.2 + 7.6	23.4 + 12.2	0.14
	Change	-18.8 ± 12.2	-12.3 ± 10.3	<0.01*
	P value‡	<0.01*	<0.01*	
$INT_{(min)}$	Preoperative			
	Interval (mm)	0.5 ± 2.6	2.6 ± 2.7	<0.01*
	Post op 12M			
	Interval (mm)	6.1 ± 3.3	2.4 ± 2.8	<0.01*
	Change	5.6 ± 3.7	-0.2 ± 1.4	<0.01*
	P value‡	<0.01*	<0.01*	
JOA	Preoperative			
	Score	13.4 ± 2.0	12.9 ± 3.1	0.42
	Final follow-up			
	Score	15.1 ± 1.8	13.8 ± 1.9	0.02*
	Change	1.7 ± 1.8	0.9 ± 1.3	0.01*
	P value‡	<0.01	<0.01	
	Recovery rate (%)	60.1 ± 38.4	42.4 ± 35.7	0.03*

VBSO = vertebral body sliding osteotomy; LMP = laminoplasty; M= months; $INT_{(min)}$ = minimum interval; JOA = Japanese Orthopaedic Association;

† Student's t-test was used for comparison of two groups

‡ Paired t-test was used for comparison of preoperative and postoperative measurements

* P value <0.05

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Presentation #90

Comparing Long-Term Outcomes Between ACDF and Minimally-Invasive Posterior Cervical Foraminotomy in the Treatment of Cervical Radiculopathy: A 7-year Follow-up Study

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Introduction: Minimally invasive posterior cervical foraminotomy (MI-PCF) has been shown in several studies to be equally effective as ACDF in treating cervical radiculopathy due to foraminal stenosis and similar pathologies. MI-PCF also has several advantages over ACDF in short term follow-up as it is associated with less hardware utilization, shortened hospital stay and time away from work, reduced blood loss, medication use and cost. Additionally, it has been hypothesized that preserving motion and avoiding fusion reduces risk for adjacent level disease, but potentially increases risk for subsequent revision to an ACDF. Recent studies have shown a similar revision rates between MI-PCF and ACDF at 2-year follow-up. With similar short-term outcomes and substantial advantages, MI-PCF may be an effective alternative to ACDF for addressing appropriate cervical pathology. Therefore, to confirm this hypothesis and to justify utilization of MI-PCF over ACDF, we must determine both overall revision rates and functional outcomes with long term follow-up.

Materials and Methods: A retrospective review was performed to identify all patients between 2009-2013 who underwent either ACDF or MI-PCF with a minimum follow-up of 7-years. Demographic data was recorded and compared between both cohorts. Revision rate between ACDF and MI-PCF patients were also compared. Functional outcomes were assessed with NDI and VAS-n and VAS-a measurements at follow-up visits. All complications were reviewed. Standard binomial and categorical comparative analysis were performed.

Results: A total of 177 consecutive patients were included, 143 in the ACDF cohort and 34 in the MI-PCF cohort. Mean follow up of the ACDF and MI-PCF cohorts were 96.8 and 94.5 months, respectively. Complication rates were 4.9% and 2.9% for the ACDF and MI-PCF cohorts, respectively ($p = 1$). The overall revision rates were 9.1% for the ACDF cohort and 11.8% for the MI-PCF cohort ($p=0.745$). All MI-PCF patients were revised to a fusion. There were 60 males and 83 females in the ACDF cohort compared to 29 males and 9 females in the MI-PCF cohort, a statistically significant difference ($p=<0.001$). Both cohorts experienced significant improvements in their functional outcome scores (NDI, VAS-neck, and VAS-arm) compared to their pre-operative values, however the magnitude of improvement was not statistically significant between the ACDF and MI-PCF cohorts.

Conclusion: MI-PCF is a safe and effective alternative to ACDF in the treatment of cervical radiculopathy, demonstrating long-lasting benefit. After long-term follow-up, MI-PCF demonstrated similar improvements in functional outcome scores, without increased complication or revision rates, and is associated with the advantages of decreased hospital length of stay, overall cost, and quicker return to work. Further studies should consist of cost analysis to evaluate how utilizing MI-PCF would impact overall health-care spending.

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Presentation #91

A Comparative Analysis of Surgical Approach in the Treatment of Cervical Myelopathy in Patients with OPLL: A Propensity-Score Matched, Multi-center Analysis on Inpatient and Post-discharge 90-day Outcomes

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Introduction: The surgical treatment of cervical myelopathy in patients with OPLL is known to be associated with significant complications. Numerous studies have compared the perioperative complications by surgical approach; however, existing literature is limited to inpatient complications[1, 2], single-institution analyses[3], regional bias[4], and inadequate control of potential confounding variables (e.g. levels fused, corpectomy). This study addresses these limitations by employing a propensity-score matching algorithm on a comprehensive set of covariates, and provides comparative analyses of surgical approach for inpatient complications and post-discharge 90-day outcomes.

Materials and Methods: A multi-center, national database was queried to identify adult (≥18 years) patients with OPLL, who underwent at least a 2-level cervical decompression and fusion for cervical spondylotic myelopathy from 2012 to 2014. A propensity-score matching algorithm, which accounted for patient, surgical, and hospital factors, was employed to compare outcomes by surgical approach (Anterior vs. Posterior). Subsequently, multivariate analyses were performed to determine if surgical approach was an independent predictor for short-term outcomes.

Results: After propensity-score matching, 627 patients remained (Anterior= 307, Posterior= 320). The mean age ± standard deviation was 58±10 years and 43% of patients were female. After controlling for co-variates (e.g. comorbidities, fusion levels, corpectomy, hospital factors), an anterior approach was found to be an independent predictor for higher inpatient surgical complications (odds ratio 5.9), which included dysphagia: 14%[anterior] vs. 1.1%[posterior] p-value<0.001, wound hematoma: 1.7%[anterior] vs. 0%[posterior] p-value=0.02, and dural tear: 9.4%[anterior] vs. 3.2%[posterior] p-value=0.001. A posterior approach was an independent predictor for longer hospital length of stay by nearly 3 days (odds ratio 3.4; 6.8 days[posterior] vs. 4.0 days[anterior] p-value<0.001). Similar rates of 90-day readmission and reoperation were seen between both surgical approaches (Readmission: 11.7%[anterior]vs.8.4%[posterior] p-value=0.177, Reoperation: 4.2%[anterior]vs.2.8%[posterior] p-value=0.261). The reasons for readmission and reoperation did not vary by approach for 2- to 3-level fusions; however, for > 3-level fusions, patients with an anterior approach more often had a respiratory complications requiring mechanical ventilation (p-value=0.038) and cervical myelopathy requiring revision fusion surgery (p-value=0.015).

Conclusion: The national estimates for inpatient complications (25%), readmissions (9.9%), and reoperations (3.5%) are substantial after the surgical treatment of multi-level OPLL. An anterior approach resulted in significantly higher inpatient surgical complications, but this did not result in a longer hospital length of stay and the overall 90-day complication rates requiring

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readmission or reoperation was similar to those seen after a posterior approach. For patients requiring > 3-level fusion, an anterior approach is associated with significantly higher risk for respiratory complications requiring mechanical ventilation and revision fusion surgery for cervical myelopathy. These findings will be important in the preoperative surgical decision-making process for patients and surgeons.

Table A. Inpatient and Post-Discharge Outcomes by Surgical Approach After Propensity Score Matching

	ALL	Anterior	Posterior	
	627	307	320	P-value
Inpatient Postoperative Complications	25.0%	33.5%	17.0%	***<0.001***
Mortality	0.8%	0.7%	0.9%	0.834
Morbidity	24.2%	32.8%	16.2%	***<0.001***
Surgical	19.8%	29.0%	10.8%	***<0.001***
Perioperative Blood Transfusion	6.1%	4.5%	7.7%	0.099
Dysphagia	7.5%	14.0%	1.1%	***<0.001***
Wound Hematoma	0.8%	1.7%	0.0%	***0.02***
Dural Tear	6.2%	9.4%	3.2%	***0.001***
Medical	7.2%	5.8%	8.4%	0.211
Urinary Tract Infection	3.0%	1.5%	4.5%	***0.03***
Acute Renal Failure	2.1%	0.6%	3.6%	***0.009***
Cerebrovascular Accident	1.0%	1.8%	0.0%	***0.016***
Cardiac Complication	0.3%	0.7%	0.0%	0.128
Acute Respiratory Failure	1.3%	1.8%	0.9%	0.33
Pneumonia	0.0%	0.0%	0.0%	0%
DVT/PE	0.0%	0.0%	0.0%	0%
Paralytic Ileus	0.0%	0.0%	0.0%	0%
Post-Discharge Complications				
90-day Readmissions	9.9%	11.6%	8.4%	0.177
90-day Reoperations	3.5%	2.9%	1.7%	0.334
Disposition				
Home	85.0%	90.5%	79.7%	***<0.001***
Subacute Rehab	14.2%	8.8%	19.4%	
Death	0.8%	0.7%	0.9%	
Length of Stay, days (mean)	5.4±7.1	4.0±5.1	6.8±8.4	***<0.001***

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Table B. Multivariate Analysis: Independent Risk Factors for Selected Outcomes				
Inpatient Surgical Complications	**Odds Ratio**	**95% Confidence Interval**		**P-value**
Anterior vs. Posterior Approach	5.9	3.1	11.3	***<0.001***
Charlson Comorbidity Index	1.3	1.1	1.6	***0.002***
Fusion > 3 Levels	1.1	0.7	1.9	0.697
Corpectomy	0.6	0.3	1.1	0.09
Extended LOS (>4 days)	**Odds Ratio**	**95% Confidence Interval**		**P-value**
Posterior vs. Anterior Approach	3.4	1.7	6.9	***<0.001***
Charlson Comorbidity Index	1.3	1.1	1.6	***<0.001***
Fusion > 3 Levels	2.1	1.3	3.3	***0.003***
Corpectomy	3.0	1.5	6.1	***0.003***
Inpatient Surgical Complication	3.5	2.1	6.0	***<0.001***
Inpatient Medical Complication	35.4	7.0	180	***<0.001***
Discharge to Subacute Rehab	8.2	4.4	15.2	***<0.001***
Metropolitan - Non-Teaching vs. Metropolitan - Teaching	0.5	0.2	0.96	0.335
Non-metropolitan vs. Metropolitan Teaching.	0.6	0.14	2.5	0.829

Table C. Reasons for Readmissions and Reoperations within 90 days of Index Hospital Stay										
	All				**2 to 3 Levels Fused**			**> 3 Levels Fused**		
	All	**Anterior**	**Posterior**		**Anterior**	**Posterior**		**Anterior**	**Posterior**	
N	627	307	320	**P-value**	174	81	**P-value**	133	239	**P-value**
Readmission	9.9%	11.6%	8.4%	0.177	12.5%	6.6%	0.156	10.4%	9.0%	0.650
Medical	5.9%	8.1%	4.0%	***0.031***	8.2%	2.4%	0.080	8.0%	4.5%	0.170
Chest Pain	0.3%	0.6%	0.0%	0.162	1.1%	0.0%	0.349	0.0%	0.0%	
Pulmonary Embolism/Deep Venous Thrombosis	0.6%	0.6%	0.6%	0.904	1.0%	0.0%	0.373	0.0%	0.8%	0.289
Urinary Tract Infection	0.3%	0.6%	0.0%	0.180	0.0%	0.0%		1.3%	0.0%	0.078
Genitourinary-related	0.6%	0.9%	0.4%	0.462	1.6%	0.0%	0.253	0.0%	0.6%	0.380
Drug Allergy	1.0%	1.9%	0.0%	***0.014***	3.3%	0.0%	0.099	0.0%	0.0%	
Septicemia	0.8%	0.5%	1.2%	0.289	0.0%	2.4%	***0.041***	1.1%	0.8%	0.843
Anemia	0.3%	0.0%	0.6%	0.188	0.0%	0.0%		0.0%	0.8%	0.316
Fever	0.3%	0.5%	0.0%	0.193	0.0%	0.0%		1.2%	0.0%	0.087
Respiratory requiring Mechanical Ventilation	0.6%	1.4%	0.0%	***0.031***	1.2%	0.0%	0.326	1.8%	0.0%	***0.038***
Constipation	0.5%	1.1%	0.0%	0.056	0.0%	0.0%		2.6%	0.0%	***0.012***
Gastritis	0.2%	0.0%	0.4%	0.273	0.0%	0.0%		0.0%	0.5%	0.403
Atrial Fibrillation	0.3%	0.0%	0.7%	0.135	0.0%	0.0%		0.0%	1.0%	0.254
Surgical	4.3%	4.2%	4.4%	0.908	5.6%	4.3%	0.656	2.4%	4.5%	0.326
Dysphonia	0.3%	0.7%	0.0%	0.150	1.1%	0.0%	0.336	0.0%	0.0%	
Dysphagia	0.5%	0.0%	1.1%	0.070	0.0%	2.0%	0.063	0.0%	0.8%	0.315
Implant-related	0.3%	0.6%	0.0%	0.158	0.0%	0.0%		1.4%	0.0%	0.064
Cervical Myelopathy/Stenosis	1.1%	2.4%	0.0%	***0.005***	3.5%	0.0%	0.088	1.0%	0.0%	0.119
Other Neurological Complication	0.5%	0.5%	0.6%	0.922	0.9%	2.3%	0.380	0.0%	0.0%	
Post-operative Pain	0.5%	0.0%	1.0%	0.075	0.0%	0.0%		0.0%	1.4%	0.173
Wound Disruption	1.0%	0.0%	1.7%	***0.020***	0.0%	0.0%		0.0%	2.3%	0.076
Reoperation	2.4%	2.9%	1.7%	0.334	3.3%	0.0%	0.102	2.4%	2.3%	0.944
Revision Fusion	1.4%	2.9%	0.0%	***0.002***	3.3%	0.0%	0.102	2.4%	0.0%	***0.015***
Wound Debridement	1.0%	0.0%	1.7%	***0.020***	0.0%	0.0%		0.0%	2.3%	0.076

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #92

The potential effects of concomitant traumatic brain injury (TBI) on the survival, and neurological and functional recovery after traumatic spinal cord injury (SCI): An analysis of a cohort of 499 cases.

Julio Furlan, MD, MBA, PhD, MSc, FRCPC

Introduction: The frequency of concomitant TBI in patients with SCI was estimated to be 32.5% (95%CI: 10.8–59.3%) in a recently published meta-analysis (Pandrich et al, 2020). While individuals with a dual diagnosis may require longer hospitalization with increased healthcare costs, the effects of concomitant TBI on the survival and recovery after SCI remain under-studied. This study examined the potential effects of concomitant TBI on the survival and neurological recovery within the first year following traumatic SCI.

Materials and Methods: This retrospective cohort study includes all patients who were enrolled into the Third National Spinal Cord Injury Study (NASCIS-3). TBI was defined as a Glasgow coma score (GCS) below 15 at admission in an acute care facility. The group of individuals with dual diagnosis (SCI+TBI) was compared with the group of individuals with SCI alone regarding survival, and neurological and functional outcomes within the first year following SCI. Survival was analyzed using Kaplan-Meier curve and log-rank test. Neurological recovery included the NASCIS motor, sensory and pain scores. Functional outcome was determined using Functional Independence Measure (FIM). Data were also analyzed using multiple regression models adjusted for the major potential confounders (i.e. baseline neurological status, age at SCI onset, sex, NASCIS-3 protocol, blood alcohol level at admission, and level and severity of SCI).

Results: There were 76 females and 423 males with mean age of 35.7 years (range from 14 to 92 years) who mostly sustained cervical SCI due to motor vehicle accident followed by falls. Of the 499 cases, there were 413 individuals in the SCI-only group and 86 individuals in the dual-diagnosis group (17.2%; GCS from 10 to 14). Both groups were comparable regarding age (p=0.7101) and sex distribution (p=0.6207). However, the dual-diagnosis group had higher proportion of complete (p=0.0059) and cervical SCI (p=0.0031) than SCI-only group. There was a trend towards a greater frequency of motor vehicle accidents in the dual-diagnosis group (p=0.0597). Likewise, the dual-diagnosis group had a greater proportion of individuals who received 48-hour methylprednisolone regimen than the SCI-only group (p=0.0384).

Survival analysis revealed the dual-diagnosis group did not significantly differ from the SCI-only group regarding survival within the first year after SCI (Fig. 1).

Among the survivors, the dual-diagnosis group showed significantly lower neurological scores on admission and at 1 year post-SCI, and lower FIM scores at 1 year post-SCI than individuals in the SCI-only group (Fig. 2). Using multiple regression analyses, all neurological outcomes (including motor, sensory and pain scores) and functional outcome (as assessed using total FIM score) at 1 year after SCI were not significantly associated with the concomitant TBI after adjusting for the major potential confounders.

Conclusion: The results of this study suggest that individuals in the dual-diagnosis group had more severe and cervical SCI that resulted in less favorable neurological and functional outcomes

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than in the SCI-only group. However, the coexistence of TBI and SCI did not appear to intrinsically affect the neurological and functional recovery within the first year after trauma. Furthermore, concomitant TBI did not significantly affect survival within the first year after SCI.

Fig. 1. Survival analysis using Kaplan-Meier curve with log-rank test (p=0.7676)

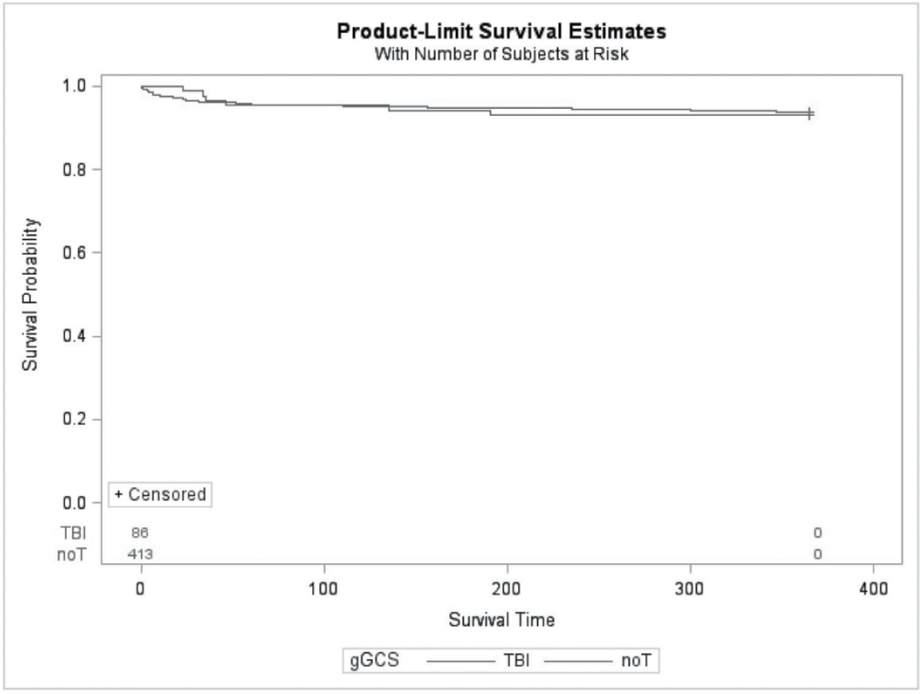
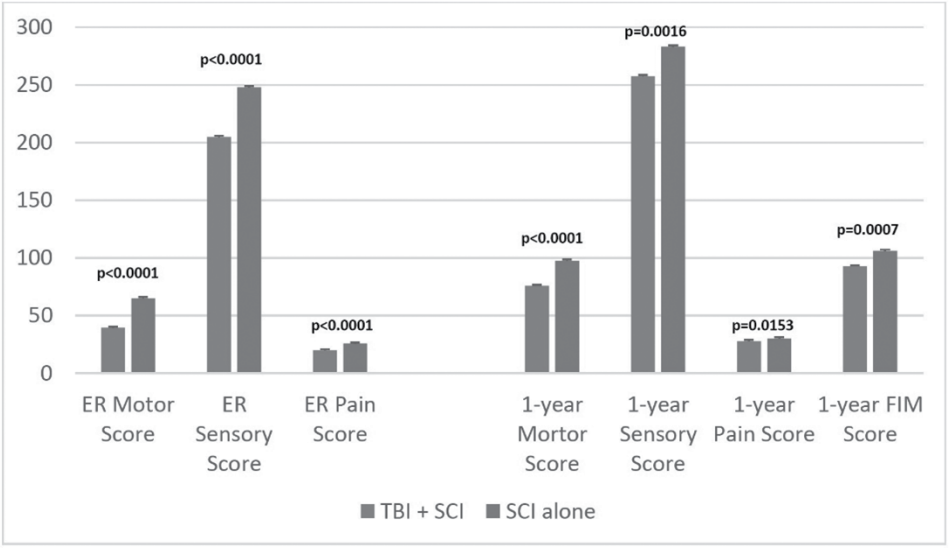


Fig. 2. Neurological and functional assessments on admission (ER: emergency room) and at 1 year after spinal cord injury comparing dual-diagnosis group (TBI+SCI) with SCI-only group.



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Presentation #93

Clinical outcomes and fate of retro-odontoid mass after upper cervical spine surgery

Kyung-Soo Suk, MD, PhD, ***Jae-Won Shin, MD, PhD,*** *JAE-HO YANG, MD, Hak-Sun Kim, MD, PhD, Sub-Ri Park, MD, Sun-Kyu Kim, MD, Jane Garcia, MD, Sang-Jun Park, MD, Hwan-Mo Lee, MD, PhD, Byung Ho Lee, MD, PhD, Seong-Hwan Moon, MD, PhD, Jin-O Park, MD, PhD*

Introduction: Upper cervical spine surgery is relatively less common than lower cervical spine surgery. There have been few case reports concerning the fate of retro-odontoid mass (R-OM) after surgical treatment. Purpose of this study was to see the outcomes of upper cervical spine surgery and the fate of R-OM.

Materials and Methods: Fifty-eight patients who underwent upper cervical spine surgery and had available postoperative MRI were included in this study. Upper cervical spine surgery included atlanto-axial fusion (C1-2 fusion, 40 patients), Occipito-cervical fusion (OC fusion, 16 patients) or decompression only (2 patients) Diagnosis were os odontoideum (7 patients), nonunion of odontoid process fx or neglected transverse atlantal ligament injury (9 patients), occipito-atlantal assimilation (17 patients), rheumatoid arthritis (10 patients), and degenerative arthritis (15 patients). Postoperative MRI was taken in all patients. Six month follow up MRI was taken in 25 patients (43.1%) who had R-OM. In radiologic outcomes, anterior atlanto-dental interval (AADI) and posterior atlanto-dental interval (PADI) were measured on x-ray and CT scan. R-OM and space available for the cord (SAC) were measured on MRI. Clinical outcome were checked neck pain visual analogue scale (VAS) and arm pain VAS, JOA score, neck disability index (NDI). Preoperative and postoperative outcomes were compared and analyzed with paired sample t-test. R-OM were evaluated on 6 month follow up MRI and compared them to those on preoperative MRI. Statistical analysis was performed using paired sample t-test and independent sample t-test. Three spine fellows performed measurements twice. In addition, intra- and inter-observer reliability was evaluated.

Results: In radiologic outcome, AADI was decreased significantly after the surgery. PADI and SAC were increased significantly after the surgery. R-OM was completely disappeared in 9 patients, decreased in size in 15 patients, and increased in size in a patient who underwent decompression surgery without fusion (Fig.1). In clinical outcome, neck pain, arm pain, NDI were decreased significantly after the surgery. JOA score were increased significantly.

Conclusion: Clinical and radiological outcomes were improved after the surgery in all parameters. Retro-odontoid mass were decreased in size or disappeared in all cases after the fusion surgery. However, retro-odontoid mass was increased in size in a patient with the decompression surgery.

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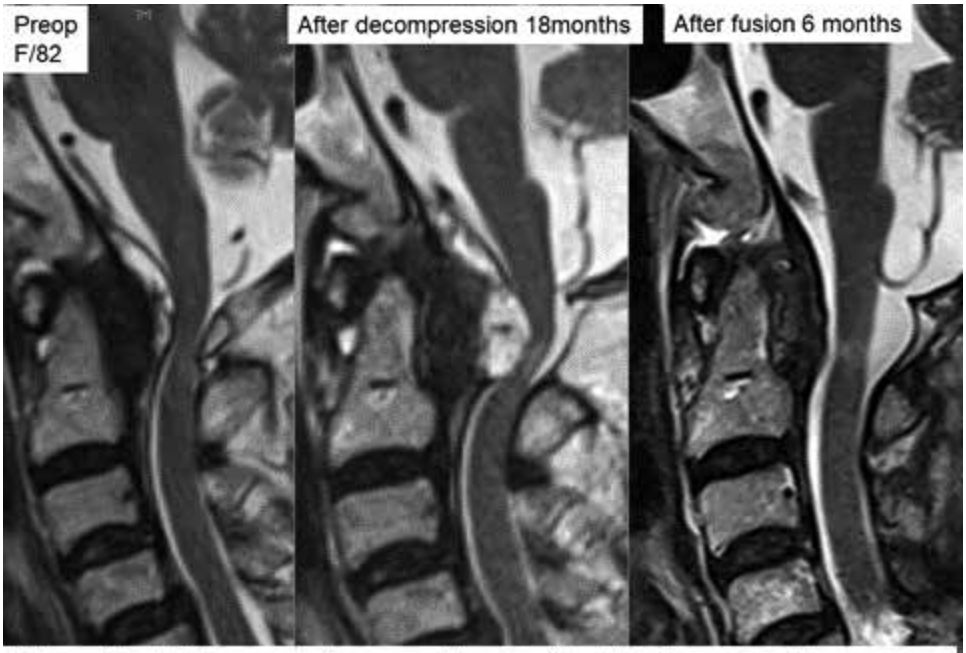

Retro-odontoid mass was increased in size after the decompression surgery. After the fusion surgery, retro-odontoid mass was decreased in size

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Presentation #94

The Huashan diagnostic criteria and clinical classification of juvenile cervical flexion myelopathy(Hirayama disease)

Hongli Wang, MD, Chaojun Zheng, MD, Xiaosheng Ma, MD, ***Feizhou Lyu, MD,*** *Xinlei Xia, MD, Xiang Jin, MD, Jianyuan Jiang, MD*

Introduction: Cases of Hirayama disease (HD) were increasingly reported globally, but there is no well-agreed diagnostic standards and treatment recommendation for those patients. We intend to establish Huashan diagnostic criteria and clinical classification system for HD.

Materials and Methods: Retrospective analysis 359 cases of puberty onset, upper extremity muscle atrophy as main clinical manifestations, and complete clinical data from September 2007 to August 2018. There were 348 males and 11 females in this group. The average age of onset was 16.7±2.2y, and the average duration of treatment was 29.3±45.4m. Descriptive study of the clinical manifestations, radiologic and neurophysiological findings of this group of patients was conducted, and the Huashan clinical diagnostic criteria of HD were established by including 100% of the clinical manifestations, imaging and neurophysiological findings. According to the following parameters, the clinical classification system of HD was proposed: muscle atrophy involves the upper limbs; with or without active tendon reflex; with or without positive Babinski sign or other pyramidal tract damage signs; with or without sensory dysfunction ; muscle atrophy location; progress of clinical symptoms or electrophysiological examination within 6 months. Thirty patients were randomly selected from the above 359 cases. Four orthopedic surgeons completed the clinical classification within the specified time. The Kappa value was used for the credibility evaluation.

Results: The Huashan diagnostic criteria of HD included clinical manifestations, imaging examinations and neurophysiological examinations. The main diagnostic indicators were: 1) occult on? set puberty, more common in men; 2) localized muscle atrophy and weakness in the upper extremities; 3) MRI of cervical flexion showed that spinal cord was significantly shift forward and the anterior spinal cord was narrowed or disappeared. 4) Obvious cyst?wall separation sign behind the spinal cord; 5) Neurophysiological examination showed that the affected muscles were neurogenic damage. 6) The affected parts are limited to the middle and lower neck segment. At the same time, cervical spondylosis with upper limb muscle atrophy and motor neuron disease were carefully excluded. HD was divided into 3 types. Type I: 72.1%, one?sided upper limb or one upper limb?based hand inner muscle and forearm muscle atrophy. According to whether progress of symptoms or electrophysiological examination was seen in the past 6 months, type I can be divided into: Ia. stable period; Ib. progression period;Type II: 14.2%, unilateral upper limb or one upper limb?based hand inner muscle and forearm muscle atrophy with pyramidal tract injury. Type III: 13.7%, atypical HD, including upper limb proximal muscle atrophy, symmetrical double upper limb muscle atrophy, and sensory disturbances associated with upper limb numbness. Different treatments were recommended for each HD type. The credibility evaluation showed that the average Kappa value of the classification was 0.732 (0.688- 0.834), which is a basic credibility.

Conclusion: The Huashan diagnostic criteria of HD was conducive to the early diagnosis. The clinical classification system of HD has good credibility and good clinical intervention guidance value.

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Presentation #95

Cervical Reconstruction for Treatment of Cervical Spinal Deformity patients invokes changes in Sagittal Spinopelvic Parameters

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Introduction: Complex global interactions occur between cervical, thoracic, lumbar and lumbopelvic spinal segments in the sagittal plane. Due to cervical kyphosis, the rest of the spine compensates to achieve horizontal gaze and sagittal balance. After the cervical kyphosis is corrected, the spine similarly equilibrates in the sagittal plane. The sagittal change of thoracic and lumbar segments influences post-op functional outcomes of patients. This study aims to investigate the interactions of cervical and spinopelvic sagittal parameters after cervical deformity correction.

Materials and Methods: A retrospective study of filtered cervical deformity patients from 13 spine units in the United States was performed. Adult patients with cervical deformity (ACD) undergoing reconstruction surgery were included with criteria of cervical kyphosis more than 10°, C2-C7 sagittal vertical axis (SVA) of more than 4 cm, or chin-brow vertical angle of more than 25°. The pre-op and post-op sagittal parameters were compared. The changes were compared within the groups which were classified via values of T1S-CL, SVA C2-C7 or SVA C7-S1. The correlation between delta values and pre-op parameters, and correlation between each delta value was investigated.

Results: For cervical parameters, Cobb C2-C7, Cobb C2-T3, Cobb C0-C2, SVA C2-S1 and T1S-CL were significantly improved after surgery, but SVA C2-C7 was not improved. For spinopelvic parameters, kyphosis of T10-L2 and T4-T12, values of GT (global tilt), T1S and SVA C7-S1 all increased significantly, and values of LL decreased significantly post-op. Values of SS, PT and PI did not change significantly post-op (Table 1). Changes in spinopelvic values for PT, GT, LL, Cobb T10-L2, and CobbT4-12 were not significantly different, but changes in cervical values for Cobb C2-C7, Cobb C2-T3, and Cobb C0-C2 were significantly different in the groups classified by pre-op T1S-CL and SVA C2-C7 values. In groups classified by pre-op SVA C7-S1 values, changes in spinopelvic values for GT, LL, Cobb T10-L2, and SVA C7-S1 were significantly different, but change in cervical values for Cobb C2-C7, Cobb C2-T3, and Cobb C0-C2 were not significantly different (Table 2). Post-op increases of GT had moderate correlation (R=-0.411) with pre-op SVA C7-S1, and moderate-high correlation with (R=0.613) increase of SVA C7-S1 post-op (Table 3). The post-op kyphotic change of LL and T10-L2 had moderate correlation (R=0.458, 0.432) with increase of SVA C7-S1 post-op (Table 3). Delta values of GT, LL, Cobb T10-L2, and Cobb T4-T12 demonstrated no significant correlation or weak correlation with values of pre-op Cobb C2-C7, T1S-CL, SVA C2-C7 or delta Cobb C2-C7, T1S-CL, SVA C2-C7. Delta PT had no significant correlation with any pre-op/delta values of cervical and spinopelvic parameters (Table 3).

Conclusion: Cervical reconstruction increased the kyphosis in the thoracic, thoracolumbar

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junction and decreased the lordosis in lumbar spine. The amount of kyphotic change neither correlated with severity of pre-op cervical kyphosis and sagittal malalignment, nor with the amount of intra-op cervical kyphosis correction. Pre-op SVA C7-S1 was a suitable predictor of total kyphotic change of lumbar and thoracic spine after surgery.

Table 1 : The comparisons between pre-op and post-op parameters(N=144)

Parameters	Pre-op:mean±SD(min-max)	Post-op:mean±SD(min-max)	t/z	P
PI (°)	54.03±11.35(19.72 – 79.52)	54.06±11.55(19.66 – 80.15)	-0.13	0.898
PT(°)	19.84±11.10(-18.03 – 53.32)	20.43±11.60(-15.57 – 61.67)	-1.15	0.250
SS(°)	34.02±9.90(4.66 – 57.55)	33.57±11.10(3.20 – 56.98)	0.82	0.413
GT(°)	18.49±15.19(-34.37 – 67.32)	21.93±15.97(-25.97 – 78.93)	-5.12	**0.000**
LL(°)	52.15±17.02(3.60 – 99.40)	50.12±17.45(-1.10 – 95.20)	2.86	**0.005**
Cobb T10-L2(°)	-7.35±13.59(-54.00 – 27.90)	-10.73±15.15(-54.80 – 19.20)	4.21	**0.000#**
Cobb T4-T12(°)	-39.44±15.35 (-80.70 – -0.30)	-42.20±16.20(-89.00 – 1.60)	3.13	**0.002**
Cobb C2-7(°)	-5.78±20.94(-76.00 – 70.70)	7.37±16.01(-34.30 – 69.00)	-6.36	**0.000#**
Cobb C2-T3(°)	-17.68±23.43(-94.40 – 43.80)	0.12±15.91(-46.00 – 47.00)	-7.55	**0.000**
Cobb C0-C2(°)	32.66±11.85(7.30 – 66.29)	27.09±10.94(0.47 – 52.60)	5.36	**0.000**
T1S(°)	33.30±18.32(-2.46 – 89.34)	36.86±15.07(-6.97 – 112.32)	-3.09	**0.002#**
T1S-CL(°)	38.90±19.88(-2.36 – 109.95)	27.72±14.19(-2.19 – 81.34)	-6.15	**0.000#**
SVA C2-C7(mm)	39.42±19.85(-5.08 – 78.57)	39.09±18.06(-6.32 – 78.19)	0.790	0.431
SVA C7-S1(mm)	3.98±70.58(-170.54 – 244.83)	26.62±70.86 (-137.91 – 265.99)	-5.19	**0.000**
SVA C2-S1(mm)	41.95±75.27(-126.06 – 297.06)	60.58±74.80(-98.54 – 295.27)	-2.56	**0.012**
SVA C2-T3(mm)	79.07±40.10(-17.59 – 153.05)	75.56±28.98(-15.86 – 147.06)	2.60	**0.011**

Wilcoxon's Sign Rank test, the others were paired T-test

Table 2. Comparisons of three groups classified by pre-op SVA C7-S1 (value≤0 group -1, 0<value≤4cm group 0, value >4cm group 1),

Parameters	group -1(n=73) mean±SD	group 0(n=34) mean±SD	group 1(n=37) mean±SD	f/z	P
delta PI(°)	0.13±2.11	-0.54±2.14	0.09±2.02	1.236	0.294
delta PT(°)	-0.73±6.02	-0.92±7.88	-0.15±4.32	0.156	0.856
delta SS(°)	0.87±6.62	0.38±7.44	-0.22±5.55	0.338	0.714
delta GT(°)	-4.77±7.45	-4.54±8.93	0.55±4.49	19.265	**0.000#**
delta LL(°)	2.95±7.77	4.47±10.89	-1.72±6.52	5.611	**0.005**
delta Cobb T10-L2 (°)	5.13±9.93	2.73±8.41	-0.31±5.51	11.898	**0.003#**
delta CobbT4-T12(°)	4.17±9.89	1.45±14.32	-0.51±9.31	2.388	0.096
delta Cobb C2-C7(°)	-16.01±26.08	-12.77±19.23	-7.78±19.01	2.075	0.354#
delta Cobb C2-T3 (°)	-20.44±26.89	-22.36±24.84	-10.73±25.99	4.133	0.127#
delta Cobb C0-C2(°)	5.28±9.96	11.20±14.50	3.15±11.34	3.017	0.053
delta T1S(°)	-3.88±11.97	-1.37±18.64	-2.97±14.62	1.101	0.577#
delta T1S-CL(°)	14.21±22.19	12.76±15.42	6.20±17.04	1.952	0.146
delta SVA C2-C7(mm)	8.08±17.00	9.18±17.87	7.51±19.43	0.067	0.935
delta SVA C7-S1(mm)	-33.48±46.01	-33.18±54.84	7.36±43.07	9.741	**0.000**
delta SVA C2-S1(mm)	-26.25±44.20	-16.77±53.41	16.28±54.65	7.791	**0.001**
delta SVA C2-T3(mm)	4.18±24.04	10.80±31.19	7.15±29.65	0.559	0.573

#Kruskal-Wallis H test, the others were ANOVA.

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Table 3. Correlation coefficients between delta values of spinopelvic parameters and values of pre-op or delta sagittal parameters

parameters		Pre-op SVA C7-S1	Pre-op SVA C2-C7	Pre-op T1S-CL	Pre-op Cobb C2-C7	delta SVA C7-S1	delta SVA C2-C7	delta T1S-CL	delta Cobb C2-C7
delta PT	R	0.078	0.103	0.132	-0.046	-0.166	0.058	0.133	-0.099
	P	0.357	0.227	0.121	0.593	0.054	0.525	0.135	0.274
delta SS	R	-0.111	-0.149	-0.139	0.055	0.187	-0.085	-0.144	0.122
	P	0.188	0.078	0.101	0.518	0.029	0.348	0.105	0.177
delta GT	R	**0.411#**	-0.117#	-0.125#	0.208#	**0.613#**	-0.031#	-0.226#	0.368#
	P	0.000	0.185	0.153	0.018	0.000	0.736	0.012	0.000
delta LL	R	-0.260	0.135	0.155	-0.100	**-0.458**	0.133	0.205	-0.191
	P	0.002	0.111	0.067	0.240	0.000	0.140	0.020	0.033
delta Cobb T10-L2	R	-0.300#	0.164#	0.192#	-0.168#	**-0.432#**	-0.005#	0.133#	-0.205#
	P	0.000	0.053	0.023	0.047	0.000	0.954	0.134	0.022
delta CobbT4-12	R	-0.226	0.048	0.232	-0.349	-0.307	-0.208	0.024	-0.342
	P	0.007	0.575	0.006	0.000	0.000	0.020	0.788	0.000
delta T1S	R	0.097#	0.312#	0.121#	**0.413#**	0.297#	0.359#	0.034#	**0.547**#
	P	0.259	0.000	0.154	0.000	0.000	0.000	0.707	0.000
delta SVA C7-S1	R	0.329	-0.291	-0.380	0.349	-	-0.046	-0.363	**0.542**
	P	0.000	0.001	0.000	0.000	-	0.609	0.000	0.000

Spearman correlation coefficient, the others were Pearson correlation coefficient

Presentation #96

High vs Low T1 Slope: Does it Affect Radiological and Functional Outcomes After Multilevel Posterior Fusion in Degenerative Cervical Spine.

Nida Fatima, MD, *Elie Massaad, MD, Muhamed Hadzipasic, MD, Ganesh Shankar, MD, John Shin, MD*

Introduction: Cervical myelopathy and sagittal imbalance are sequela of degenerative cervical spine disorders (DCSD) and requires expeditious treatment to prevent permanent deficits. This study sought to determine the association of preoperative T1 slope with the functional and radiographic outcomes related to cervical sagittal balance (CSB) in patients with DCSD after posterior fusion surgery.

Materials and Methods: Consecutive patients who underwent posterior fusion surgery for DCSD at an academic tertiary care hospital from 2009 to 2019 were identified through retrospective chart review. Neurological outcomes-modified Japanese Orthopedic Association score (mJOA) and Nurick Grading, and radiographic parameters- T1 slope, C2-7 Sagittal Vertical Axis (SVA) mm, and C2-7 Lordosis- were assessed before and after surgery for DCSD. With a high and low pre-operative T1 Slope based on the median cutoff of 32, clinical and radiographic factors were compared between the initial and final visit using t-test and Pearson correlations.

Results: The study cohort included 199 patients (50.8% females, mean age: 65.5±12.5 years) with a median clinical follow-up of 361 days (1 month-10 years). Overall, C2-7 SVA increased from 38.1 to 41.1 mm ($p<0.0001$) and C2-7 lordosis decreased from 17.1° to 15.3° ($p<0.0001$) respectively. Preoperative C2-7 lordosis and C2-7 SVA were greater in patients with high T1 slope (19.3° and 39.0 mm) than in the low T1 slope (15.7° and 30.3 mm) ($p=0.02$ and $p=0.005$ respectively). The degree of compensation in terms of C2-7 SVA (mm) changed significantly in the patients with high T1-slope compared to the low T1 slope (4.6mm vs -2.9mm, $p=0.03$). However, there was no comparative difference in terms of changes (Ch) in the C2-7 lordosis between the groups ($p=0.97$). Although there was an overall improvement in neurological outcome among the patients ($p<0.001$) in our study, there did not exist significant difference in the degree of improvement between the two groups (Ch_mJOA: 1.8 vs 1.9, $p=0.68$).

Conclusion: Our results corroborate that the preoperative T1 slope correlates with the degree of postoperative C2-7 SVA. However, preoperative T1 slope does not affect the clinical outcome and C2-7 lordosis after posterior fusion surgery in DCSD.

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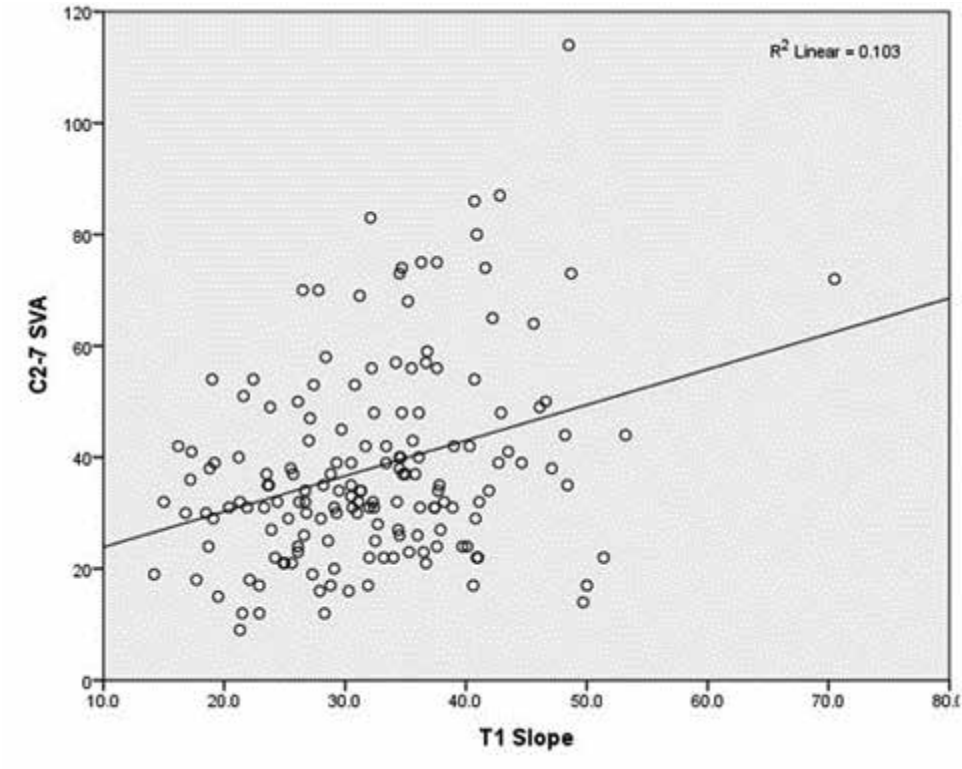

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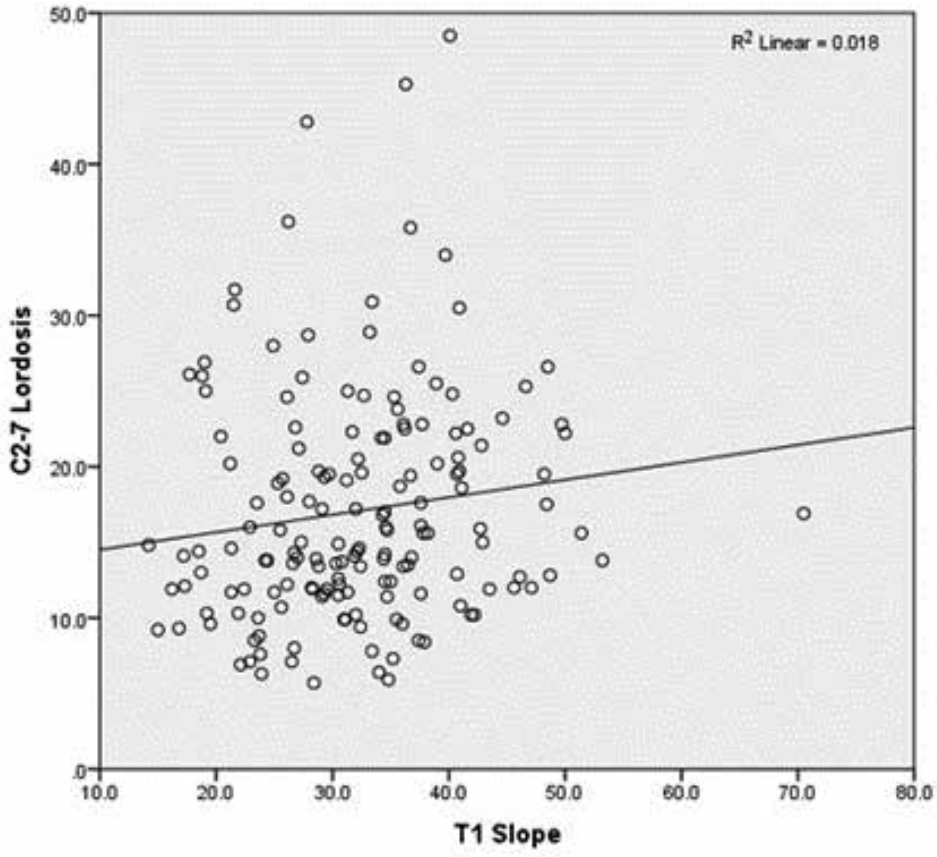

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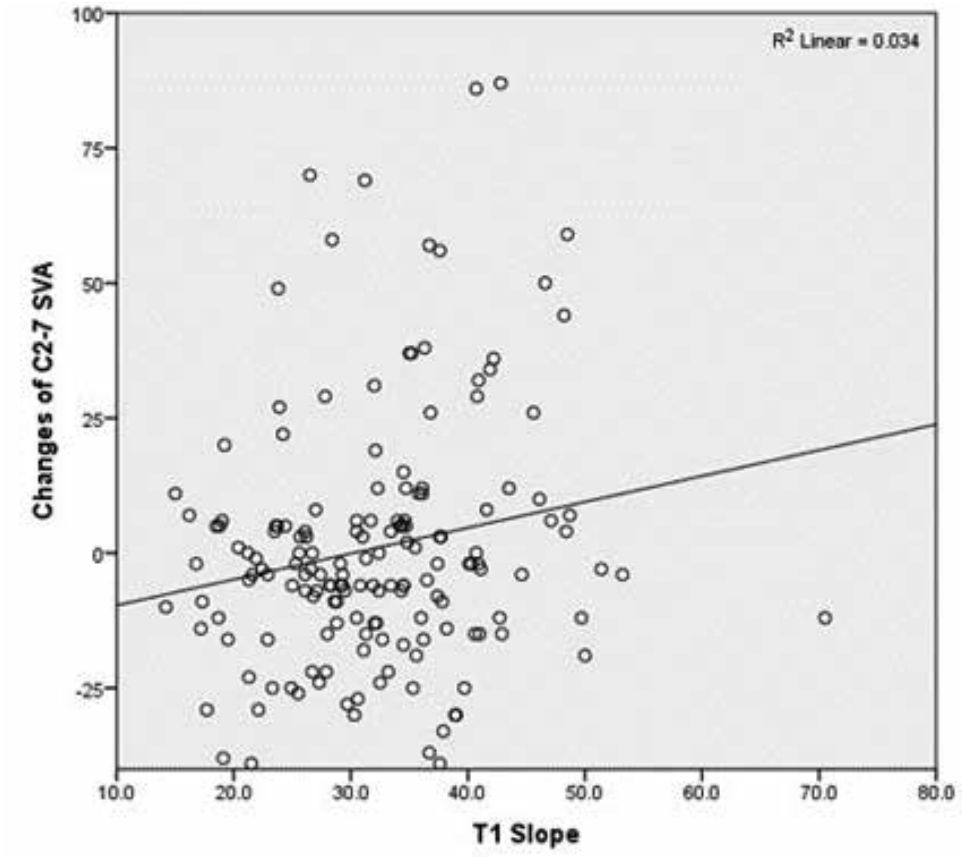

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Presentation #97

Predictors of Acute Distal Junctional Failure Following Posterior Fusion Surgery in Cervical Myelopathy.

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Introduction: Distal junctional failure (DJF) is a significant complication following corrective cervical deformity surgery with a potential of neurological injury and increased need of revision surgery. To elucidate the predictors of DJF in patients with degenerative cervical spine disease (DCSD) after posterior fusion surgery. The predictors for acute DJF in DCSD are not well defined.

Materials and Methods: A retrospective chart review of a single-institutional cervical deformity database was conducted. Acute DJF was defined as either---postoperative evidence of distal kyphosis (>-10° increase in C2-7 lordosis), >10° change in C7-T1 disc angle, >10 mm worsening of SVA, instrumentation failure, revision surgery, and medical and surgical complications within 6-months of posterior fusion surgery. For the outcome, univariable association with pre-operative characteristics were first determined using logistic regression, and a predictive model was then constructed using all characteristics significant at the 0.45 alpha level. All associations were reported as odds ratio (OR) with 95% Confidence Interval (CI).

Results: Statistical analysis included 43 patients (mean age: 61.6±12.8 years) undergoing long cervical deformity correction (median levels: 5, 66.6% C3-C7 fusion). Within 6-months of surgery, 48.8% of the patients met the clinical and radiographic definition of DJK. No significant relationship was found between the demographics, surgical and radiographic parameters except preoperative neurological status (p=0.04) and C2-C7 lordotic angle (p=0.009) between patients with DJF and no DJF. Multivariable Regression Analysis revealed that pre-operative C2-C7 lordotic angle (<14°/≥14°) was significantly associated with predicting acute DJF by 10.8-folds (OR: 10.8, 95%CI: 1.48-79.2, p=0.01). Furthermore, pre-operative modified Japanese Orthopedic Association Score (mJOA) of 0-11 had 1.3-folds higher likelihood to be associated with acute DJF (OR: 11.3, 95%CI: 0.85-152.4, p=0.06). The gender (OR: 0.56, 95% CI: 0.07-4.41, p=0.57) and the fixation range (>4/≤4) (OR: 1.04, 95% CI: 0.08-13.1, p=0.97) were not statistically significantly associated with acute DJF.

Conclusion: Preoperative C2-C7 lordotic angle <14° and mJOA score of 0-11 were identified as independent predictors of acute DJF. Thus, a surgical strategy to minimize acute DJF may include a preoperative planning for reconstruction with a goal to optimal postoperative alignment.

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Presentation #98

Rate of Revision Surgery following Multilevel Posterior Cervical Fusion at the Cervicothoracic Junction

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Introduction: The optimal caudal extent of posterior cervical fusion in relation to the cervicothoracic junction is controversial. Some studies suggest traversing the cervicothoracic junction for posterior fusion constructs in order to avoid an increased rate of revision and others suggest stopping constructs short of the junction is reasonable in many patients. The purpose of our study was to compare the reoperation rate in patients who underwent posterior cervical laminectomy and fusion where the caudal extent of the fusion terminated cranial verses caudal to the junction. A secondary goal of the study was to compare radiographic parameters between the two groups.

Materials and Methods: All patients who underwent multilevel posterior cervical fusion at a single institution between 9/1/2013 and 1/21/2016 were reviewed. Exclusion criteria included surgery for trauma, tumor, infection, or history of previous cervical surgeries, or lack of follow up. Preoperative, postoperative, and C2-7 SVA and lordosis were calculated at 1 year follow up.

Results: 78 patients met the inclusion criteria. 16 were excluded from the final cohort for failure of radiographic follow up. 5 patients were deceased within 6 months of their primary procedure. This left 62 subjects who had posterior constructs terminating at C7 and 16 that had constructs terminating at T1-4. There were no significant differences in the demographics of the two cohorts except a significantly higher Charlson co-morbidity index in the C7 group in comparison to T1-4 (P value .012). Average length of follow up in the C7 cohort was 53 months verses 44 months for our T1-4 cohort. In our cohort, there were 13 revisions in 12 patients in the C7 group vs. 2 revisions in the T1-4 group. Only 2 patients in the C7 group had revision for adjacent segment disease or instrumentation issues, with most of the revisions occurring for wound complications (11 revisions). No patients in the T1-4 group had revision for adjacent segment disease. There was no difference in time to revision between the groups. Radiographic parameters did not differ between the two groups with exception of pre-operative SVA. The C7 group had a statistically significant lower preoperative C2-7 SVA than the T1-4 group.

Conclusion: There was no difference in this study in revision rates, time to revision, or postoperative sagittal plane alignment between posterior cervical fusion stopping at C7 compared to constructs traversing the cervicothoracic junction. This study, along with other recent studies, suggests that uniform inclusion of the thoracic spine in posterior cervical fusion is not indicated. However, including the upper thoracic spine appears to be a reasonable option if there are concerns about bone quality or fixation, tobacco use, or sagittal alignment.

Individual Disclosures can be found in the Disclosure Index pages 32-42.

Presentation #99

When Can we Expect Global Sagittal Alignment to Reach a Stable Value Following Cervical Deformity Surgery?

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Introduction: Cervical deformity (CD) is a complex condition with a clear impact on patient quality of life, which can be improved with surgical treatment. A previous study following thoracolumbar surgery demonstrated a spontaneous and maintained improvement in cervical alignment following lumbar PSO1. This study aims to investigate the complementary aspect: does change in cervical alignment induce a change in global alignment and does this change stabilize over time?

Materials and Methods: This study is a retrospective review of a prospective multicenter database of CD patients with a minimum of 1 year (1Y) follow-up. In order to analyze spontaneous changes in unfused segments, only patients with at least 5 levels unfused post-op were retained for analysis. After describing the entire cohort, repeated measures analysis were conducted between preop, 3 month (3M) and 1Y follow-up with a post-hoc analysis and Bonferroni correction for multiple comparisons. A sub-analysis of patients with a completed 2 year follow-up was performed.

Results: 121 pts out of 168 (72%) eligible had 1Y follow-up available, and 89 had at least 5 levels unfused post-op (mean age: 60.8yo±10.2 65.2%F). Pre-operative sagittal alignment demonstrated a moderate anterior cervical alignment (CL: -7.7° (kypo); TS-CL: 37.1°; cSVA: 37) combined with a posterior global alignment (SVA:-8mm) due to a lumbar hyperextension (PI-LL: -0.6°). Patients underwent a significant correction of the cervical alignment (median ΔCL: 13.6°) between pre and 1Y. Simultaneously, PI-LL (pre: -0.7°; 3M: 2.0° ; 1Y 1.4°), TPA (Pre: 11.8° ; 3M: 15.0° ; 1Y: 14.4°) and SVA (Pre:-8mm ; 3M: 14mm 1Y:13mm) increased significantly (all $p<0.05$) between pre, 3M and 1Y but not PT ($p=0.052$). Post-hoc analysis demonstrated significant differences in TL alignment between pre and 3M and pre and 1Y but no significant difference between 3M and 1Y. Stratification by amount of change in the cervical spine ($\Delta CL \leq 13.6°$ vs $\Delta CL > 13.6°$) or LIV position (T3 and above vs T4 and below) demonstrated that only large correction and/or long fusion were able to impact significantly the global alignment (TPA and SVA) at 3M while global alignment was maintained between 3M and 1Y. Sub analysis of patients with a complete 2Y follow-up demonstrated similar results with stable post-operative TL alignment reached at 3M.

Conclusion: Correction of the cervical malalignment can impact significantly the thoracolumbar regional and global alignment. As a group, the peak relaxation of compensatory mechanisms is achieved by 3-months and remains stable. Sub-analysis with 2 year data supports this finding. This result can help to identify when outcomes of the cervical surgery on global alignment can be evaluated.

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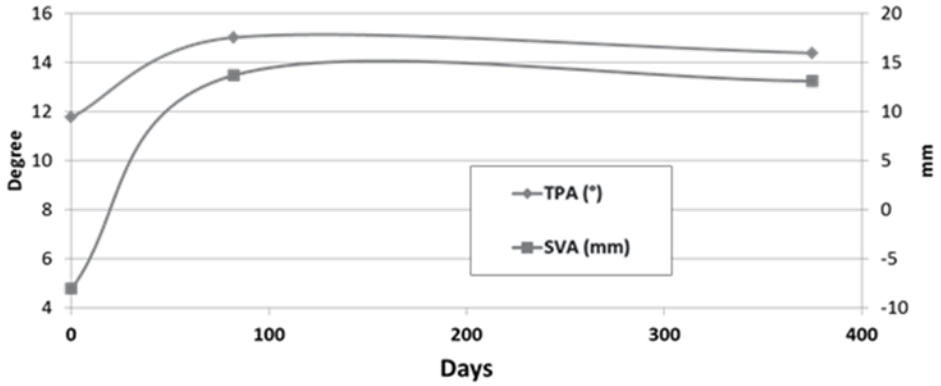

Fig. 1_Evolution of global alignment measured by TPA and SVA following cervical deformity surgery

Presentation #100

Risk Factors for Failure to Achieve MCID Following Cervical Disc Replacement

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Introduction: Patient reported outcome measures (PROMs) and minimal clinically importance difference (MCID) thresholds have emerged as effective, reliable parameters to assess improvement and surgical success.1 Previous studies have identified patients with Charlson Comorbidity Index (CCI) ≥2 to be associated with failure to achieve MCID in NDI following anterior cervical discectomy and fusion (ACDF)2; however, there is a paucity of literature on the risk factors associated with failure to achieve MCID following cervical disc replacement (CDR) specifically.

Materials and Methods: 107 patients who had undergone primary, one-or-two level CDR by three surgeons at a single academic institution were retrospectively analyzed, of which 83 (77.6%) had a minimum 3-month follow-up and 70 (65.4%) had a minimum 6-month follow-up. Rates of MCID achievement in neck disability index (NDI), VAS (visual analogue score) neck, and VAS-arm were calculated with the following threshold values, based on previously published studies: NDI: -15.0, VAS-neck: -2.5, and VAS-arm: -2.5.3-7 Risk factors for failure to achieve MCID were identified using multivariate logistic regression models with alternating backward stepwise elimination and forward entry of removed variables (entry: 0.05, removal: 0.10). Receiver operating characteristic (ROC) curves were generated to assess the performance of each of the final models.

Results: A total of 107 CDR met inclusion criteria (mean age: 42.99±9.13 years, mean BMI: 26.02±4.01 kg/m2), with the majority being male (61.7%) and white/Caucasian (84.1%). Overall, 99 patients presented for a follow-up visit within three months of their operation, of which 82 (89.1%) had achieved MCID in NDI, VAS-neck, or VAS-arm. Specific to the NDI, BMI≥25 kg/m2 (OR:153.75, p=0.002), depression (OR:50.32, p=0.016), myelopathy (OR:51.44, p=0.022), degenerative disc disease/spondylosis (OR:21.54, p=0.001), and two-level procedures (OR:6.59, p=0.027) were identified as significant risk factors for failure to achieve MCID within the first three months. Preoperative narcotic use (OR:0.11, p=0.027) was associated with a lower risk for failure to achieve MCID in NDI within the first three months. The area under the ROC curve (AUROC) assessing the logistic regression model's performance was 0.873 (p<0.001), suggesting strong predictive ability (Table 1; Figure 1a). No significant risk factors were identified for failure to achieve MCID in VAS-neck and VAS-arm scores in the early postoperative period.Overall, 103 patients had valid MCID calculations, of which 93 (90.3%) had achieved MCID in NDI, VAS-neck, or VAS-arm at any time point (2 weeks, 6 weeks, 3 months, 6 months, or 1 year) following CDR. Depression (OR:18.21, p=0.022), myelopathy (OR:18.81, p=0.037), and two-level procedures were associated with failure to achieve MCID in NDI by the 1-year time point. The AUROC assessing model performance was 0.840 (p<0.001), demonstrating strong predictive ability (Table 2; Figure 1b).

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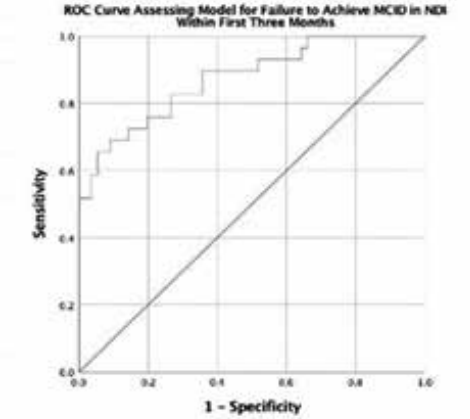
Conclusion: The large majority of patients had achieved MCID in at least one of the three PROMs. Clinical depression, myelopathy, and two-level procedures were associated with failure to achieve MCID in NDI by one year and also within the early postoperative period (first three months) following CDR. BMI ≥ 25 kg/m2 and spondylosis were also significant factors associated with failure to achieve MCID in NDI within the early postoperative period.

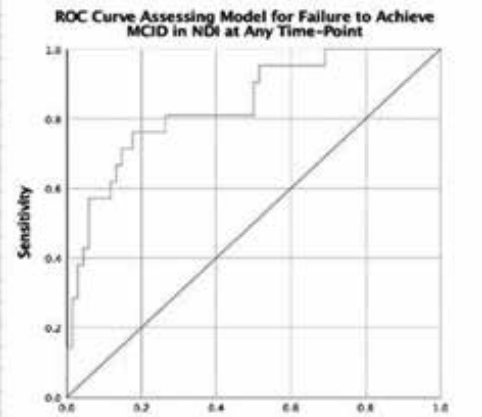
Figure 1

Figure 1a: MCID in NDI within First Three Months



AUROC	Significance	Std. Error	95% CI	
0.873	**<0.001**	0.041	0.793	0.954

Figure 1b: MCID in NDI Overall by One-Year



AUROC	Significance	Std. Error	95% CI	
0.840	**<0.001**	0.050	0.741	0.938

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Table 1: Risk Factors for Failure to Achieve MCID Within the First 3 Months

	Odds Ratio	95% CI		P-Value
Neck Disability Index				
Age	1.003	0.925	1.088	0.941
Body Mass Index (≥ 25 kg/m^2)	153.752	6.685	3536.309	**0.002**
Current Smoker	0.044	0.002	1.084	0.056
Hypertension	0.022	0.000	1.181	0.060
Dyslipidemia	12.611	0.684	232.495	0.088
Preoperative Narcotic Use	0.106	0.015	0.771	**0.027**
Psychiatric Disorders				
Depression	50.318	2.055	1232.026	**0.016**
Anxiety	3.829	0.356	41.222	0.268
Depression & Anxiety	1.136	0.096	13.457	0.920
Diagnosis				
Radiculopathy	0.740	0.070	7.876	0.803
Myelopathy	51.444	1.753	1510.018	**0.022**
Myeloradiculopathy	0.527	0.048	5.799	0.600
DDD/Spondylosis	21.544	3.415	135.911	**0.001**
Foraminal Stenosis	0.222	0.048	1.023	0.054
Two Level Surgery (Ref: 1-level)	6.487	1.234	34.100	**0.027**
VAS-Neck				
Age	0.982	0.924	1.045	0.568
Male Gender	2.537	0.744	8.647	0.137
Predominant Symptom of Concern				
Predominant Neck Pain	Reference	-	-	-
Predominant Arm Pain	1.958	0.509	7.529	0.328
Equal Neck and Arm Pain	0.728	0.205	2.577	0.622
Diagnosis				
Radiculopathy	1.063	0.166	6.800	0.949
Myelopathy	3.838	0.386	38.178	0.251
Myeloradiculopathy	0.389	0.047	3.229	0.382
VAS-Arm				
No Factors Identified	-	-	-	-

MCID: Minimal Clinically Important Difference; CI: Confidence Interval; NDI: Neck Disability Index; DDD: Degenerative Disc Disease; VAS: Visual Analogue Scale;

The final multivariate logistic regression model was selected using a backward stepwise process with sequential elimination and forward entry of removed variables (entry: 0.05, removal: 0.10). All models initially included age (only forced entry), BMI, gender, race, insurance type, CCI (without age component), smoking status, depression, anxiety, preoperative narcotic use, hypertension, osteoarthritis, history of cancer, dyslipidemia, predominant symptom of concern (neck vs. arm pain), spondylosis, herniated nucleus pulposus, central stenosis, foraminal stenosis, radiculopathy, myelopathy, number of levels, ASA class, total operative time, estimated blood loss, and total length of stay. The remaining variables were entered into the final logistic regression models to analyze significant risk factors for failure to achieve MCID in NDI, VAS-Neck, and VAS-Arm.

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Table 2: Risk Factors for Failure to Achieve MCID by One-Year Follow-up

	Odds Ratio	95% CI		P-Value
Neck Disability Index				
Age	1.023	0.962	1.088	0.465
ASA 2 (Ref: ASA 1)	8.897	0.888	89.094	0.063
Psychiatric Disorders				
Depression	18.211	1.513	219.196	**0.022**
Anxiety	-	-	-	0.999
Depression & Anxiety	1.224	0.157	9.512	0.847
Diagnosis				
Radiculopathy	0.451	0.055	3.666	0.456
Myelopathy	18.810	1.198	295.272	**0.037**
Myeloradiculopathy	10.155	0.518	199.066	0.127
Two Level Surgery (Ref: 1-level)	4.440	1.080	18.258	**0.039**
VAS-Neck				
No Factors Identified	-	-	-	-
VAS-Arm				
No Factors Identified	-	-	-	-

MCID: Minimal Clinically Important Difference; CI: Confidence Interval; NDI: Deck Disability Index; ASA: American Society of Anesthesiologists; VAS: Visual Analogue Scale;

The final multivariate logistic regression model was selected using a backward stepwise process with sequential elimination and forward entry of removed variables (entry: 0.05, removal: 0.10). All models initially included age (only forced entry), BMI, gender, race, insurance type, CCI (without age component), smoking status, depression, anxiety, preoperative narcotic use, hypertension, osteoarthritis, history of cancer, dyslipidemia, predominant symptom of concern (neck vs. arm pain), spondylosis, herniated nucleus pulposus, central stenosis, foraminal stenosis, radiculopathy, myelopathy, number of levels, ASA class, total operative time, estimated blood loss, and total length of stay. The remaining variables were entered into the final logistic regression models to analyze significant risk factors for failure to achieve MCID in NDI, VAS-Neck, and VAS-Arm.

Presentation #101

Case-level Matched Analysis of the NASCIS-2 and Sygen Randomized Controlled Trials to Study the Effect of Methylprednisolone in Cervical Spinal Cord Injury

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Introduction: Methylprednisolone (MPSS) was reported by the NASCIS-2 group (n=472) to have a beneficial effect in Acute Traumatic Spinal Cord Injury (ASCI) 30 years ago[1]. After high initial praise and almost universal use of MPSS for ASCI, its use was curtailed after ambiguity was noted in the statistical presentation. Subsequently MPSS was removed from the ATLS protocol as a treatment in 2008. There have been over 1500 articles attempting to provide clarity for MPSS in ASCI, but without a consensus. A second prospectively collected ASCI study, the Sygen Study (n=760)[2], followed the NASCIS-2 study at the height of enthusiasm of MPSS and used MPSS in both the Placebo and GM-1 treatment groups. The case-level combination of the NASCIS-2 and Sygen studies permitted new statistical analysis of the historical pharmaceutical treatment of ASCI

Materials and Methods: This new database started with the original motor and sensory measurements for each patient and then ASIA grades and other variables were uniformly recalculated. Where major differences in the entrance criteria occurred between the two studies, only the patients with similar or matching entrance criteria were included. The guiding principle of creating this new database was to use contemporary definitions and knowledge of SCI, as if proposing a new prospective study. For the purposes of this investigation, only major cervical spinal cord injuries were selected. The Thoracic-Lumbar and minor SCI (motor score >20 of 50 in LE) will be analyzed separately.

Results: In total we had 906 cervical SCI patients, of which 40 were excluded from the study based on extremes of age, GCS, missing baseline exam and intact baseline motor exam (Table 1). Of this group 111 patients were removed from the primary analysis due to minor injuries (Table 1). The Placebo-MPSS group from the Sygen study was combined with the MPSS group of the NASCIS-2 study. The baseline demographics of the patients across the different studies and drugs were similar (Table 2). Average time to surgery was greater in the NASCIS-2 trial. Including the placebo only group, none of the interventions stratified by ASIA grade had a significant impact on the recovery of Lower Extremity Motor Scores from baseline to 26 weeks follow-up (Table 3). At 26-weeks 106 (14.04%) of patients were lost to follow-up.

Conclusion: In this study we were successful in conducting a case-matched analysis and are able to verify that the two MPSS groups in the two RCTs were statistically similar. This combined dataset gives us a greater number of patients in the MPSS treatment group for analysis. Mild injuries have an associated ceiling effect and they will be presented in a separate analysis that factors in the ceiling effect. The preliminary overall results do not reveal an MPSS effect on LEM score improvement at 26 weeks in major cervical SCI. With this successfully combined data-set the patient sample size is increased and will allow further time and trajectory based analyses. These analyses are planned for future presentations and will be aimed at obtaining a fact based consensus on the impact of MPSS on ASCI.

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Table 1: Cases excluded from analysis in the combined case-matched study

Variable	NASICS 2	Sygen
Exclusions from new case-matched data base		
Age less than 15 or greater than 75	12	6
GCS less than or equal to 12	12	0
No baseline exam	1	6
Intact total baseline motor score	3	0
Total unique patients excluded	40	
Other spinal column injuries to be analyzed separately from major acute SCI patients		
Lower extremity motor score greater than 20 (mild SCI injury)	81	37
Total unique patients separate from this analysis	111	

Table 2 Baseline Charecteristics of patients by drug intervention

	MPSS			Naloxone	Placebo	Sygen + MPSS
Study						
NASCIS2	74			77	75	0
Sygen	231			0	0	298
	NASCIS-2	**Sygen**	**Combined**			
Mean Age (yrs)	30.64	33.50	32.81	30.64	32.09	33.79
Gender						
Male	66	187	250	66	66	238
Female	8	47	55	11	9	60
Surgery						
No	30	46	76	31	30	53
Yes	44	185	229	46	45	245
Average Time to Surgery (hrs)	428.54	274.45	313.13	428.18	401.69	163.25
Baseline ASIA Grade						
A	61	144	205	52	60	181
B*	8	55	63	17	9	74
C&D	5	32	37	8	6	43

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Table 3 Lower Extremity Motor (LEM) Score recovery at 26 weeks from baseline by different drug interventions

Drug	Average Difference in LEM from Baseline to 26 Weeks	Number of Patients	ANOVA p-Value
ASIA A			
MPSS	1.63	175	
Naloxone	0.55	49	
Placebo	1.94	50	
Sygen + MPSS	2.75	155	
			0.2400
ASIA B*			
MPSS	20.81	54	
Naloxone	30.93	15	
Placebo	25.56	9	
Sygen + MPSS	20.75	60	
			0.2598
ASIA C&D			
MPSS	29.58	36	
Naloxone	28.75	8	
Placebo	29.33	6	
Sygen + MPSS	28.75	32	
			0.9826

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Presentation #102

Preoperative and Postoperative Sagittal Cervical Alignment is Predictive of PROMIS Patient Reported Outcomes and Nurick Scores

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Introduction: Cervical spinal deformity causes increased muscular energy expenditure that may contribute to pain (Rajnics et al., 2002). This study explores the impact of cervical sagittal alignment on patient reported outcomes and neurologic function following cervical spine fusion surgery.

Materials and Methods: We conducted a retrospective analysis of 54 cervical spine fusion patients who had (1) 12 months (12M) of follow-up office visits, and (2) pre- and 12M post-operative cervical X-rays in the lateral view (Table 1). The following parameters were measured: (1) C2-C7 Slope (CL), the C2–C7 Cobb angles which are obtained by drawing a line parallel to the inferior end plate of C2 and another line parallel to the inferior end plate of C7. Perpendicular lines are drawn from each of these lines, and the angle subtended by their intersection is measured; (2) T1 sagittal slope (T1S), the angle between the superior endplate of T1 and the horizontal plane; (3) cSVA, the distance between the C2 and C7 plumb lines. Patient-Reported Outcomes Measurement Information System (PROMIS) physical pain and mental stress scores were assessed at pre-op and 12M post-op. The effect of radiographic and clinical parameters on these scores was analyzed by multiple linear regression modeling. Nurick Grades, for myelopathic disability, were estimated from office visits pre- and post-op and analyzed by multivariable binary logistic regression, with Nurick scores >1 coded as "1" and Nurick scores of 0 or 1 coded as "0". Odds ratios are reported as (OR [95% CI]).

Results: The multiple linear regression analysis built significant models for physical pain and mental stress PROMIS scores at 12M post-op (Physical: $F(7, 47) = 7.631$, $p < .0001$; Mental: $F(7, 47) = 6.6292$, $p < .0001$)(Table 2). Values are reported as (Increase in PROMIS score per unit change in sagittal, cervical parameter, p value). Significant predictors for a higher physical PROMIS score at 12M were pre-operative CL (0.4711, p=0.0010), cSVA (0.3080, p=0.0129) and post-op CL (0.3592, p=0.0299). Significant predictors for a higher mental PROMIS score were pre-operative CL (0.5268, p=0.0033), and cSVA (0.3444, p=0.0299). Higher physical PROMIS scores (OR:1.797, [1.115-5.840]) and higher post-op cSVA (OR:1.607 [1.054-4.500]) as well as lower pre-op T1S (OR:0.4544 [0.09399-0.9195]) were associated with increased odds of having a Nurick score of >1 at 12M post-op (Table 3).

Conclusion: Pre-operative C2-C7 lordosis, pre-op cSVA, and post-op C2-C7 lordosis strongly predicted increase in physical pain and mental stress patient reported, PROMIS scores. Increased physical pain PROMIS score, lower pre-op T1 slope, lower post-op T1 slope, and higher post-op cSVA were associated with increased odds of developing a Nurick score of >1 at 12M follow up.

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Table 1. Patient demographics, comorbidities, and follow up details for the overall cohort. The upper extremity complaints refer to the pre-op symptoms patients presented with or suffered from post-op. The lower extremity complaints refer to complaints that patients reported by 12M post-op. The lower extremity symptoms were graded on the Nurick Scale, for myelopathic related disability. Mean ± SEM is reported where relevant. PROMIS refers to Patient-Reported Outcomes Measurement Information System (PROMIS) physical pain and mental stress scores which were assessed pre- and post-op.

Number of Cases	54
Age (Years)	59.2 ± 1.44
Sex (male%)	32 (59.26%)
Mean Months Follow Up	12.68 ± 0.42
Presenting Neurologic Symptoms By 12 Months (%)	
Symtoms	# cases (% of cohort)
Upper Extremity Complaint (%)	52 (100)
Neck Pain/Stiffness (%)	46 (88.46)
Radiculopathy (%)	40 (76.92)
Myelopathy (%)	45 (86.54)
Motor Weakness (%)	41 (78.85)
Sensory Weakness (%)	32(61.54)
Lower Extremity Complaint(%)	17 (32.69)
Radiculopathy (%)	15 (28.85)
Myelopathy (%)	8 (15.38)
Motor Weakness (%)	13 (25.00)
Sensory Weakness (%)	12 (23.07)
Ambulatory Complaint (%)	19 (36.54)
Pre-Operative Nurick Score	0.42 ± 0.06
12 M Post-Operative Nurick Score	0.91 ± 0.17
Comorbidities	
Diabetes (%)	7 (13.46)
Coronary Artery Disease (%)	2 (3.85)
Osteoporosis (%)	2 (3.85)
Obesity (%)	4 (7.69)
Smoking History (%)	11 (21.15)
Hypertension (%)	17 (32.69)
Depression (%)	5 (9.62)
Patient Reported Physical Pain and Mental Stress Outcomes	
Pre-Operative Physical PROMIS Score	5.79 ± 0.32
12 M Post-Operative Physical PROMIS Score	13.88 ± 2.3
Pre-Operative Physical Mental Score	9.13 ± 0.48
12 M Post-Operative Mental PROMIS Score	15.92 ± 3.18

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Table 2. Ordinary Least Squares (OLS) Regression model for physical pain and mental stress PROMIS scores to determine the effect of pre- and post-op radiographic parameters on patient reported outcomes.

	Physical PROMIS Score	P Value	Mental PROMIS Score	P Value
Constant	25.62	0.3002	30.14	0.2761
Independent Predictors of Physical and Mental PROMIS Scores				
Age	0.1786	0.9721	0.1997	0.6626
Pre-Op T1 Slope	0.3813	0.0585	0.4263	0.0587
Pre-Op C2-C7 Lordosis	0.4711	**0.001**	0.5268	**0.0033**
Pre-Op cSVA	0.308	**0.0129**	0.3444	**0.0299**
Post-Op T1 Slope	0.4461	0.9725	0.4988	0.7531
Post-Op C2-C7 Lordosis	0.3592	**0.0299**	0.4016	0.0568
Post-Op cSVA	0.3211	0.0737	0.3591	0.1156
	Physical PROMIS Score		**Mental PROMIS Score**	
Observations	54		54	
Multiple R^2	0.7293		0.6955	
R^2	0.532		0.4837	
F	7.631		6.292	
Model p-value	**P<0.0001**		**P<0.0001**	

Table 3. Binary logistic regression analysis for risk factors of a Nurick Score of >1 at 12 M following cervical fusion. A Nurick score of >1 was considered "1" and a Nurick score of 0 or 1 was coded as "0". The independent variables were physical PROMIS Score, pre- and post-op T1 slope, C2-C7 lordosis, and cSVA.

Cervical Alignment Parameters	Odds Ratio	95% Confidence Interval
Physical PROMIS Score	**1.797**	**1.116 to 5.840**
Pre-Op T1 Slope	**0.4544**	**0.09399 to 0.9195**
Pre-Op C2-C7 Lordosis	1.422	0.8732 to 3.343
Pre-Op cSVA	0.9479	0.6701 to 1.412
Post-Op T1 Slope	**0.908**	**1.134 to 6.802**
Post-Op C2-C7 Lordosis	0.6541	0.2485 to 1.064
Post-Op cSVA	**1.607**	**1.054 to 4.500**

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Presentation #103

Assessing pseudarthrosis after ACDF with dynamic radiographs using novel angular measurements.

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Introduction: A common complication necessitating reoperation after anterior cervical discectomy and fusion (ACDF) is pseudarthrosis. Previous studies have suggested a <1mm interspinous motion at 150% magnification is predictive of fusion. However radiographic calibration to detect a 1mm difference in motion may not be the most precise or efficient method of assessment. An alternative approach is to use angles, which do not require calibration. This study aims to validate a novel method of detecting pseudarthrosis using dynamic radiographs.

Materials and Methods: A retrospective review of operative patients at a single institution was conducted. Interspinous motion was measured on 143 dynamic radiographs using angles between spinous processes and the previously published linear method (figure 1). Regression analysis determined relationship between linear and angular measures. Based on 1mm linear cutoff for fusion, the regression equation was used to calculate the angular cutoff. Sensitivity and specificity of linear and angular measures were confirmed by postop CT. Pseudarthrosis in standalone and plated polyetheretherketone (PEEK), allograft, and titanium cage fusions were assessed using both linear and angular cutoffs. Inter and intra reliability measurements were performed by 5 observers on patients with postop CTs to assess accuracy and precision of linear and angular methods.

Results: A total of 242 levels (81 allograft, 84 PEEK, 40 titanium, 37 standalone cages) were measured in 143 patients (mean age 52y, 42% female). Linear and angular measures were closely correlated (R=.872), with an angle of 2.3 degrees corresponding to 1mm of interspinous motion. 36 patients with 66 fused levels had postoperative CTs; 13 levels in 13 patients had confirmed pseudarthrosis. 1mm linear cutoff had 85% sensitivity and 88.7% specificity and 2.3o angular cutoff had 85% sensitivity and 98% specificity for detecting pseudarthrosis, with CT validation. There was high intra- and inter-observer reliability for both angular and linear measurements, with slightly higher reliability using angular measures. The intraclass correlation coefficient for the angular measurement was .986 and for linear measures was .974 (both $p<.001$). The mean intra-rater reliability was .974 for angular and .953 for linear measures (both $p<.001$).Using the angle cutoff, potential pseudoarthrosis was found in 9/37 (24%) standalone cages and in 15/81 (18%) allograft, 16/84 (19%) PEEK, and 6/40 (15%) titanium plated fusions. Pseudoarthrosis tended to occur in patients with more fused levels (24.6% in single, 36.6% in 2-level, 44.8% in 3-level), and in lower levels in multilevel fusions (60% in lower level in 2-level fusions $p=.08$, and 92.3% in lowest level in 3 level fusions $p<.001$).

Conclusion: Angular measures for assessing potential pseudoarthrosis is as sensitive as published linear methods, more specific in ruling out false positives, is highly reliable between multiple observers, and can be used without the need for calibration. There were no significant

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differences in pseudoarthrosis between cage types, but lower fusion levels had a higher likelihood of pseudoarthrosis.

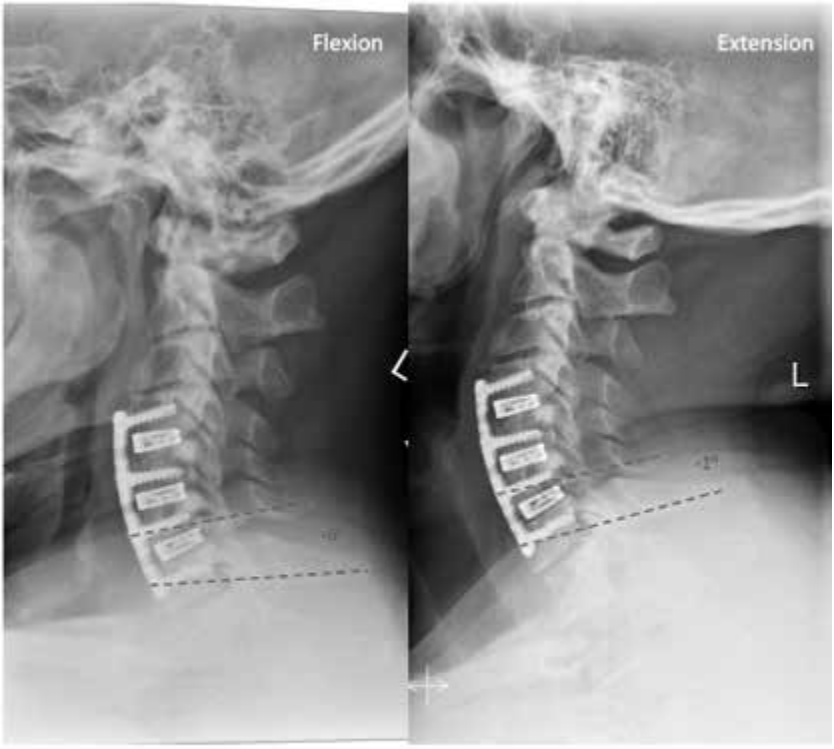

Figure 1: Measurement of interspinous motion on dynamic radiographs using angles between spinous processes

Presentation #104

Risk Factors Of Surgical Complications Following Posterior Cervical Spinal Surgery For Ossification Of The Posterior Longitudinal Ligament

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Introduction: Posterior cervical surgery is the treatment of choice for myelopathic patients with > 3 levels of ossification of the posterior longitudinal ligament (OPLL) in a lordotic spine. While clinical and functional outcomes have been reported, few studies have analyzed predictors of perioperative OPLL complications specific to the posterior approach. The aim of this study was to investigate clinical, surgical, and radiological risk factors of complications following laminoplasty (LAMP) and laminectomy and fusion (LF) for cervical OPLL.

Materials and Methods: A retrospective review of patients who underwent posterior cervical decompression for OPLL with a minimum of 2 years follow-up at a university hospital was conducted. Clinical, surgical, and radiological data were collected. All patients had symptomatic cervical myelopathy and confirmed OPLL on computed tomography (CT). Surgical complications were defined as any unforeseen adverse event directly relating to the operation. SPSS software was used for statistical analysis to determine risk factors of complications.

Results: Eighty-eight patients, 77.8% of whom were male, with a mean age of 60.6+10.0 years were analyzed. The average cervical lordosis was 5.5+11.4 degrees with 51.1% of patients being K-line (-). Thirty-three percent of patients had segmental-type OPLL and 27.3% had mixed-type OPLL. Fifty-one percent of patients had hill-shaped morphology diagnosed on lateral radiographs. At the level of maximal cord compression on T2-weighted axial magnetic resonance imaging (MRI), boomerang-shaped, teardrop-shaped, and triangle-shaped spinal cord compression was found in 30.7%, 29.5%, and 39.8% of patients, respectively. CT scan revealed a double-layer sign and a C-sign in 44.3% and 35.2% of patients. Sixty-four percent of patients had LAMP and 36% had LF. Overall mean JOA scores improved from 11.0+ 4.1 preoperatively to 14.2+2.7 and 14.7+2.6 at 1- and 2 years. There were 21 complications found in the study of which 14 (16.0%) were found in the LF group and 7 (8.0%) were found in the LAMP group ($p=0.034$). Majority of the complications were neurological in nature with 8 patients suffering from postoperative C5 palsy, 1 patient from C6 palsy, and 2 patients from global weakness. Other complications included 3 incidental dural tears, 4 surgical site infections, 2 epidural hematomas, and 1 instrumentation error. Univariate analysis found that female gender (OR 3.82, $p=0.018$), LF (OR 3.14, $p=0.034$), K-line (-) OPLL (OR 3.43, $p=0.038$), boomerang-shaped spinal cord compression (OR 4.56, $p=0.01$) and presence of the C-sign (OR 77.54, $p<0.001$) were significant risk factors for postoperative complications. Multiple logistic regression confirmed that boomerang-shaped spinal cord compression (OR 10.14, $p=0.003$) and a C-sign (OR 6.20, $p=0.017$) OPLL morphology were predictive of surgical complications.

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Conclusion: Posterior cervical surgeries in the treatment of cervical myelopathy due to OPLL are reproducible with acceptable complications. In this study, patients who underwent LF or were K-line (-) experienced a trend towards higher complication rates. To the best of the authors' knowledge, this is the first study to associate preoperative C-sign and boomerang-shaped spinal cord with postoperative complications and possible nerve root palsy in OPLL patients following treatment with the posterior approach.

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Presentation #105

7mm Is a Critical Threshold of Cervical Canal Stenosis: Long-term Analysis of an Asymptomatic Cohort

Sean Rider, MD, *Michael Kelly, MD*

Introduction: The natural history of patients with asymptomatic cervical spondylotic stenosis is not known. As such, the treatment of these patients remains controversial. Radiographic factors associated with progression to surgery are poorly defined, compromising the shared-decision making process.

Materials and Methods: Adult patients with an AP spinal canal diameter < 9 mm on MRI without T2-signal intensity and no signs nor symptoms of myelopathy were enrolled in a prospective, observational cohort study. Exclusion criteria were: age over 80 years, pathologic or traumatic compression, instability requiring stabilization. Enrolled patients were recommended to have repeat physical exams and MRIs annually. At last contact patients completed Neck Disability Index and mJOA outcomes questionnaires. Any patients developing myelopathy or recalcitrant radiculopathy underwent surgery. MRIs were reviewed, and AP spinal canal diameter were measured C2-T1 at the level of vertebral body and intervertebral disc using a digitized viewer. Optimal cutoff was obtained by using receiver operating characteristic (ROC) analysis and finding Youden's Index.

Results: 86 patients were enrolled. Mean follow-up was 9.9yrs (range, 2-19.6 years; cumulative follow-up of 758.7 patient*yrs). 26 patients lost to follow-up. Total of 74 patients (18 surgical, 56 non-surgical) had available cervical MRIs for review. The mean AP spinal diameter at the most stenotic level was 7.5mm (STD 0.1). At a mean of 5 year followup (Range 0-14 years) there was no clinically significant change in stenosis at any level. Youden's Index indicated an appropriate cut-off of 7.0mm (Sensitivity: 73%, Specificity: 77%, ROC AUC 0.78). Patients with stenosis <7.0mm were more likely (Odds Ratio: 9.3, 95%CI 2.8-30.6) to undergo surgery. 10 % (5/48) of patients with baseline measures above 7.0 mm had surgery, while 52% (14/27) with baseline measurement below 7.0 mm had surgery ($p<0.001$).

Conclusion: At a mean of almost 10yr follow-up, those patients presenting with AP spinal canal diameter of < 7.0 mm had increased odds (9.3x) of undergoing surgery. The mean canal diameters were essentially unchanged, emphasizing the need for improved imaging of and prognostication with neural tissues.

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Presentation #106

Incidence and predictors of kyphotic deformity following resection of cervical intradural tumors in adults.

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Introduction: The first line of treatment for most cervical intradural tumors is surgical resection through laminotomy or laminectomy. This can lead to kyphosis, which is associated with decreased functional outcome. However, the incidence and predictors of kyphosis in these patients are poorly understood. The aim of this study was to assess the incidence of posterior fixation, as well as predictors of radiological kyphotic increase, following resection of cervical intradural tumors in adults.

Materials and Methods: A population-based cohort-study was conducted of all adult patients who underwent intradural tumor resection via cervical laminectomy with or without laminoplasty between 2005 and 2017. The primary outcome was kyphosis requiring posterior fixation (PF). The secondary outcome was radiological development of kyphosis, as measured by comparing pre- and postoperative magnetic resonance images.

Results: Eighty-four patients were included. Twenty-four percent of the tumors were intramedullary. The most common diagnosis was meningioma. The mean laminectomy range was 2.4 levels, and laminoplasty was performed in 40 % of cases. No prophylactic PF was performed. During a mean follow-up of 4.4 years, 2 patients (2.4 %) required delayed PF. The mean kyphotic increase after surgery was 3.0 º, which was significantly associated with laminectomy of C2 and C3. Of these, C3 laminectomy demonstrated independent risk association.

Conclusion: There was a low incidence of delayed PF following cervical intradural tumor resection. Kyphotic increase was associated with C2 and C3 laminectomy. These findings could help identify a subset of at-risk patients were targeted radiological and clinical follow-up is indicated.

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Presentation #107

Risk Factors for Patients Undergoing Anterior Cervical Discectomy and Fusion after a Prior Posterior Cervical Foraminotomy

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Introduction: Cervical foraminotomy is a commonly employed procedure for patients with cervical myelopathy or radiculopathy and has the advantage of preserving segmental motion when compared to anterior cervical discectomy and fusion (ACDF). However, a key concern with foraminotomy is the subsequent segmental instability at the index level secondary to the partial facetectomy, which may necessitate a secondary surgical intervention. Not much is known about risk factors for patients to undergo ACDF after a prior foraminotomy.

Materials and Methods: A retrospective review was performed for patients who underwent cervical spine procedures at a single institution between January 1997 and April 2019. Power analysis was conducted to determine control group size. Patient demographics, comorbidities, and operative variables were characterized. Time between procedures was assessed using a Kaplan-Meier plot. Predictor importance analysis for undergoing ACDF after a prior foraminotomy was performed using the Wald chi-squared metric.

Results: A total of 153 patients were analyzed; 22 (14.4%) patients underwent ACDF with a prior foraminotomy and 131 (85.6%) underwent foraminotomy without ACDF. There were no significant differences in demographics, comorbidities, or operative variables between groups. The median time between foraminotomy and ACDF procedures for patients who underwent both was 448 days (Q1-Q3: 63.75-1257.5). Predictor importance analysis indicated that radiculopathy (Wald χ^2 = 5.7, accounting for 15.8% of the total Wald χ^2; p-value: 0.017) and ossification of the posterior longitudinal ligament (OpLL) (Wald χ^2 = 4.9, accounting for 13.6% of the total Wald χ^2; p-value: 0.027) were relative significant predictors of undergoing ACDF after foraminotomy.

Conclusion: Radiculopathy and OpLL may be significant risk factors for undergoing ACDF after a prior foraminotomy. These indications can aid spine surgeons in setting appropriate preoperative expectations with patients.

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E-Poster #1

Development of Risk Stratification Predictive Models for Cervical Deformity Surgery

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Introduction: As the field of corrective cervical deformity surgery progresses, surgeons continue to take on more challenging cases. In order to minimize suboptimal postoperative outcomes it is important to develop a tool that allows for proper preoperative risk stratification.

Materials and Methods: CD patients(cervical kyphosis >10°, coronal scoliosis >10°, cSVA >4cm, TS-CL >10°, or CBVA >25°) =18 years old with complete baseline(BL), 1Y HRQoL and radiographic data. Patients were stratified into two groups based on their outcome from surgery: Revision[Rev] and Major Complication[MC]. Descriptive analysis identified cohort demographics, radiographic parameters, and surgical details. Univariate analysis of preoperative and surgical factors was conducted to determine associations with any of the two outcomes. Stepwise logistic regressions identified surgical, radiographic, and HRQL factors that were associated with Rev or MC. Decision tree analysis established cut-offs for predictive variables.

Results: 105 CD patients were included(61.6yrs, 67%F, BMI: 28.4kg/m2, CCI: 0.96±1.3). Surgical details: 7.6± 3.7 levels fused; mean EBL of 816 mL. By surgical approach, 45.71% had a posterior approach, 35.24% combined approach, and 19.05% anterior approach. Radiographically at baseline, patients presented with: PT: 18.9± 11.3; PI: 53.0±11.2; PI-LL: -0.45±17.2; SVA: -4.3±66.8, TS-CL: 37.9 ±20.2; cSVA: 38.4±19.9. Postoperatively, 20 patients experienced a MC and 17 patients underwent a subsequent Rev. Instrumentation location (LIV: 1.1[1.0-1.3] and UIV: 1.5[1.1-2.1]) was significantly associated with undergoing a Rev after index surgery(all $p<0.05$). The development of a postoperative MC was significantly associated with BL radiographic pelvic parameters (all <0.05). Predictive modeling incorporating preoperative and surgical factors identified development of a Rev to include: UIV>C3, LIV>T3, C2-T3 SVA<46.7°, C2-C7 SVA>57.6°, CTPA>7.8°, and C2S<60.4 (AUC:0.80). For developing a MC, a model consisting of preoperative and surgical factors included BL EQ5D-VAS<30, TS-CL>59.2°, C2-C7 SVA > 69.1°, C2-T3 SVA < 18.6, Apex C2-C7 SVA >4.25, surgical invasiveness and posterior osteotomies(AUC:0.83).

Conclusion: Major adverse events are not uncommon following adult cervical deformity correction. Risk stratification models were developed to predict with high accuracy the occurrence of these common significant post-operative events. Revisions were predicted with an accuracy of 80% using a predominance of radiographic variables, while the occurrence of other major complications was also predicted with high reliability utilizing additional baseline HRQoL data, and surgical factors.

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E-Poster #2

Predicting the Achievement of Optimal Outcomes for Surgical Adult Cervical Deformity Patients

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Introduction: Multivariate regression modeling is increasingly being utilized to predict postoperative outcomes for corrective adult cervical deformity surgery. There is paucity in the literature with utilization of statistical modeling to predict the achievement of a satisfactory optimal outcome.

Materials and Methods: CD patients (cervical kyphosis >10°, coronal scoliosis >10°, cSVA >4cm, TS-CL >10°, or CBVA >25°) ≥18 years old with complete baseline(BL), at least 1Y HRQoL and radiographic data were included. Patients were isolated to include only those that showed minimal clinical importance difference(MCID) in one of the following: EQ5D, NDI, mJOA, or not severe mJOA. Descriptive analysis identified cohort demographics, radiographic parameters, and surgical details. Three satisfactory outcomes were defined: 1) No major complications or reoperations; 2) No distal junctional kyphosis; 3) No severe deformity at 1Y according to SRS-Schwab classification and Ames Modifier (PT, PI-LL, TS-CL). An "Optimal" outcome was defined as achieving all three outcomes where as "Suboptimal" outcome was achieving only one. A multivariate regression was utilized to predict the achievement of an optimal outcome. Cut offs for radiographic parameters were identified via decision tree analysis.

Results: 115 CD patients were included(61.1±10.1, 66%F, BMI: 28.8±7.7 kg/m2 , CCI: 0.94±1.3). Surgical details: 7.4± 3.7 levels fused; mean EBL of 721 mL. By surgical approach, 45.2% had a posterior approach, 35.7% combined approach, and 19.1% anterior approach. Radiographically at baseline, patients presented with: PT: 19.5± 11.5; PI: 54.0±11.6; PI-LL: 0.79±18.2; SVA: 0.95±70.1, TS-CL: 38.1 ±21.2; cSVA: 38.5±19.5; CBVA: 4.1±7.7. Overall, 31.3% of patients had a major complication or reoperation, 40% had DJK at 1Y, and 80.9% presented with moderate or severe sagittal deformity according to SRS-Schwab and Ames-Smith modifiers. At 1-year, mean count of satisfactory outcomes was 3.0±1.5 and overall patient breakdown by count of satisfactory outcomes was: 0) 10 (8.7%) 1) 31 (27.0%); 2) 56 (48.7%); 3) 18 (15.7%). A multivariate model predicting the achievement of a "Optimal" outcome vs. "Suboptimal" included the following combination of factors: TS-CL > 13.8, C2-C7 SVA <24.5°, C2SS < 27.6°, and lack neurological dysfunction(AUC:0.83).

Conclusion: Overall, 15.7% of patients achieved all three satisfactory outcomes following adult cervical deformity surgery. Achieving this "Optimal" outcome was predicted with an accuracy of 83% utilizing radiographic factors and a lack of preoperative neurological dysfunction.

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E-Poster #3

The Importance of Incorporating Proportional Alignment in Adult Cervical Deformity Corrections Relative to Regional and Global Alignment; Steps Toward Development of a Cervical Specific Score.

Peter Passias, MD, *Katherine Pierce, BS, Waleed Ahmad, MS, Sara Naessig, BS, Aaron Buckland, MD, Themistocles Protopsaltis, MD, Han Jo Kim, MD, Bassel Diebo, MD, Renaud Lafage, MS, Virginie Lafage, PhD*

Introduction: Yilgor and colleagues developed a Global Alignment and Proportion (GAP) Score that proposed pelvic-incidence based proportional parameters that predicted mechanical complications in adult spinal deformity patients. Like the global spine, restoration of cervical sagittal alignment is imperative and the aim of corrective adult cervical deformity (CD) surgery in order to improve patient outcomes and prevent mechanical complications. The Ames-ISSG proposed CD classification system is based upon a modified Delphi approach and expert opinion, but does not cover the entire spectrum of cervical malalignment. The purpose was to modify the existing GAP score to a cervical-specific (RAP) score in operative CD patients.

Materials and Methods: Surgical adult CD patients (C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°). Patients with baseline radiographic and patient-reported data were included. RAP score parameters were modified from the original GAP via Delphi approach to include: ideal McGregor's Slope[MGS] (the measured minus the ideal MGS[0]), relative cervical lordosis (the measured minus the ideal C2-C7[T1S-16.5]), cervical lordosis distribution index (C2-C7 lordosis divided by C2-T3 lordosis multiplied by 100), relative pelvic version (the measured minus the ideal sacral slope[0.59xPI +9]), and age. RAP was scored between 0-13 and patients were categorized accordingly: <3 Proportional State, 3-6 Moderately Disproportionate State, >6 Severely Disproportionate State. The accuracy of the RAP score was analyzed with Cochran-Armitage tests analyzed the relationship between patients with available RAP categories and development of distal junctional kyphosis(DJK).

Results: 60 operative CD patients were included (60±10.1 years, 63% female, 16.4% smoker, CCI: 0.64. 28.7±6.4 kg/m2). By approach, 13.3% of patients were anterior, 58.3% posterior, and 28.3% combined (mean total levels: 5.2; operative time: 508.7min; EBL: 1131ccs). Assessment of baseline RAP score in the present cohort found a mean of 5.2/13 possible points. This categorized patients with: 20% in a proportional state, 55% in a moderately disproportionate state, and 25% in a severely disproportionate state. 20% of patients had a mechanical or radiographic complication, including postoperative distal junctional kyphosis, with 8.3% of the cohort undergoing a revision for their DJK. Cochran-Armitage tests found that patients who were moderately or severely disproportionate in their RAP were significantly related to development of mechanical or radiographic complication (4.4756, p= 0.034), but unrelated to other complications or reoperation (p>0.05).

Conclusion: The regional alignment and proportional score is a new method of analyzing the regional proportionality of the cervical spine in the context of global alignment, that predicts mechanical and radiographic complications in operative cervical deformity patients. Setting surgical goals according to the RAP score may decrease the prevalence of postoperative DJK.

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E-Poster #4

Do the Newly Proposed Realignment Targets Bridge the Gap Between Radiographic and Clinical Success in Adult Cervical Deformity Corrective Surgery?

Katherine Pierce, BS, Waleed Ahmad, MS, Sara Naessig, BS, Bassel Diebo, MD, ***Peter Passias, MD***

Introduction: In an attempt to provide more clinical relevancy to existing cervical deformity (CD) classifications, Passias and the ISSG developed novel thresholds for low, moderate and severe deformity through McGregor's Slope, CL, TS-CL, C2-T3 angle, C2 Slope and frailty based upon myelopathy severity by way of the health-related quality of life (HRQL), mJOA. The purpose of this study was to investigate the relationship between myelopathy-based CD thresholds with patient-reported outcomes.

Materials and Methods: CD patients(C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) with HRQL and radiographic data. Modifiers assessed included cut-offs for low(L), moderate(M) and severe(S) deformity: CL(L:>3°; M:-21° to 3°; S:<-21°), TS-CL(L:<26°; M:26° to 45°; S:>45°), C2-T3 angle(L:>-25°; M:-35° to -25°; S:<-35°), C2 slope(L:<33°; M:33° to 49°; S:>49°), MGS(L:>-9° and <0°; M:-12° to -9° or 0° to 19°; S:<-12° or >19°), and frailty(L:<0.18; M:0.18 to 0.27, S:>0.27). Means comparison and ANOVA assessed outcomes (reop, complications, DJK, meeting MCID for HRQLs) in each of the severity groups at baseline, and those that improved, remained the same or worsened in patients with follow up at 1-year. Correlations were ran between the modifiers to determine internal relationship.

Results: 104 pts included (57.1yrs, 50%, 29.3kg/m2, CCI:0.59). Baseline mJOA score was 13.1±2.9. At baseline, the rate of S myelopathy-modifiers is as follows: 9.2% TS-CL, 14.7% MGS, 8.7% C2-C7, 7.9% C2-T3, 10.5% C2 slope, 49.5% frailty. Baseline S TS-CL, C2-T3, and C2S modifiers were significantly associated with increased reoperations ($p<0.01$), while S MGS, CL, and C2-T3 had increased EBL(>1000ccs, $p<0.001$). S MGS and C2-T3 had more postop DJK (60%, $p=0.018$). At 1Y, 22.1% of patients improved or remained Low in TS-CL modifier, 8.7% in MGS, 24% in CL, 56.7% in C2-T3 modifier, 11.5% C2S, and 28.8% in frailty. Improved in TS-CL, C2S, C2-T3 and CL patients had better NSR Back(<5) and EQ5D scores at 1-year ($p<0.05$). Patients who improved in frailty modifier at 1-year met MCID for NDI (50%) and EQ5D more (30%), $p<0.001$.Worsened or remained severe Δ baseline to 1-year ranged from 3.8-10.6% (majorly in the frailty category). Improving in TSCL, CL, C2-T3, C2S and frailty modifiers correlated strongly with each other(0.213-0.785, $p<0.001$). Patients worsened in their TS-CL had increased NRS Back scores at 1-year (9, $p=0.042$). Worsened CL had increased 1-year mJOA scores(7, $p=0.001$). Worsened C2-T3 had significantly worse NRS Neck scores at 1-year ($p=0.048$). Improvement in all 6 modifiers(8.7%) had significantly better HRQL scores at follow up (EQ5D, NRS, NDI).

Conclusion: For surgical CD patients, use of the newly proposed CD modifiers based on the mJOA scores were more closely associated with outcomes at 1-year. Improvement and deterioration in the modifiers significantly impacted health-related quality of life outcomes.

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E-Poster #5

Laminoplasty: The Underutilized Procedure for Cervical Spondylotic Myelopathy

Wylie Lopez, MD, *Brian Goh, MD, PhD*

Introduction: Cervical spondylotic myelopathy is common and national trends suggests it is treated differently in different parts of the world. Despite numerous studies citing decreased EBL, OR time, revision rates, hospital stays, and overall cost of laminoplasty, it is still significantly underutilized in the United States when compared to posterior cervical laminectomy and fusion. We report treatment trends at 2 major academic teaching institutions.

Materials and Methods: 250 patients > 18 years old undergoing cervical laminectomy and fusion or laminoplasty for cervical spondylotic myelopathy at two large academic institutions from 2017-2019 were included in the study. Bivariate testing was performed using chi-square analyses with categorical variables. Continuous variables were compared using the Wilcoxon rank-sum test. Correlation analysis was performed using the restricted maximum likelihood (REML) method. Multivariate analysis was performed using logical regression and density ellipses represent 95% confidence. Surgical factors such as EBL, OR time, and hospital stay were analyzed independently, then normalized to the number of operative levels and reanalyzed.

Results: 108 patients underwent laminectomy and fusion while 142 underwent laminoplasty. When normalized to the number of levels operated, EBL between the 2 groups was equivocal. Hospital stay and revision rate was less for laminoplasty (about 1 day less on average, and 6.3% vs 9.3%). OR time was longer for laminoplasty ($p < 0.001$). Of the 108 patients who underwent laminectomy and fusion, 76.9% were eligible to undergo laminoplasty.

Conclusion: In our patient cohort, cervical laminoplasty showed equivalent EBL, decreased hospital stay and revision rates, but higher OR time when compared to posterior cervical laminectomy and fusion. ¾ of the patients who underwent laminectomy and fusion were eligible to undergo laminoplasty. When considering the cost-benefits associated with the 2 procedures in the literature, our study suggests that cervical laminoplasty is underutilized in the treatment for cervical spondylotic myelopathy.

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E-Poster #6

Pseudoarthrosis Following Long Segment Anterior Cervical Discectomy and Fusion: Incidence, Risk Factors, and Associated Clinical Outcomes

Joshua Bell, MD, *Ryan Aschenbrener, MD, Varun Puvanesarajah, MD, Amit Jain, MD, Adam Shimer, MD, Francis Shen, MD, Hamid Hassanzadeh, MD*

Introduction: Pseudoarthrosis (PA) is a common complication following anterior cervical discectomy and fusion (ACDF), with variable incidence across the literature.[1,2] While much has been reported on PA rates and risk factors in short segment (3-or-less levels) ACDF, there is limited information on this complication in 3-or-more level fusions and its impact on patient reported outcome measures (PROMs). The aim of this study was to 1) determine the incidence of PA among patients undergoing 3-or-more level ACDF; 2) the examine the risk factors associated with developing PA in this population; 3) evaluate the impact PA has on postoperative PROMs.

Materials and Methods: Single institution review of patients who underwent 3-or-more level ACDF for degenerative cervical pathology between the years of 2008 to 2019 was performed. Cases involving same day revisions and/or concurrent posterior fusion were excluded. The resulting cohort was divided into those who went on to develop radiographic evidence of PA and those who didn't (controls). PA was defined as radiographic evidence of nonunion at a minimum of 6 months following index surgery. Risk factors for PA were determined using multivariate regression model. Baseline (BL) and 1-month, 3-month, 6-month, 1-year, and 2-year follow-up patients PROMs including Visual Analog Scale (VAS) Neck and Arm Scores, EQ-5D, Modified Japanese Orthopaedic Association (JOA) Score, and Neck Disability Index (NDI) were compared between populations using student's t-test. Significance was defined as $p<0.05$.

Results: 128 patients met study criteria with an average of 3.12 ± 0.35 levels fused per patient. Average follow up was 14.79 ± 15.41 months. 40 patients (31%) went on to developed radiographic evidence of PA following fusion, of theses PA occurred in the distal level of the fusion in 35 patients (88%). 18 of the PA patients (35%) had symptomatic manifestations, while only 8 (20%) required eventual revision for PA. Average time to revision for PA was 11.25 ± 7.07 months. (see Table 1) Compared to those undergoing 3-level fusion, patients with 4-level fusion had a higher risk of developing PA (OR 4.01 [1.07-15.11] p=0.034). No other risk significant factors were identified following regression analysis. No difference in BL PROMs was observed. At initial 1-month follow-up, controls had superior VAS Neck (p=0.020) and Arm (p=0.018) and EQ-5D (p=0.037) scores compared to their PA counterparts. Modified JOA Score (p=0.008) at 3-month and VAS Neck (p=0.020) and Arm Scores (p=0.004) at 6-month follow-up were also significantly better among the control population. There were no significant differences in clinical outcomes at both the 1- and 2-year follow-up intervals. (see Figure 1)

Conclusion: Almost one-third of patients undergoing 3-or-more level ACDF went on to develop PA, most prominently at the most distal level. While no medical risk factors for PA were identified, those with 4-or-more levels fusion were at higher risk of developing PA. Despite initially superior PROMs among control patients, 1- and 2-year outcomes were similar between the two populations. This may be reflective of a majority of PA patients having asymptomatic

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presentation, in addition to almost half of symptomatic patients undergoing revision within a similar time interval.

Table 1 Demographics

		Control n = 88		Pseudoarthrosis n = 40		p-value
Age (Years)		59.95 ± 8.94		59.28 ± 10.20		0.722
Female Sex		40	45.5%	22	55.0%	0.317
ASA Status		2.52 ± 0.57		2.54 ± 0.65		0.873
# Levels Fused		3.07 ± 0.30		3.23 ± 0.42		0.034
Length of Stay		2.69 ± 2.61		2.26 ± 1.29		0.217
Comorbidities						
Tobacco Use		23	27.3%	12	30.0%	0.649
Obesity (BMI>30)		34	38.6%	13	32.5%	0.504
Hypertension		52	59.1%	23	57.5%	0.866
Hyperlipidemia		36	40.9%	15	37.5%	0.715
CHF		5	5.7%	1	2.5%	0.430
CAD		12	13.6%	6	15.0%	0.837
Diabetes		20	22.7%	8	20.0%	0.729
RA		1	1.1%	1	2.5%	0.564
PVD		1	1.1%	1	2.5%	0.564
COPD		7	8.0%	2	5.0%	0.545
CKD		8	9.1%	4	10.0%	0.870
Depression		27	30.7%	14	35.0%	0.627
Pseudoarthrosis Outcomes						
PA Location	Most Proximal Segment	-	-	4	10.0%	-
	Intermediate Segment(s)	-	-	9	22.5%	-
	Most Distal Segment	-	-	35	87.5%	-
Symptomatic PA		-	-	14	35.0%	-
Reoperation for PA		-	-	8	20.0%	-
Time to Reoperation (months)		-	-	11.25 ± 7.07		-

ASA, American Society of Anesthesiologists; BMI, Body Mass Index; CHF, Congestive Heart Failure; Coronary Artery Disease; RA, Rheumatoid Arthritis; PVD, Peripheral Vascular Disease; COPD, Chronic Obstructive Pulmonary Disease; Chronic Kidney Disease

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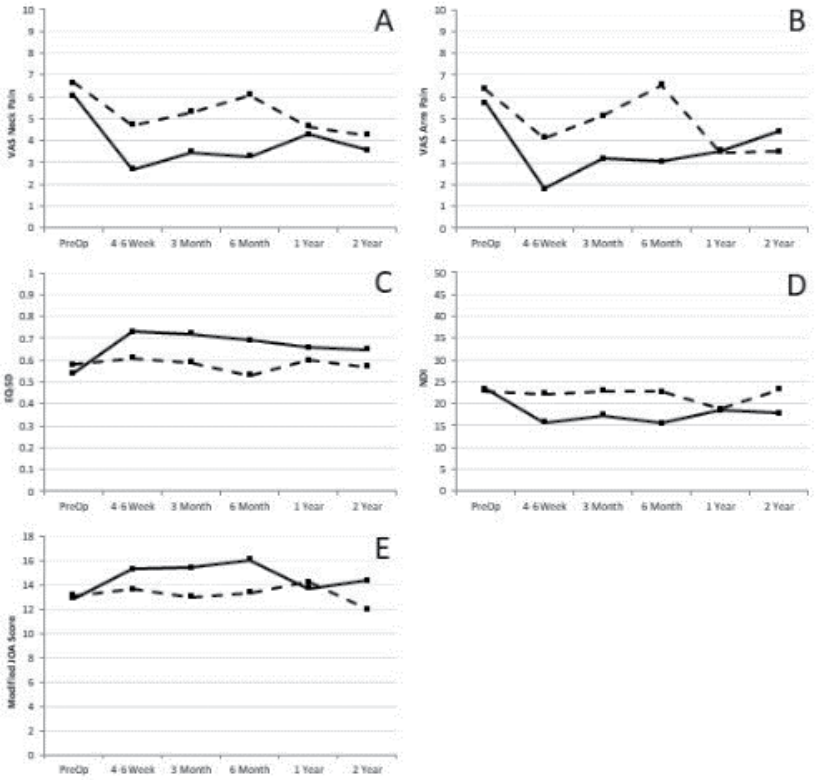

Figure 1. Comparison of **(A)** VAS Neck Pain, **(B)** VAS Arm Pain, **(C)** EQ-5D, **(D)** NDI, and **(E)** Modified JOA Score between control population (solid line) and PA patients (dashed line).

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E-Poster #7

To Cross the Cervicothoracic Junction? Terminating Posterior Cervical Fusion Constructs Proximal to the Cervicothoracic Junction Does Not Impart Increased Risk of Reoperation in Patients with Cervical Spodylotic Myelopathy

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Introduction: Cervical spondylotic myelopathy (CSM) is commonly treated with posterior cervical laminectomy and fusion (PCLF). However, the unique biomechanical environment at the cervicothoracic junction (CTJ) has led to controversy about where to terminate posterior fusion constructs. Specifically, for PCLF the question remains -- is there an advantage to crossing the cervicothoracic junction? Terminating fixation in the thoracic spine allows for more robust fixation, however, fusing the CTJ can result in substantial loss of cervical motion and increased surgical time, blood loss and cost. Thus, the purpose of the present study was to determine if terminating PCLF constructs cranial to the cervicothoracic junction results in a higher revision rate when compared to constructs terminating in the upper thoracic spine.

Materials and Methods: Following Institutional Review Board approval, a prospectively collected database was used to identify all patients who underwent PCLF performed by two fellowship-trained spine surgeons at a single institution from August 2012 to August 2019. Patients with less than one-year clinical follow-up, less than four vertebral levels fused, surgery performed for trauma, deformity, or tumor, or fusion constructs terminating caudal to T2 were excluded. Following exclusion, 177 patients were included in analysis. The electronic medical record was queried to identify patients who required revision cervical surgery following their index procedure. Patients were divided into “cervical” and “thoracic” groups based on the caudal level of their index fusion construct. Revision rates of each group were calculated. Continuous variables were analyzed using two-way Student t-tests, and categorical variables were analyzed using Fischer’s exact test. Statistical significance was defined as $p<0.05$.

Results: One hundred twenty-seven (127/177, 71.8%) patients received fusion constructs that terminated in the cervical spine, while 50 (50/177, 28.2%) received fusion constructs that crossed the CTJ and terminated in the thoracic spine. Patients in the “thoracic” group were significantly older, had higher Age-Adjusted Charlson Comorbidity Index (CCI) scores, and had more instrumented levels on average than patients in the “cervical” group (Table A). Patients who required revision had a significantly lower CCI than patients who did not require revision (Table B). The groups did not differ in regard to other demographic characteristics.The revision rate was 7.9% (14/177 patients) in the combined cohort, 7.1% (9/127 patients) in the cervical group (Table C, green), and 10.0% (5/50 patients) in the thoracic group (Table C, gold). There was no significant difference in revision rates between the cervical and the thoracic group ($p=0.54$). Symptomatic adjacent segment disease (ASD) was the most common indication for revision (5/9 revisions in the cervical group, 3/5 revisions in the thoracic group).

Conclusion: This study shows no evidence of increased risk of revision in patients with fusion constructs terminating in the cervical spine when compared to patients with constructs crossing

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the cervicothoracic junction. These findings support prior evidence showing that terminating the fusion construct proximal to the cervicothoracic junction is a feasible and safe option in posterior cervical fusions.

Table A: Demographic and Operative Characteristics of Fusions Terminating in Cervical Spine vs. Thoracic Spine

	Index Fusions Terminating in the Cervical Spine (n=127)	Index Fusions Terminating in the Thoracic Spine (n=50)	p-value
Age	59.6 ± 10.8	66.7 ± 9.9	**<0.001**
Gender (M/F)	64/63	19/31	0.18
BMI	31.4 ± 7.0	30.5 ± 6.0	0.44
CCI	1.3 ± 1.7	1.5 ± 1.4	0.46
Age-Adjusted CCI	2.9 ± 2.1	3.8 ± 1.8	**0.01**
Prior ACDF	20.5% (26/127)	20.0% (10/50)	0.08
Number of Instrumented Levels	4.9 ± 0.4	6.4 ± 1.0	**<0.001**
Active Smokers	26.0% (33/127)	20.0% (10/50)	0.44
Follow-Up (Months)	32.3 ± 17.1	28.7 ± 14.3	0.16
Caudal Fusion Level			
C4	1	-	
C5	1	-	
C6	13	-	
C7	112	-	
T1	-	30	
T2	-	20	

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Table B: Demographic and Operative Characteristics in Cases Requiring Revision vs. Those that Did Not			
	Index Fusions Requiring No Further Surgery (n=163)	Index Fusions Requiring Revision Cervical Surgery (n=14)	p-value
Age	62.1 ± 10.7	56.6 ± 13.2	0.15
Gender (M/F)	75/88	8/6	0.58
BMI	30.9 ± 6.6	33.2 ± 7.5	0.29
CCI	1.4 ± 1.7	0.9 ± 0.9	**0.04**
Age-Adjusted CCI	3.2 ± 2.0	2.4 ± 1.7	0.10
Prior ACDF	23.3% (38/163)	35.7% (5/14)	0.33
Number of Instrumented Levels	5.3 ± 0.9	5.5 ± 0.9	0.51
Active Smokers	23.3% (38/163)	35.7% (5/14)	0.33
Follow-Up (Months)	30.9 ± 16.3	36.6 ± 18.0	0.40
Caudal Fusion Level			
C4	1	-	
C5	1	-	
C6	11	2	
C7	105	7	
T1	26	4	
T2	19	1	

Table C: Revision Rates Stratified by Caudal Level of Index Fusion			
Caudal Level of Index Fusion	Number of Cases Requiring Revision	Total Cases	Revision Rate
C4	0	1	0.00%
C5	0	1	0.00%
C6	2	13	15.38%
C7	7	112	6.25%
T1	4	30	13.33%
T2	1	20	5.00%
Total	14	177	7.91%

E-Poster #8

At What Point Should the Thoracolumbar Region be Addressed In Patients Undergoing Corrective Cervical Deformity Surgery?

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Introduction: Thoracolumbar malalignment is often seen in patients presenting with cervical deformities. For operative cervical deformity (CD) patients, it is unknown whether certain thoracolumbar parameters play a large role in poor outcomes (complications, DJK, reoperation) and whether addressment of such parameters is warranted. The purpose of this study was to investigate the impact of cervical to thoracolumbar ratios on poor outcomes in CD corrective surgery

Materials and Methods: Included: surgical CD pts (C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) with full baseline and 1-year data. Patients were assessed for ratios of preop cervical and global parameters including: C2 Slope/T1 slope, TS-CL/PI-LL, cSVA/SVA. Deformity classification ratios of cervical(Ames-ISSG) to spinopelvic(SRS-Schwab) were investigated: cSVA modifier/SVA modifier, TS-CL modifier/PI-LL modifier. Cervical to thoracic ratios included C2-C7 lordosis/T4-T12 kyphosis. Correlations assessed the relationship between ratios and poor outcome (major complication, reoperation, HRQL decline or failure to meet MCID). Decision tree analysis through multiple iterations of multivariate regressions) assessed cut-offs for ratios for acquiring suboptimal outcomes.

Results: 110 cervical deformity patients were included in the present analysis (61.5±9.9 years, 66% female, 28.8±7.5 kg/m2). By approach, 18.2% underwent anterior-only procedures, 46.4% posterior, and 35.4% combined. Average levels fused: 7.7±3.7 levels (Anterior: 3.5, posterior: 8.5). The average preoperative radiographic ratios assessed included a C2 slope/T1 slope 1.56, TS-CL/PI-LL of 11.1, cSVA/SVA of 5.4, CL/TK of 0.26. Ames-ISSG and SRS-Schwab modifier ratios of cSVA/SVA 0.1 and TS-CL/PI-LL of 0.35. Pearson correlations demonstrated a significant relationship between major complications and the baseline TS-CL/PI-LL with a cutoff of >12.72 (p=0.034), >0.482 Ames TS-CL/Schwab PI-LL modifiers(p=0.019), and the CL/TK ratios (>0.814, p=0.050). Reoperation had a significant correlation with the TS-CL/PI-LL (>5.819, p=0.009) and the cSVA/SVA (>3.79, p=0.002) ratios. Postoperative DJK had a correlation with the C2 slope/T1 slope (>1.59, p=0.017) and CL/TK (>0.692, p=0.0629) ratios. Not meeting MCID for NDI correlated with the CL/TK ratio (>1.402, p=0.016) and not meeting MCID for EQ5D correlated with the Ames TS-CL/Schwab PI-LL (>0.564, p=0.010).

Conclusion: Consideration of the ratio of distal regional to global alignment is a critical determinant of outcomes in cervical deformity corrective surgery. Several key ratios of cervical to global alignment were found to correlate with the occurrence of sub-optimal realignment parameters, or poor clinical outcomes. A larger cervical lordosis to thoracic kyphosis was most representative of this risk, which predicted a complication, DJK, and not meeting MCID for NDI.

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E-Poster #9

Establishment of Key Patient, Surgical, and Radiographic Factors Predictive of Reoperation Following Primary Cervical Deformity Correction

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Introduction: While advances in spinal realignment have shown promising short-term clinical results in cervical deformity surgery patients, the durability of CD-corrective surgery remains a clinical challenge. This study aims to identify inherent patient and surgical factors associated with reoperations, and quantify the effect on outcomes.

Materials and Methods: CD reop pts were compared to non-reop pts in BL demographics and radiographic alignment via $\chi 2$, Fisher exact, and t-tests. Conditional inference trees identified top factors that were associated with reop(patient, surgical, radiographic). Stepwise logistic regressions were used to identify BL patient-specific, surgical, radiographic, and HRQL factors that were associated with receiving a reop. Decision tree analysis established cut-offs for variables that were predictive of receiving a reop.

Results: 105 CD pts were included(61.5±10yrs, 28.3±7.1kg/m3, 67%F). Surgical details:7.5lvls fused, 532.3min op time, 815.9mL blood loss. By Ames modifiers, pts were most significantly maligned in their TS-CL. Of these pts, 15.2% required a reop(31.2% within 6M and 61.8% within 1Y). Pts that received a reop were younger($p<0.05$). Indications for reop were radiographic(38% DJK), neurological(13% nerve sensory deficit, 6% C5 motor deficit, 6% central cord), and instrumentation(6% painful implant). Conditional inference trees identified the top factors associated reop:[Surgical] LIV T8 to T10(4.6[1.1-20.1]) and UIV C4 to C5(4.7[1.2-18.2]; all $p<0.05$), [Radiographic] BL T4-T12<-60°, and [Clinical] BMI>28kg/m2. Multivariate analyses identified NDI score>48 increased a pts odds of undergoing a reop(1.03[1.06-1.0]) as well as having past medical history of osteoporosis(2.11[0.6-7.55]; all $p<0.05$). After controlling for DJK, postop cSVA wasn't associated with reop, however; 3M TS-CL(1[1.02-1.05]; all $p<0.05$) was associated. A predictive model for reoperation, including surgical and realignment, with an AUC of 80% was created and included UIV, LIV, preop neurodysfunction, Cobb angle T1CL>28°, and a difference in BL to 3M kyphosis value >-20. By 1Y, reop pts had a higher overall mortality rate(18.8% vs 2.2%)and were more moderately deformed cSVA(4-8cm; [53.4% vs 28.4%, all $p<0.05$]). These pts also had higher recurrent complication rates(45.5% neurological, 25% GI, and 37.5% radiographic) which were higher than anticipated after primary CD surgery. Having a reop within 6M of index surgery, was associated with developing DJK(5.6[0.9-32], increased frailty state(6[1.1-33.1]), and increased death rate(16[2.1-124.2]; all $p<0.05$).Pts that received a reop due to DJK had a greater 1Y NDI(63.6 vs 40.8) and NSR-Back score(7.6 vs 5; all $p<0.05$).

Conclusion: Overall 15% of patients required a reoperation following corrective realignment, most of which occurred after 6 months and was associated with development of Distal Junctional Kyphosis. Baseline disability, radiographic severity, flexibility and osteoporosis were able to

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predict the occurrence with good reliability. Reop patients had worse outcomes at 1 year and higher mortality rates.

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E-Poster #10

Five-Year Reoperation Rates after ACDF or Posterior Cervical Foraminotomy for Cervical Radiculopathy: Results Vary between Different Patient Populations

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Introduction: There is limited long-term comparative data for patients with cervical radiculopathy treated with either anterior cervical discectomy and fusion (ACDF) or posterior cervical foraminotomy (PCF). The aim of the current study was to compare 5-year reoperation rates after either ACDF or PCF for cervical radiculopathy in both a general commercial insurance cohort and an elderly Medicare cohort.

Materials and Methods: A retrospective cohort study was performed of both a national cohort of commercial insurance beneficiaries (2007-2016) and a national cohort of Medicare beneficiaries (2005-2014). Patients undergoing single-level ACDF or PCF with a diagnosis of cervical radiculopathy without myelopathy were identified in both cohorts. All patients were followed for a minimum 5 years postoperatively and rates of all additional cervical spine surgery were assessed for up to 5 years. Univariate logistic regression and multivariate logistic regression was used to determine the relative odds of reoperations.

Results: A total of 4,279 patients were identified in the Medicare insurance cohort (403 undergoing PCF and 3,876 undergoing ACDF). After propensity matching, 806 patients were selected for analysis (403 PCF and 403 ACDF patients). The reoperation rate at 5 years was 3.0% after PCF and 5.0% after ACDF ($P = 0.05$; Figure 1). In multivariate analysis, PCF was associated with decreased odds of reoperations within 5 years (OR = 0.55, $P < 0.05$; Table 1). A total of 2,608 patients were identified in the commercial insurance cohort (73 undergoing PCF and 2,535 undergoing ACDF). After propensity matching, 146 patients were selected for analysis (73 PCF and 73 ACDF). The reoperation rate at 5 years was 12.3% after PCF and 4.3% after ACDF ($P = 0.08$; Figure 2). In multivariate analysis, PCF was associated with increased odds of reoperations within 5 years (odd ratio [OR] = 2.09, $P < 0.05$).

Conclusion: The reoperation rates after PCF were significantly less than ACDF in the older Medicare population, but were significantly higher than ACDF in the younger commercial insurance population. These differences may be due to the lower risk of reherniation in the older population and underscores the importance of understanding patient factors for surgical planning.

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Figure 1: Reoperations in Medicare Population

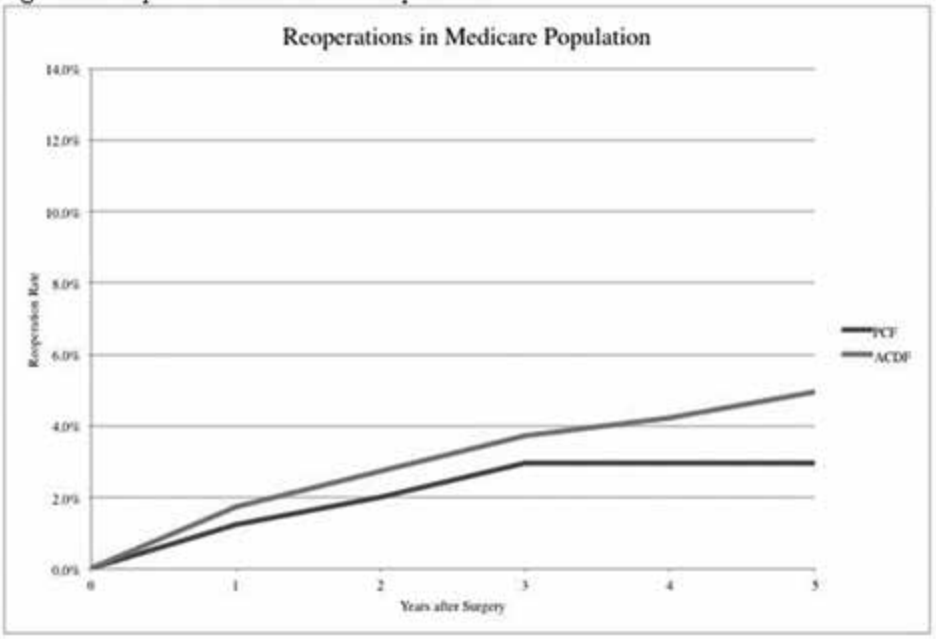

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Figure 2: Reoperations in Commercial Insurance Population

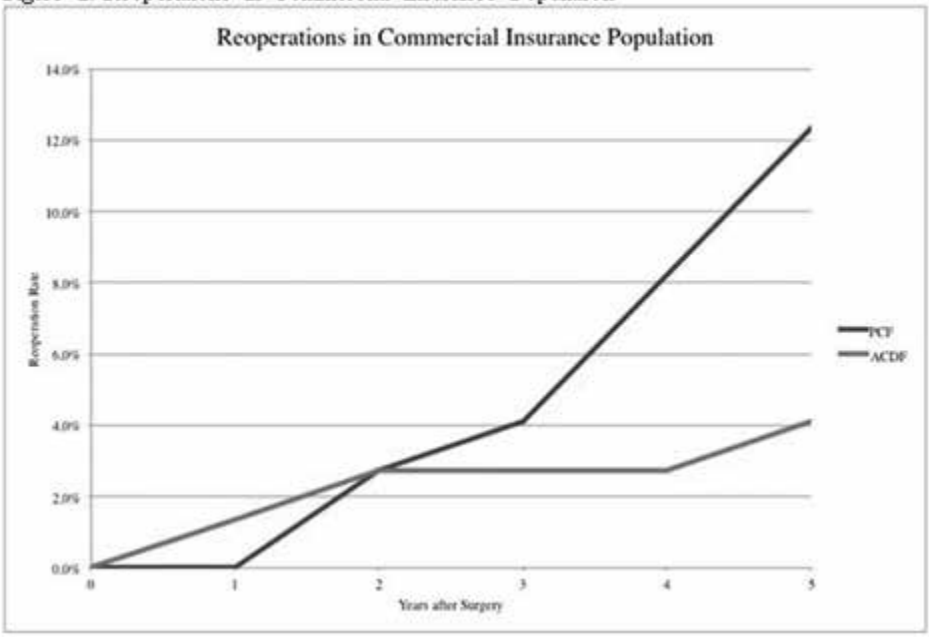

Table 1: Multivariate Analysis of Relative Odds of Reoperations

	Odds Ratio of 5-Year Reoperations for PCF, compared with ACDF (97.5% Confidence Interval)	P- value
Medicare Cohort		
Univariate Analysis	**0.55 (0.29 - 0.95)**	**0.047***
Multivariate Analysis	**0.55 (0.29 - 0.95)**	**0.048***
Commercial Insurance Cohort		
Univariate Analysis	1.90 (0.87 - 3.69)	0.078
Multivariate Analysis	**2.09 (0.94 - 4.10)**	**0.047***

NOTE: Multivariate analyses control for age, gender, and Charlson comorbidtiy index
Asterisks (*) indicate statistically significant association with reoperations ($\alpha = 0.05$)
PCF = posterior cervical foraminotomy, ACDF = anterior cervical discectomy and fusion

E-Poster #11

Laryngoscopy Screening Prior to Revision Anterior Cervical Spine Surgery: Is Vocal Cord Palsy a Relevant Factor in Deciding Approach Direction?

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Introduction: Vocal cord palsy (VCP), either symptomatic or asymptomatic, is a frequent complication of anterior cervical spine surgery (ACSS) caused by recurrent laryngeal nerve (RLN) injury, of which incidence is reported to be 10–22%. Since bilateral VCP could lead to devastating complications caused by airway compromise, preoperative laryngoscopy is recommended before revision ACSS to avoid a contralateral approach in the presence of unilateral VCP. However, the previously reported incidence of VCP—demonstrated by preoperative laryngoscopy screening performed before revision ACSS—seemed to be much higher than the authors' experience. Therefore, this study was conducted to re-evaluate the exact incidence of VCP caused by previous ACSS and aid surgeons in deciding the approach direction in revision anterior cervical surgery.

Materials and Methods: Sixty-nine patients who underwent revision ACSS between February 2009 and July 2019 were analyzed with prospectively collected data. All patients previously underwent operation via the standard Smith-Robinson approach. Before the revision operation, preoperative laryngoscopy was performed in all patients to evaluate the presence of palsy and/or structural abnormalities of the vocal cords. Patients' characteristics, results of laryngoscopy, and patient symptoms before revision surgery potentially caused by previous RLN injuries such as voice change, foreign body sensation, and chronic aspiration were recorded.

Results: The mean period between the original and revision operations was 43.1 ± 39.8 months. The approach direction during revision surgery was the same as that during original surgery in 62 (89.9%) patients, while in 7 patients (10.1%) the revision operation was carried out via a contralateral approach. The laryngoscopy result demonstrated no complete VCP or decreased motility of vocal cords (0.0%). However, arytenoid pachydermia was observed in 8 (11.6%) patients, Reinke's edema in 2 (2.9%), and laryngopharyngeal reflux disease in 2 (2.9%). In addition, 1 (1.4%) vocal cord polyp was identified. Eleven (15.9%) patients complained of symptoms that mimicked RLN injury before the revision operation. Eight (11.6%) patients experienced voice changes, 5 (7.2%) perceived a foreign body sensation, and 1 (1.4%) had chronic aspiration (Table 1). Symptoms mimicking RLN injury occurred more frequently when 3 or 4 segments—compared with 1 or 2 segments—were involved in the original operation (4/6, 66.6% vs. 10/66, 15.1%, $p<0.01$) (Table 2).

Conclusion: In contrast to previous reports, this study demonstrated that VCP detected before revision ACSS is rare. Mostly, VCP caused by ACSS is transient, and the results of the present study demonstrate that most cases of VCP is likely to recover within 4 years. Therefore, when a contralateral approach is favored because of the risk caused by adhesion and anatomic distortion at the approach side of the original operation, there is less of a need to avoid a contralateral approach owing to fear of a complete VCP. However, 15.9% of patients had RLN injury-related

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symptoms, especially in patients who underwent longer operations. Thus, vocal cord function may not recover completely, although visually identifiable vocal cord motility tended to recover earlier.

Table 1. Patients' characteristics and results of laryngoscopy

Factors		Values
Patient characteristics		
Age		57.1 ± 12.3
Sex (M: F)		46:23 (67%:33%)
Underlying disease	DM	9 (13.0%)
	HTN	24 (34.7%)
	Malignancy	5 (7.2%)
Initial diagnosis	Spondylotic myelopathy	28 (40.6%)
	Radiculopathy	21 (30.4%)
	Myeloradiculopathy	18 (26.1%)
	Trauma	2 (2.9%)
Revision diagnosis	Pseudoarthrosis	20 (29.0%)
	ASD	22 (31.9%)
	Graft failure	10 (14.5%)
	New lesion & recurrence	16 (23.2%)
	Infection	1 (1.4%)
Procedure	ACDF	54 (78.3%)
	ACCF	7 (10.1%)
	ADR	6 (8.7%)
	Discectomy & foraminotomy	2 (2.9%)
Number of previous operations	1	57 (82.6%)
	2	10 (14.5%)
	3	2 (2.9%)
Number of levels involved	1	30 (43.5%)
	2	33 (47.8%)
	3	5 (7.2%)
	4	1 (1.4%)
Laryngoscopy results		
Vocal cord palsy	No	69 (100%)
	Yes	0 (0.0%)
Abnormal laryngoscopy findings	Arytenoid pachydermia	8 (11.6%)
	Reinke's edema	2 (2.9%)
	Laryngopharyngeal reflux disease	2 (2.9%)
	Vocal cord polyp	1 (1.4%)

E-Poster #12

Graft Type and Residual Motion Do Not Affect Patient-Reported Outcomes One-Year Following Anterior Cervical Discectomy and Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) remains the standard of surgical care for cervical spondylotic radiculopathy, with more than 150,000 procedures performed per year (1). Although most patients develop a solid fusion based on static imaging, dynamic imaging has revealed that the majority of patients continue to have residual motion at the arthrodesis (2). The predisposing factors and implications of arthrodesis micromotion remain unknown. Therefore, the objective of this study was to determine the effect that graft type has on residual motion at the arthrodesis site and the implications of arthrodesis micromotion on patient-reported outcome (PRO) scores.

Materials and Methods: Following IRB approval, data was collected from 48 participants (22M, 28F; age 48.5 ± 7 years) who performed full neck flexion/extension and axial rotation range of motion (ROM) within a biplane radiography system. Twenty-one patients underwent single-level arthrodesis (1 at C4-C5, 12 at C5-C6, 8 at C6-C7) and 27 underwent double-level arthrodesis (7 at C4-C6, 20 at C5-C7) via standard anterior approach with surgeon-selected graft type and rigid plate fixation. SF-36, Neck Disability Index (NDI), and Cervical Spine Outcome Questionnaires (CSOQ) were completed by participants prior to and one year after surgery. Dynamic biplane radiographs were collected before and one year after surgery at 30 images/second in the static neutral position and as participants moved through full flexion/extension and axial rotation ROM. A model-based tracking process was used to match subject-specific bone models (obtained from CT) to the biplane radiographs with an in vivo validated accuracy of 1.1° or better in rotation (2). Residual motion was measured across the entire arthrodesis site for both single- and double-level fusions. The residual motion at arthrodesis segments and PROs were compared between autograft and allograft groups using Student's t-test. Patients were then divided into a "pseudarthrosis" group and a "solid fusion" group to compare PROs based on different degrees of residual motion. Pseudarthrosis was defined as more than 3° of flexion/extension residual motion based upon previous studies that used 2° to define pseudarthrosis (3), plus our measurement precision of 1°. PROs between the two groups were compared using Student's t-test, with $p<0.05$ defining statistical significance.

Results: Patients who received allograft showed greater flexion (2.1° vs. 1.3°, p=0.16), extension (2.4° vs. 1.5°, p=0.04), and total flexion/extension (4.1° vs. 2.8°, p=0.06) residual motion (Figure 1). There was no significant difference between groups in twist or coupled bending residual motion during the head rotation movement. No significant differences were found between groups with respect to SF-36 subcategories, NDI, or CSOQ subcategories (Figure 2). Further, when comparing the PROs of patients who developed pseudarthrosis with those who did not, there were no significant differences in PROs between the two groups (Figure 3).

Conclusion: Allograft may result in slightly more residual motion at the arthrodesis site one year

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after ACDF. However, there is no evidence that PROs are adversely affected by slightly increased residual motion at the arthrodesis site one-year after surgery. The results of this study suggest that the current definition of pseudarthrosis correlates poorly with clinically significant findings.

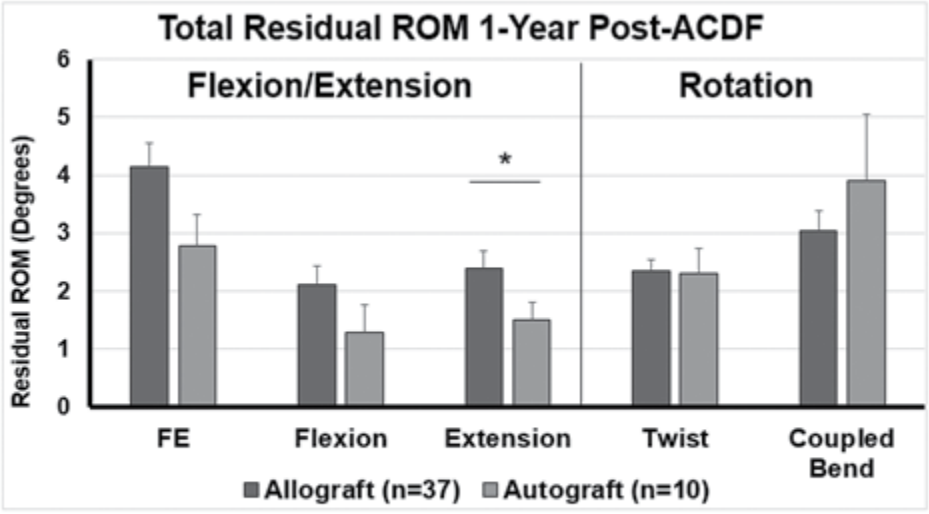

Figure 1: Residual Motion by Graft Type and Motion Pattern. This graph demonstrates the one-year post-operative residual motion at arthrodesis segments, as sorted by head movement and graft type. Asterisks represent statistically significant differences between allograft and autograft groups ($p<0.05$). Error bars represents one standard error. FE- Combined Flexion/Extension.

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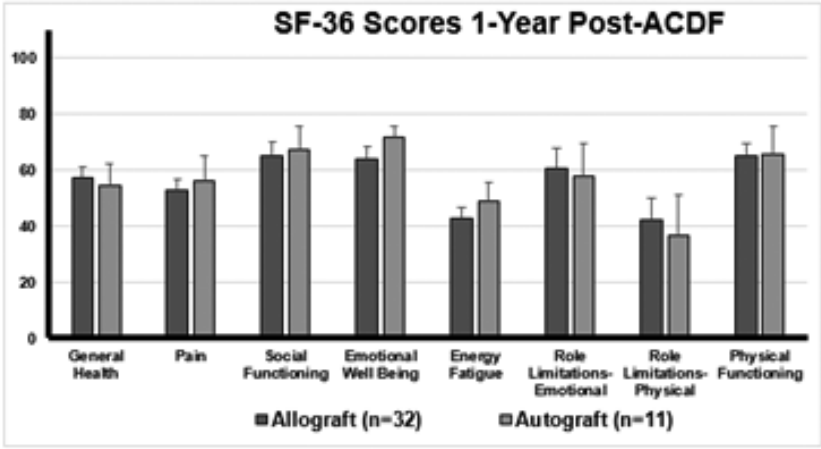

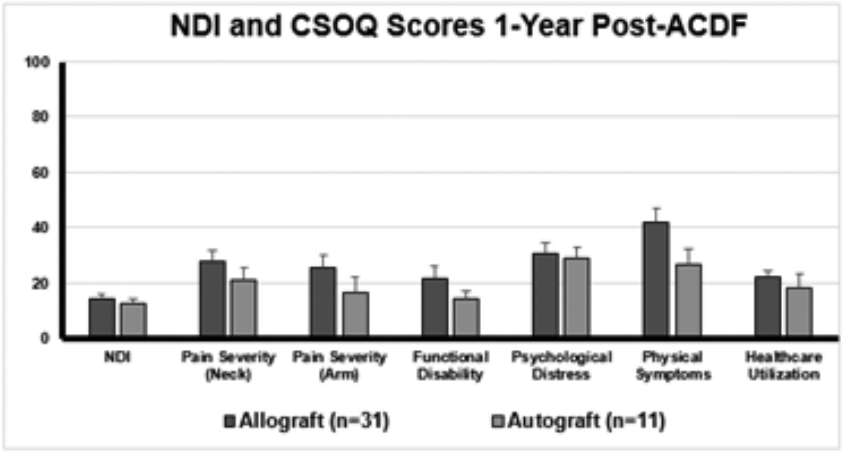

Figure 2: Patient-Reported Outcomes One-Year Following ACDF. This figure demonstrates the one-year postoperative SF-36 (top), and NDI and CSOQ (bottom) subcategory scores in allograft and autograft groups. Higher scores on the SF-36 represent better outcomes, whereas lower scores on the NDI and CSOQ represent better outcomes. Error bars represent one standard error.

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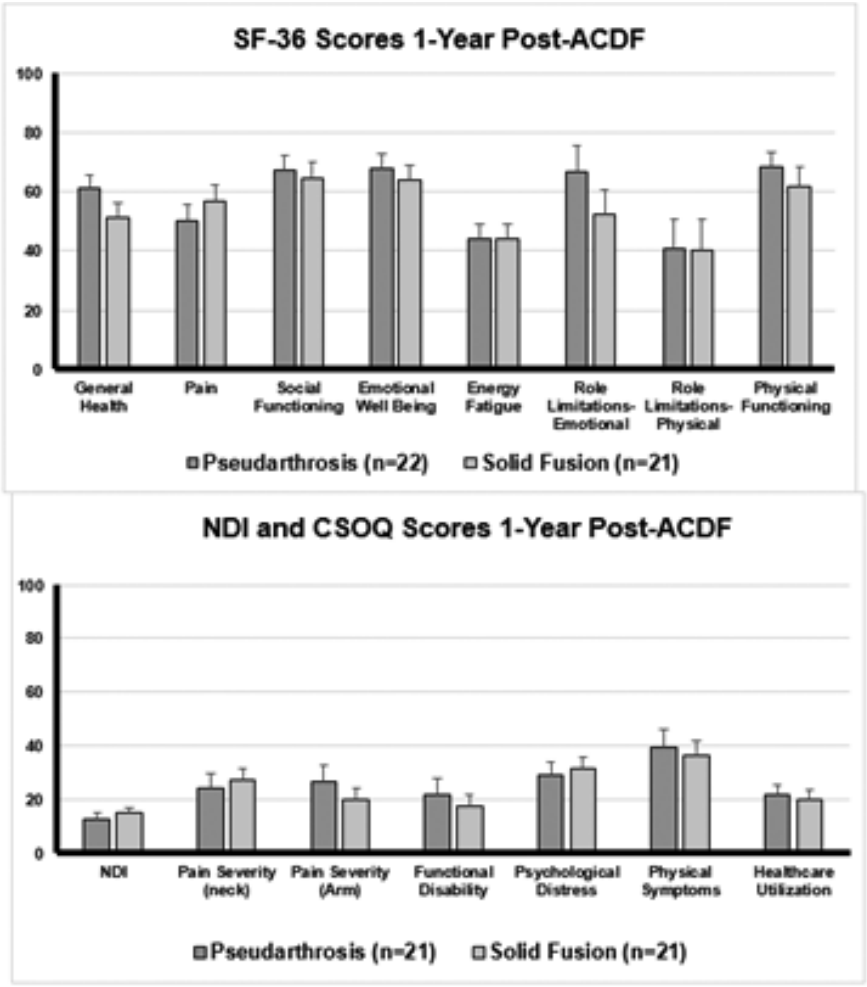

Figure 3: Patient Reported Outcome Scores Based on Residual Motion One-Year Following ACDF. This figure demonstrates the one-year postoperative SF-36 (top), and NDI and CSOQ (bottom) subcategory scores in pseudarthrosis and solid fusion groups. Pseudarthrosis was defined as >3° flexion/extension residual motion. Higher scores on the SF-36 represent better outcomes, whereas lower scores on the NDI and CSOQ represent better outcomes. Error bars represent one standard error.

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E-Poster #13

Association of patient body mass index (BMI) with posterior subcutaneous fat thickness in the cervical spine

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Introduction: Surgical site infections are a relatively rare, but significant potential complication following cervical spine operations. Patient body mass index (BMI) has previously been shown to be a risk factor for post-operative infections in the spine [1,2]. However, more recent studies [3,4] have challenged this notion and shown that local subcutaneous fat thickness is a better predictor of post-operative infections, and this is likely due to the fact that body mass is not evenly distributed. To our knowledge, no study has directly investigated whether or not there is an association between patient BMI and the thickness of the posterior cervical subcutaneous fat. This leaves a void in knowledge on whether or not BMI can be used as a reliable surrogate marker for local subcutaneous fat when counseling patients pre-operatively on the potential risks of undergoing a cervical spine procedure. We performed a retrospective cohort imaging review study to test the hypothesis that patient BMI is not strongly correlated with local subcutaneous fat thickness throughout the cervical spine.

Materials and Methods: A total of 96 adult patients were retrospectively identified who had preoperative cervical non-contrast computed tomography (CT) scans and a BMI recorded within 30 days of the scan. Subcutaneous fat thickness was assessed by manually measuring the distance (mm) from the spinous processes of C2-C7 to the edge of the skin (Figure 1). Bivariate Pearson correlations and linear regression were used to analyze the relationship between BMI and subcutaneous fat thickness at each individual C2-C7 level, as well as the average total thickness at C2-C7. A one-way analysis of variance (ANOVA) was used to analyze differences in C2-C7 average distances while stratifying by BMI groups of less than 25, 25-30, 30-40, and greater than 40.

Results: BMI had a moderate correlation with average C2-C7 (r=.546) subcutaneous fat thickness (Figure 2). BMI had a weak to moderate correlation with each individual C2-C7 distance, with the strongest correlation at the C7 level (r=.583). All correlations were significant ($p<0.05$). These same analyses remained significant using linear regression models controlling for patient age, gender, and presence of diabetes ($p<0.05$). One-way ANOVA models showed no difference in the average C2-7 distance in patients with BMIs of 25-30 compared to those with BMIs of 30-40 (P=0.999). However, those at the extremes with BMI <25 and BMI >40, were significantly different from the other groups (Figure 3).

Conclusion: Patient BMI has a weak to moderate correlation with posterior subcutaneous fat thickness in the cervical spine. Patients with a BMI of 25-40 do not have significant differences in their average C2-7 fat thickness. These results imply that BMI is not a strong predictor of posterior subcutaneous fat thickness in the cervical spine, especially in patients with BMIs of 25-40. BMI should not be used as a surrogate for local subcutaneous fat thickness in preoperative risk assessments in posterior cervical spine surgery.

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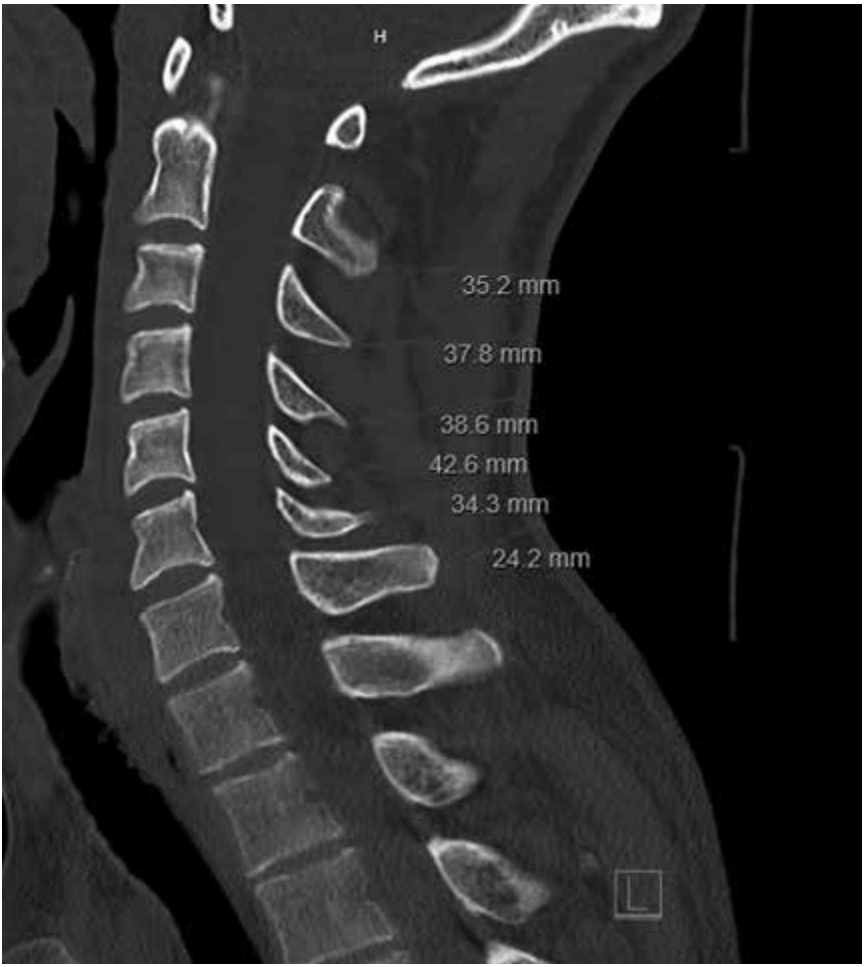

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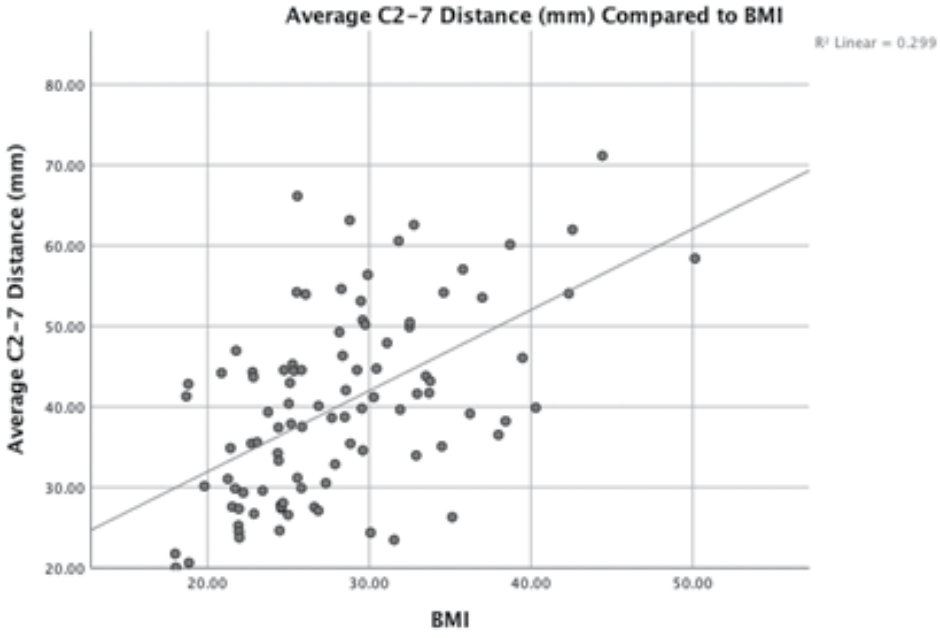

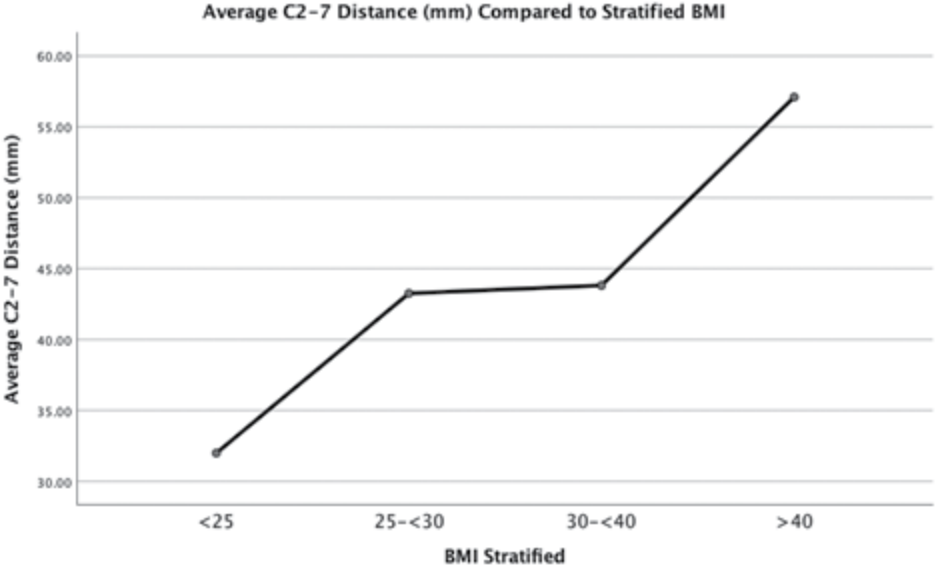

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E-Poster #14

Classification System for Cervical Spine Deformity Morphology: A Validation Study

Philip Louie, MD, *Basel Sheikh Alshabab, MD, Michael McCarthy, MD, Sohrab Virk, MD, James Dowdell, MD, Michael Steinhaus, MD, Francis Lovecchio, MD, Andre Samuel, MD, Kyle Morse, MD, Todd Albert, MD, Sheeraz Qureshi, MD, MBA, Sravisht Iyer, MD, Yoshihiro Katsuura, MD, Russel Huang, MD, Matthew Cunningham, MD, PhD, Yu Cheng Yao, MD, Karen Weissmann, MD, Virginie Lafage, PhD, Renaud Lafage, MS, Han Jo Kim, MD*

Introduction: The high variability in normal cervical alignment based on postural- and thoracolumbar-driven changes have been shown to indirectly impact cervical alignment. Without an organized method of analysis, CD-focused research findings may be compromised in the setting of wide heterogeneity of pathology. The purpose of this study is to provide an initial validation of a recent morphological classification of cervical spine deformity pathology.

Materials and Methods: The cervical radiographs (AP, lateral, flexion, extension views) of 38 patients with cervical deformity were distributed (10 each of focal [F], flatneck [FN], cervicothoracic [CT], and 8 coronal [C] deformities). Based on the available imaging, the reviewers were asked to group the cervical deformities based on the dominant morphology per Kim et al.1 (Figure). Fleiss kappa coefficient was utilized to evaluate intra- and inter-rater reliability. Reviewers performed the classification of all patients twice with a minimum of 7 days between each round for intra-rater reliability. The classification accuracy of the main driver of deformity was reported overall and compared between deformity type and rater experience using chi-square test.

Results: Overall classification of the deformity demonstrated a Substantial reliability (Inter-rater Fleiss kappa score 0.612 [95% CI: 0.606 0.619], mean Intra-rater 0.686). Of 570 possible questions, reviewers provided 419 correct answers (73.5%). Stratification of the correct grouping by type of deformity demonstrated a lower reliability for flatneck and CT compared to focal (FN 67.3%, F 84.7%, CT: 68.7%, C: 73.3%, p=0.002). There was lower accuracy for patients having a secondary driver of deformity, as 50% of the rater selected the first driver and 50% selected the secondary driver. When combining the true answer as being selected at least one of the 2 main drivers, overall accuracy increased to from 73.5% to 86.0%. Similarly, following combination of the 2 main drivers, the accuracy by type of deformity increased and was no longer significantly different (FN 90%, F 86.7%, CT 91.7%, C 82.5% p=0.078). There were no significant differences between the level of training of the reviewers (Resident 86.2%, Fellow: 89.5% Surgeon: 84.5% p=0.432). When looking at individual accuracy, accuracy ranged from 68.4% to 100% with 12 raters at an accuracy above 80%.

Conclusion: The overall reliability of cervical deformity morphology has been demonstrated. Accuracy of the classification system was not impacted by experience, demonstrating its simplicity. Further analysis of the surgical treatment strategy for these different patterns will guide the most effective treatment.

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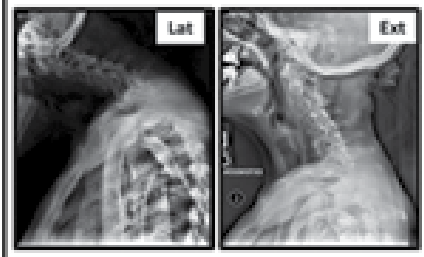
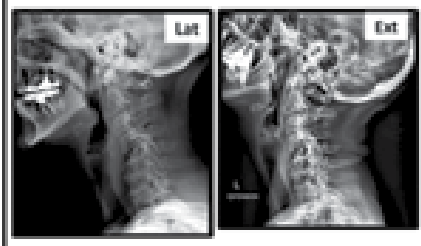
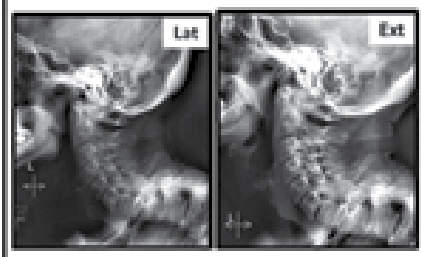
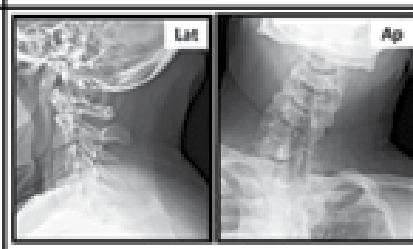
Table 1. Description of Cervical Spine Morphologic Classification Groups

Cervical Deformity Classification	Radiographic examples	Description of Presentation
Flatneck		A pattern involving a flat neck with lack of compensation. Large cervical mismatch (TS-CL) despite having some ability to compensate for their deformity. "Chin-on-chest" deformity or those patients with poor muscle health who are unable to maintain horizontal gaze.
Focal		A pattern involving a focal deformity. Large focal kyphosis between 2 adjacent vertebrae without a necessarily large regional cervical kyphosis. Global alignment of the cervical spine for these patients with focal deformity, however, not compromised due to large compensation in T1S (< 22°).
Cervicothoracic		A pattern involving a cervicothoracic deformity. Cervical mismatch due an extremely large T1S (> 30°) Hyperlordosis of the cervical spine as a compensatory mechanism that is not able to compensate enough to meet the T1S and resulted in CD.
Coronal		A pattern involving an isolated coronal plane deformity. Sagittal alignment appears within normal ranges without sagittal plane deformity.

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E-Poster #15

The Impact of Spondylolisthesis on Patients Undergoing Laminoplasty for Cervical Spondylotic Myelopathy: Clinical and Radiographic Outcomes

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Introduction: The subaxial cervical spine can develop degenerative cervical spondylolisthesis (DCS) and instability in the setting of cervical spondylotic myelopathy (CSM).1-3 Laminoplasty may be an effective technique to halt the progression of myelopathy in these patients. The purpose of this study was to evaluate the radiographic and clinical outcomes of CSM patients undergoing laminoplasty comparing those with or without DCS in the operative levels. Additionally, we evaluated the progression of DCS over time following laminoplasty.

Materials and Methods: Consecutive patients who underwent laminoplasty for DCM by one of three surgeons were included if they had a minimum of 1-year follow-up and 4 sets of cervical spine radiographs available (pre-operative, 6 weeks and 6 months, and 1 year postoperative). Lateral cervical spine plain radiographs were evaluated for the presence of spondylolisthesis (and listhesis in mm), cervical lordosis, and cervical sagittal vertical axis (cSVA). Demographic and perioperative data was collected. Patients were separated into 2 cohorts based on the presence or absence of a spondylolisthesis pre-op: non-spondylolisthesis (NoS), spondylolisthesis (S). Numerical rating scale (NRS) neck scores were recorded at the latest follow-up. Categorical data was evaluated with mean and standard deviation or percentile based on distribution using Kolmogorov Smirnov testing. Comparisons between patients with or without DCS were performed with independent t-test of Mann-Whitney based on distribution.

Results: Overall, 45 patients with a mean age of 64.0±11.6 years were included. Males made up 51% of the study population and the mean BMI was 28.17±6.17. In total, 12 patients were in the S group while 33 patients were in NoS. There were no differences in age, sex, or BMI between groups. Operatively, there was no difference in operative time (NoS: 141±41min vs S: 147±49min; p=0.59), estimated blood loss (NoS: 154±96ml vs S: 128±75ml; p=0.28), or length of stay (NoS 2.9±1.8 days vs S 2.1±1.0 days; p=0.10). There was only a single re-operation in the NoS group that underwent an anterior cervical discectomy fusion for an acute disc herniation at C7-T1; 3 years following the initial laminoplasty. Overall, NRS scores were pre-operatively 2.08±2.8, 6-weeks post-op 2.06±2.5 and significantly improved by 6 months (1.17±1.6; p=0.03) and 1 year (0.81±1.8; p=0.009) post-op. There were no significant differences in NRS neck scores by NoS and S patients at any time period. Radiographically, there were no differences in cervical sagittal alignment with no differences noted in the change in C2-7 lordosis or cSVA at all time points.The average pre-operative spondylolisthesis was 2.9±0.9mm/15.8±5.6% (flexion 3.1±1.7mm/17.1±9.7% and extension 1.6±0.9mm/8.8±4.9%). When evaluating the fate of the spondylisthesis following laminoplasty, there was no significant difference between pre-operative spondylolisthesis and early post-operative time point, indicating a lack of progression.

Conclusion: In one year following laminoplasty for CSM, patients have similar radiographic and

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clinical outcomes despite the presence of a spondylolisthesis in the subaxial cervical spine, with no change in the magnitude of spondylolisthesis. CSM patients presenting with DCS can expect similar outcomes compared to those without DCS.

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E-Poster #16

Long-term radiographic outcome of occipitocervical fixation for craniocervical instability: An average 7-year follow-up

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Introduction: Occipitocervical fixation (OCF) is a procedure used for treating craniocervical instability caused by inflammatory arthritis, congenital condition, trauma, and tumor invasion. Clinical improvement after OCF has been well established.(1) However, few studies have reported fusion rate and radiographic alignment change in unfused subaxial segments at long-term follow-up. Understanding the potential alignment change would be paramount to optimize postoperative horizontal gaze. The purpose of this study is to investigate the long-term radiographic outcome of patients who underwent OCF using modern pedicle screw and rod/plate system.

Materials and Methods: We retrospectively reviewed 22 patients (an average age of 62.1 years, 12 female) who underwent OCF in a single academic institution. The patients satisfied minimum 2-year radiographic follow-up. We investigated baseline demographics and following pre- and postoperative sagittal alignment parameters: Macgregor slope, C0-2 angle, C2-7 cobb angle, and cSVA. We subgrouped the patients into those whose C0-2 angle increased postoperatively (the C0-2 increase group) and those whose C0-2 angle decreased postoperatively (the C0-2 decrease group). The unfused subaxial segments (C2-7 angle) was compared between the two groups at the final follow-up. The fusion status was evaluated based on CT scan at the final follow-up.

Results: Preoperative diagnosis included rheumatoid arthritis (n=11), degenerative craniocervical instability (n=7), congenital instability (n=2), traumatic odontoid fracture (n=1), and metastatic tumor destruction (n=1). The average follow-up period was 78.6 months. The lowest instrumented vertebra was at C2 (63.6%), C3 (18.1%) and C4 (18.1%). 22.7% of the patients required simultaneous posterior decompression in the subaxial segments. The fusion rate at the final follow-up was 77.2%. Distal junctional kyphosis occurred in 2 patients (9.0%). The C0-2 increase group demonstrated ave. 4.8° decrease of C2-7 angle as a compensation for 5.1° of C0-2 increase. In contrast, the C0-2 decrease group showed ave. 9.2° increase of C2-7 angle as a compensation for 6.3° of C0-2 decrease. Chronological progression of subaxial spondylolisthesis was observed in 30% of the C0-2 increase group vs. 33.3% of the C0-2 decrease group ($p>0.05$). During the follow-up period, revision subaxial decompression surgery was required in 10% of the C0-2 increase group vs. 8.3% of the C0-2 decrease group ($p>0.05$)

Conclusion: The fusion rate of occipitocervical fusion for craniocervical instability was 77.2% at average 78.6-month follow-up. Compensatory sagittal alignment change may occur in the unfused subaxial segments in align with the alignment change in the instrumented occipitocervical segments, resulting in the maintenance of horizontal gaze. During the long-term follow-up, additional decompression in subaxial segments may be required regardless of the lordotic or kyphotic spontaneous alignment change.

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E-Poster #17

Predictors for poor outcomes after posterior decompression surgery in patients with cervical spondylotic myelopathy: A multicenter retrospective study of 685 cases.

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Introduction: Posterior decompression surgeries have been performed for the treatment of patients with cervical spondylotic myelopathy (CSM), and their clinical results have been reported to be favorable in several studies. Conversely, some patients show poor neurological recovery even after these surgical procedures. Evidence on the predictors of surgical outcomes in patients with CSM was limited. The purpose of this study was to identify the predictors of poor outcomes after a posterior decompression surgery for CSM.

Materials and Methods: A total of 675 patients who underwent posterior decompression surgery and were followed up for >1 year between January 2012 and December 2014 were enrolled in this study. The Japanese Orthopedic Association (JOA) recovery rate was determined, and patients were divided into the following three outcome groups based on the JOA recovery rate: fair (recovery rate, <22.2%: mean-1SD), moderate (22.3–77.1%), and good (>77.2%: mean+1SD) groups. Demographic patient information, including age, sex, body mass index (BMI), smoking history, symptom duration, and medical history of comorbidities were retrospectively collected. Radiographic parameters and MRI data were also assessed preoperatively, and predictors of poor outcomes were identified using the univariance analysis with one-way analysis of variance and the multinominal logistic regression analysis.

Results: The study included 675 patients, with the mean JOA recovery rate of 49.7% (range, from -50 to 100; skewness -0.24). According to the JOA recovery rate, 105 (15.6%), 462 (68.4%), and 108 (16.0%) were assigned to the fair, moderate, and good groups, respectively, with the mean JOA recovery rates of 6.0% ± 13.8%, 50.1% ± 15.0%, and 90.6% ± 8.5%. The univariance analysis showed that the mean age of 69.8 ± 10.8, 67.5 ± 11.4 years, and 63.2 ± 10.6 years in the fair, moderate, and good groups, indicating a significant decrease with improving outcomes ($p < 0.01$). The frequency of DM showed significant differences among the three groups (27.6% vs. 21.4% vs. 12.0%; $p = 0.02$) In the multinominal regression analysis between fair and good groups, old age (odds ratio = 2.47; $p = 0.001$) and longer symptom duration (odds ratio, 1.02; $p = 0.039$) were found as significant independent predictors of poor outcomes.

Conclusion: Our findings suggest that old age and longer symptom duration are independent predictors of poor functional outcomes after a posterior decompression surgery in patients with CSM.

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Table1 Multinominal logistic regression analysis between fair and good groups

	b	Odds ratio	95% CI	P-value
Age (per decade increase)	0.91	2.47	1.47–4.17	0.001
Duration of symptoms (mo)	0.02	1.02	1.00-1.03	0.039

CI, confidence interval

E-Poster #18

Patient Factors Associated with Spine Trauma Injury Patterns in the Elderly

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Introduction: As the population ages, the incidence of spine trauma in the elderly also continues to rise. Spine trauma includes a wide variety of injury patterns and range of severity in the elderly. What remains relatively unexplored are the underlying patient factors that contribute to and potentially predict these many patterns of spine trauma. With better understanding of the unique combination of patient comorbidities, mechanisms, and physical features associated with different spine injuries, better directed efforts can be made at prevention and risk management. The aim of this study is to better characterize the patient factors associated with different spine injury types as well as their severity in an elderly population.

Materials and Methods: All elderly (65+) trauma patients with spine trauma who presented to a single, large, level I trauma center from 2010-2019 were identified via an institutional trauma database. Retrospective chart review was completed to record comorbidities, presenting injury information, imaging findings, treatment, and long-term outcomes for all patients. Patients were divided based on injury type into the following categories: burst, compression, flexion type, extension type, lateral mass, occipital condyle, odontoid, fracture-dislocation, and articular facet fractures/disruptions. A multivariable regression was conducted to assess for correlation or statistical difference between various patient characteristics and each injury category. Additional multiple regression analysis was done to find factors associated with injury severity measures (eg, the Injury Severity Score, ISS) as well as concomitant injuries (eg, multiple rib fracture).

Results: A variety of factors, including sex, markers of osteoporosis and sarcopenia such as Hounsfield unit (HU) of the L3 vertebral body and psoas index, place of injury, and BMI were significantly associated ($P<0.05$) with distinct types of injury. For example, Odontoid fractures (AO types A-C) were significantly associated increased age ($P<0.0001$), dementia ($P=0.0025$), low L3 HU ($P=0.0258$), and low psoas total area ($P=0.0008$). In contrast, other injury patterns, like flexion-distraction, had no significantly correlated factors. Several factors were significantly associated with increased ISS, including male sex ($P=0.0043$), motor vehicle collision (MVC) mechanism ($P<0.0001$), diabetes ($P=0.0232$), and low L3 HU ($P<0.0001$). Concomitant closed head injury, multiple rib fractures, pelvic fractures, and appendicular fractures also had significant associations with multiple patient characteristics ($P<0.05$).

Conclusion: The wide variety of comorbidities, physical attributes, and lifestyles seen in the elderly are associated with the equally broad spectrum of spine trauma see in this population. While some fracture patterns had strong associations with patient factors—sex, BMI, and bone density—other fracture patterns had no significant association with patient factors. Furthermore, injury severity is also associated with certain comorbidities and patient factors, such as male sex and diabetes. Closer examination of these factors could provide insight into pathomechanism, epidemiology, and prevention. For example, focusing on treatments for osteoporosis and malnutrition in the elderly population may have protective benefits for certain injury patterns in spine trauma.

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Table 1

	Injury Type																	
	Burst (eg, 51._.A3-4)		Compression (eg, 51._.A1-2)		Flexion Type (eg, 53._.B1)		Extension Type (eg, 51._.B)		Lateral Mass. (eg, 51._.CF1)		Occipital Condyle. (AO Type 1)		Odontoid (AO Types A-C)		Fracture-Dislocation. (eg, 51._.Cbl)		Articular Facet (eg, 51._.CF)	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Male	143	769	326	586	104	808	215	697	54	858	17	895	127	785	10	902	38	874
Female	157	656	320	493	59	753	135	678	58	755	17	796	170	643	2	811	25	788
P-Value	*0.047		0.122		*0.003		*<0.001		0.307		0.735		*<0.001		*0.034		0.228	
Dementia Yes	35	169	73	131	19	185	35	169	11	193	2	202	68	136	0	204	5	199
Dementia No	265	1256	579	948	144	1376	315	1206	101	1420	32	1489	229	1292	12	1509	58	1463
P-Value	0.925		0.601		0.942		0.236		0.497		0.278		*<0.001		0.203		0.331	
MVC	122	581	248	455	70	633	153	550	60	643	15	688	77	626	8	695	36	667
Other Mechanism	178	844	398	624	93	928	197	825	52	970	19	1003	220	802	4	1018	27	995
P-Value	0.973		0.122		0.554		0.206		*0.004		0.687		*<0.001		0.067		*0.007	
	P-Value		P-Value		P-Value		P-Value		P-Value		P-Value		P-Value		P-Value		P-Value	
Age	0.389		0.209		*0.042		0.738		0.852		0.361		*<0.001		0.799		*0.014	
BMI	0.065		*0.048		*0.002		0.075		0.981		0.271		0.140		0.192		0.169	
L3 Average HU	0.555		*0.002		0.093		0.116		0.864		0.782		*<0.001		0.521		*<0.001	
Psoas Total Area	*0.003		0.227		*0.012		*0.033		0.076		0.175		*<0.001		0.305		0.075	

*Indicates statistical significance (P<0.05)

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E-Poster #19

Development of a patient-centered educational video resource for cervical myelopathy

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Introduction: Introduction: Accurate educational cervical spondylotic myelopathy videos with animation produced by physicians are not accessible. The literature for spinal cord injury patient education has demonstrated that 91% of viewers prefer video presentations over text for education (Hoffman et. al).Our goal was to develop a freely accessible, animated educational intervention media resource, guided by patients, physicians and medical illustrators.

Materials and Methods: A search was performed using keywords "cervical myelopathy" on YouTube® and the first 50 videos for the keyword were analyzed. Video source, time since upload, duration, and number of views, likes, and dislikes were recorded. Video popularity was reported using the video power index (VPI) and view ratio. Video educational quality was measured using the recognized DISCERN, the Journal of the American Medical Association (JAMA) score and a novel RC-specific score (RCSS). Articles on neurosurgical conditions and treatments listed on both the AANS site and MedlinePlus were analyzed.An animated educational intervention was developed. A focus group of patients, a medical communications expert, leaders in patient advocacy, myelopathy researchers, and neurosurgeons provided detailed guidance on areas of focus. Medical illustration experts, publication experts, and neurosurgeons collaborated to produce animated, patient friendly visuals to address these topics.

Results: An analysis of YouTube videos using the search term "cervical myelopathy" showed that only the 11th search result from the first 50 videos contained accurate animation and was produced by a physician. Further, online neurosurgical patient education materials from the American Association of Neurological Surgeons and Medline Plus can be difficult to understand and can act as barriers to proper healthcare engagement (Ramos et al).Video: To provide a broadly accessible education resource, the video will be freely available, and has been narrated by neurosurgeons in several languages including English, Spanish, Mandarin Chinese, French, German, and Japanese.

Conclusion: We developed one of the first accurate patient centered educational videos to help patients and health care professionals recognize cervical myelopathy and decrease suffering and anxiety from the disease.

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E-Poster #20

Baseline Myelopathic Severity is an Independent Determinant of Adverse Outcomes, Complications and Functional Recovery Following Adult Cervical Deformity Corrective Surgery

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Introduction: Little is known of the impact of myelopathy severity in patients undergoing cervical deformity (CD) on postoperative patient-reported outcomes when taking into account neck disability severity and symptomatic presentation. The purpose was to investigate the impact of myelopathy severity on post-operative outcomes.

Materials and Methods: Surgical CD patients (C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) with baseline HRQLs and radiographic follow-up[1-yr]. mJOA was utilized to assess baseline myelopathy severity, categorized per Tetreault et al. (Severe <12). Ratios of baseline myelopathy groups to neck pain severity groups (based off of NDI categories Vernon et. al:), assessed the impact of myelopathy in conjunction with neck disability. A ratio greater than 1 indicated that the patient's myelopathy severity weighed more than their reported neck disability, and vice versa. In a subanalysis, Severe and Not Severe myelopathy groups were propensity score matched (PSM) for cSVA to account for differences in CD severity at baseline. Univariate analyses were performed to determine whether myelopathy severity had an impact on postop outcomes.

Results: 136 CD patients included(56.6yrs, 49%F, 29.9kg/m2). Cohort surgical factors included, by approach, 26.9% anterior, 46.9% posterior, 26.2% combined (levels fused: 5±2.1). Baseline mJOA score was 13.1±2.9, with a mean NDI of 58.9±18.8. 28.7% had Severe baseline myelopathy, 71.3% Not Severe. Severe myelopathy patients presented with smaller L1-S1 (3.4° vs 28°, p=0.047), larger T4-T12 (-1.2° vs -20.6°, p=0.024), and increased diabetes (34%, p=0.015). Severe patients had greater baseline NDI scores (68.2 vs Not Severe: 55.1, p<0.001). The mJOA/NDI ratio mean for the cohort was 0.64±0.31. 72.8% of patients were more impacted by their neck disability over their myelopathy severity (ratio <1), 17.6% had equal severity of NDI and mJOA, and 2.9% had more severe myelopathy (ratio >1). Patients that were more impacted by myelopathy had significantly greater incidence of postop neurological complications(25%, vs greater NDI: 3%, p=0.042) and DJK(25%), p=0.034. After PSM for cSVA in the subanalysis, 26 patients remained in Severe and Not Severe myelopathy groups (mean cSVA: 28.5mm). Severe patients had increased neurologic complications(15.4%) and met MCID for EQ5D significantly less than the Not Severe baseline myelopathy patients (11.5% vs 34.6%), both p<0.05. From baseline to 1-year, 31.5% improved, 49.3% same, and 19.2% deteriorated in their myelopathy severity. Patients who improved in mJOA severity by 1-yr had less incidence of DJK (0% vs 8.3 vs 28.6).

Conclusion: Patients who report more severe myelopathy over neck disability preoperatively are at increased risk for neurologic complications and distal junctional kyphosis occurrence. When controlling for baseline deformity severity, this remained true for patients with severe myelopathy presentation along with decreased overall quality of life at follow up.

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E-Poster #21

Posterior ligament-bone injury classification and severity score: A novel approach to predict the failure of anterior-only surgery for subaxial cervical facet dislocations

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Introduction: To propose a novel posterior ligament-bone injury classification and severity (PLICS) score system that can be used to reflect the severity of subaxial cervical fracture dislocations (SCFDs) and predict the failure of anterior-only surgery; and to measure the intraobserver and interobserver reliability of this system.

Materials and Methods: Ten patients were randomly selected for intraobserver reliability evaluation on two separate occasions, one month apart. Another 30 patients were randomly selected, and the interobserver reliability was measured by comparing results of each case between each reviewer and averaging. Lateral digital radiograph, computed tomography (CT) scans and MRI of the cervical spine were made for all patients at the time of presentation. The presence of at least two of the above three conditions (no postoperative cervical kyphosis or deformity, no interspinous widening at the cervical dynamic radiography and without hyperintensive signal changes through posterior ligament structure (PLS) on T2-weighted and/or STIR images) is considered radiologically stable. PLICS is based on the injury severity of the ligament-bone structure of three elements, in which a specific point value (0 - 3) is assigned to a particular variable within each element reflective of the severity of injury. To analyze the difference in the PLICS score, 354 patients fulfilled the follow-up were divided into stable and unstable groups according to whether radiologically stable was observed during follow-up. The inclusion criteria included as followed: 1. the preoperative magnetic resonance imaging (MRI) detected fracture dislocation accompanying with an extruded disc, which deformed the dural sac beyond the line between the postero-inferior corner of cranial vertebrae and the postero-superior corner of caudal vertebrae; 2. the clinical level of neural dysfunction corresponds to the segment of reconstruction without the requirement of an extensive posterior decompression; 3. the reduction can be achieved under an attempt at the awake skull traction preoperatively or via anterior approach after the removal of herniated disc intraoperatively. The exclusion criteria included as followed: reduction can't be by preoperative skull traction, or by an anterior approach intraoperatively; the patients obtained a posterior reconstruction surgery when the intramedullary edema may extend beyond the segment of dislocation; severe traumatic cervical spondylolisthesis (over grade 3); the patients are accompanying by ankylosing spondylitis.

Results: For the intraobserver reliability, the mean intraclass correlation coefficient for the ten reviewers was 0.931. For the interobserver reliability, the mean interobserver correlation coefficient for the three elements was 0.863. Among 16 patients with PLICS score 7, 2 patients in the stable group manifested with severe injury of the posterior ligamentous complex (PLC); extremely unstable lateral mass fractures with or without severe injury of PLC was detected in the 14 patients of the unstable group.

Conclusion: The proposed PLICS score system showed excellent intraobserver and interobserver reliability. Bilateral facet dislocation is not an absolute indication for posterior reconstructive

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surgery. When a PLICS score is > 7 or = 7 accompanied by extremely unstable lateral mass fractures, the risk of postoperative failure after an anterior-only reconstruction is high and supplemental posterior strengthening can be considered.

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E-Poster #22

What Type of Incision for Anterior Cervical Spine Surgery Involving Long Segments Can Bring Better Cosmetic and Fucntional Outcomes?

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Introduction: Although the Smith-Robinson approach using a single transverse incision is most widely applied for anterior cervical spine surgery (ACSS), operations involving ≥3 segments often require longitudinal incisions for better exposure. However, longitudinal incisions often involve sacrificing neurovascular structures connected to the pharynx, larynx, and esophagus, which can adversely affect their function. Further, a longitudinal incision is made perpendicularly to the minimal skin tension line, which creates more tension than with a transverse incision, thereby possibly leading to inferior cosmetic results. Therefore, the authors of this study consecutively performed double transverse incisions for ACSS involving ≥3 segments (Figure 1). This study aimed to determine whether a double transverse incision can provide superior cosmetic and functional outcomes over a longitudinal incision.

Materials and Methods: This prospective study included 40 patients who underwent ACSS involving ≥3 segments. The results of 17 patients who underwent surgery with a double transverse incision (DT group) were compared with those of 23 patients who underwent surgery with a longitudinal incision (L group). Dysphagia, dysphonia, and skin scaring were assessed using patient-reported outcome measures at 1, 3, 6, 12, and 24 months postoperatively. The Bazaz score was used to assess postoperative dysphagia, and the voice handicap index-10 (VHI-10) was used to assess dysphonia. The Vancouver scar scale (VSS) and patient and observer scar assessment scale (POSAS) were used to assess cosmetic results.

Results: In total, 19 patients underwent anterior cervical discectomy and fusion (ACDF), 20 underwent corpectomy, and 1 underwent corpectomy with ACDF. Dysphagia assessed using the Bazaz score significantly improved with consecutive follow-ups in the DT and L groups ($p<0.01$ and <0.01, respectively). Bazaz scores at postoperative 1 and 3 months were significantly lower in the DT group than in the L group ($p<0.01$ and <0.01, respectively), although the difference was nonsignificant at 6, 12, and 24 months postoperatively. Dysphonia assessed using VHI-10 also significantly improved with successive follow-ups in the DT and L groups ($p<0.01$ and <0.01, respectively), but the difference was nonsignificant between groups. Cosmetic results assessed using the VSS showed significantly better cosmesis in the DT group at all follow-up periods ($p<0.01$ for all timepoints). Furthermore, cosmetic results assessed using POSAS showed significantly superior results in the DT group at all time points except at 24 months ($p<0.01$ for 3, 6, and 12 months) (Table 1, Figure 2). There were no significant differences in the rate of complications such as dural tears, infections, and pseudarthrosis between the groups.

Conclusion: A double transverse incision can incise the skin parallel to the tension line without bridge flap invasion between incisions, thereby minimizing wound contraction and avoiding incidental neurovascular injury during this approach. In this study, the DT group demonstrated less dysphagia during the early postoperative period and better cosmetic results at all follow-up

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periods. Furthermore, complication rates were not significantly different between the groups. Therefore, a double transverse incision can be a feasible option when performing long-segment ACSS, with better cosmesis and less postoperative dysphagia than with a longitudinal incision.

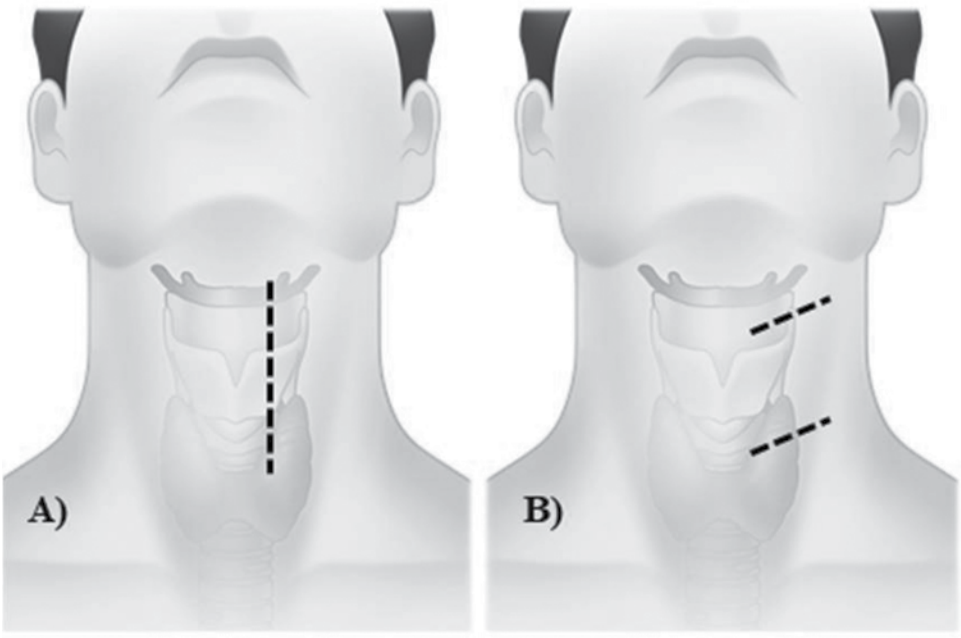

Figure 1. Incision line for the anterior cervical spine surgery A) Longitudinal incision, B) Double Transverse incision

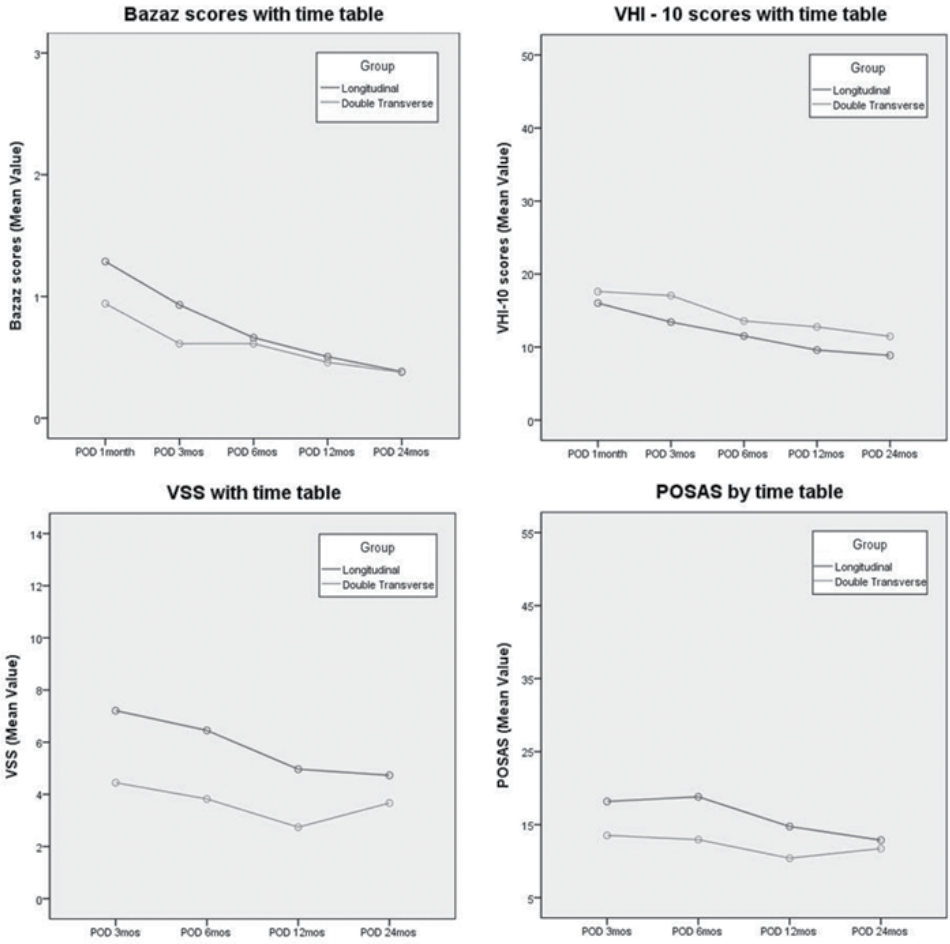

Figure 2. Graphical representation of patient outcomes

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Table 1. Clinical Data and Patient Outcomes			
Factor	**Longitudinal**	**Double Transverse**	**p value**
No. of patients (males/females)	23 (19/4)	17 (8/9)	
Age (mean)	57.1 ± 11.3	65.7 ± 11.3	<0.0001
No. of involved levels	3 levels (21) 4 levels (2)	3 levels (3) 4 levels (13) 5 levels (1)	
Operation	ACDF (2) Corpectomy (20) ACDF+Corpectomy (1)	ACDF (17)	
Bazaz scores			
POD 1 month	1.28 ± 0.83	0.94 ± 0.87	**0.005**
POD 3 mos	0.93 ± 0.80	0.61 ± 0.84	**0.007**
POD 6 mos	0.66 ± 0.69	0.61 ± 0.87	0.660
POD 12 mos	0.50 ± 0.50	0.45 ± 0.60	0.575
POD 24 mos	0.38 ± 0.50	0.37 ± 0.63	0.939
VHI-10 scores			
POD 1 month	16.02 ± 9.32	17.61 ± 10.43	0.615
POD 3 mos	13.42 ± 9.00	17.05 ± 11.27	0.265
POD 6 mos	11.52 ± 9.05	13.57 ± 10.97	0.521
POD 12 mos	9.59 ± 8.57	12.75 ± 10.23	0.295
POD 24 mos	8.86 ± 7.50	11.46 ± 9.52	0.339
VSS			
POD 3 mos	7.20 ± 2.64	4.44 ± 1.94	**<0.0001**
POD 6 mos	6.45 ± 2.92	3.82 ± 3.11	**<0.0001**
POD 12 mos	4.96 ± 2.71	2.74 ± 2.81	**<0.0001**
POD 24 mos	4.73 ± 2.77	3.67 ± 2.88	**0.009**
POSAS			
POD 3 mos	18.17 ± 7.10	13.52 ± 4.34	**<0.0001**
POD 6 mos	18.81 ± 8.11	12.94 ± 5.27	**<0.0001**
POD 12 mos	14.74 ± 6.85	10.40 ± 3.92	**<0.0001**
POD 24 mos	12.88 ± 6.89	11.72 ± 7.01	0.247
Complications			
Dural tear	1	0	
Infection	0	0	
Pseudarthrosis	6	4	

ACDF = anterior cervical discectomy and fusion, VHI-10 = Voice Handicap Index-10, VSS = Vancouver Scar Scale, POSAS = Patient and Observer Scar Assessment Scale, POD = post operative day, mos = months

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E-Poster #23

The Association between Atlantoaxial Instability and Anomaly of Axis and Vertebral Artery

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Introduction: Transarticular screw, C1 lateral mass screw, and C2 pedicle screw fixation are widely applied instrumentation methods used for atlantoaxial instability (AAI). However, anatomical variations of vertebral artery (VA) and axis are not uncommon at the craniovertebral junction, and neglecting anomalies could lead to fatal complications, such as massive bleeding, stroke, and cord injury. It is unclear whether presence of long-lasting AAI is associated with bony and vascular anomaly in high cervical region. The present study aimed to investigate the incidence and characteristics of anomalies which occur in VA, C2 isthmus and pedicle using three-dimensional computed tomography with vertebral arteriography (3D CTVA) among 120 patients with and without long-lasting AAI.

Materials and Methods: A case-control study with matched cohort analysis was performed. A total of 120 patients who had taken preoperative CTVA of the cervical spine were included. Sixty patients with AAI caused by os odontoideum, rheumatoid arthritis, or trauma (AAI group) were compared with 60 patients without AAI controlled by age- and sex-matching with the AAI group (Control group). VA anomaly such as fenestration, persistent first intersegmental (PFIS) artery, and VA dominance side were evaluated. Presence of high-riding vertebral artery (HRVA) was also assessed. Furthermore, C2 isthmus height, C2 internal height of its lateral mass, and C2 pedicle width were measured using 3D reconstructed images.

Results: Five patients (8.3%) in the AAI group had VA anomaly (4 fenestration, 1 PFIS artery), while there was no VA anomaly in the control group ($p<0.01$). VA dominance side did not significantly differ between the two groups ($p=0.31$). C2 isthmus height, C2 internal height, and C2 pedicle width were significantly narrower in the AAI group ($p<0.01$, <0.01, <0.01, respectively). Furthermore, a significantly greater portion of patients in the AAI group had HRVA than in the control group ($p<0.01$). Among patients with AAI, C2 isthmus height, C2 pedicle width, and proportion of HRVA did not significantly differ according to etiology ($p=0.71$, 0.79, 0.44, respectively). However, C2 internal height was significantly narrower in patient with rheumatoid arthritis ($p<0.01$).

Conclusion: Atlantoaxial fixation using C1 lateral mass screws and C2 pedicle screws as well as transarticular fixation provides the most rigid fixation. Anomalous anatomy of VA and C2 in AAI patients makes screw insertion into C1 and C2 more difficult or even impossible. The results of the present study demonstrate that VA anomalies, including fenestration, PFIS artery, and HRVA, are more common in patients with AAI. Furthermore, the C2 isthmus height and the internal height of its lateral mass differed, and width of C2 pedicle was significantly narrower in the AAI group. Therefore, posterior instrumentation in patients with AAI has a narrower safe zone compared to in patients without AAI complicated by vascular and bony structural anomalies. When performing posterior atlantoaxial fixation in AAI patients, more thorough preoperative evaluation of vascular and bony anatomy should be performed, and suitable surgical technique

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should be selected accordingly in order to avoid accidental VA injury.

Table 1. Comparison between AAI group and control group

	AAI group (N=60)	Control group (N=60)	P-value
Age	62.4±18.4	62.4±18.4	1.00
Sex (N, %)			
M	14 (23.3)	14 (23.33)	1.00
F	46 (76.7)	46 (76.7)	
VA dominance (N, %)	21 (35.0)	17 (28.33)	0.43
Right	4 (6.67)	4 (6.67)	
Left	17 (28.33)	13 (21.67)	
Both	39 (65.0)	43 (71.67)	
VA anomaly (N, %)			
Fenestration	3 (5.0)	0 (0.0)	0.03*
PFIS artery	2 (3.3)	0 (0.0)	
C2 Isthmus height (mm)	4.9±1.5	6.57±1.6	<0.01*
C2 Internal height (mm)	4.4±1.4	5.59±1.5	<0.01*
C2 Pedicle width (mm)	5.0±1.4	6.1±1.1	<0.01*
HRVA (N, %)	44 (73.3)	11(18.3)	
Bilateral	27 (45.0)	7 (11.7%)	<0.01*
Right	13 (21.7%)	1 (1.7%)	
Left	4 (6.7%)	3 (5.0%)	

AAI, atlantoaxial instability; N, number; M, male; F, female; VA, vertebral artery; HRVA, high riding vertebral artery; PFIS, persistent first intersegmental

Table 2. Comparison according to etiology within AAI group

	Os odontoideum	Rheumatoid arthritis	Trauma	P-value
C2 Isthmus height (mm)				
Right	5.1±1.7	4.8±1.7	4.5±1.9	0.28
Left	5.0±1.7	5.0±1.4	4.9±1.7	0.98
Mean	5.0±1.5	4.9±1.4	4.7±1.6	0.67
C2 Internal height (mm)				
Right	5.1±1.7	3.5±1.6	3.6±1.1	<0.01*
Left	5.3±1.8	4.2±1.1	4.5±1.4	0.10
Mean	5.2±1.5	3.8±1.1	4.1±1.0	<0.01*
C2 Pedicle width (mm)				
Right	5.3±1.3	4.9±1.5	4.7±1.3	0.38
Left	5.1±1.7	4.9±1.2	5.2±2.1	0.80
Mean	5.2±1.4	4.9±1.2	5.0±1.7	0.79
HRVA (N, %)	16 (66.7)	17 (81.0)	11 (73.3)	0.44
Bilateral	7 (29.2)	11 (52.4)	9 (60.0)	
Right	7 (29.2)	5 (23.8)	1 (6.7)	
Left	2 (8.3)	1 (4.8)	1 (6.7)	

AAI, atlantoaxial instability; HRVA, high riding vertebral artery

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E-Poster #24

Predictors of Failed Radiographic Outcomes Following Posterior Fusion Surgery in Degenerative Cervical Spine Disease.

Nida Fatima, MD, *Elie Massaad, MD, Muhamed Hadzipasic, MD, Ganesh Shankar, MD, John Shin, MD*

Introduction: Positive sagittal malalignment following reconstructive posterior fusion surgery impact the pathomechanics of the cervical spine. To elucidate the predictors of failed cervical alignment corrections following posterior fusion surgery in Degenerative Cervical Spine Disease (DSCD).

Materials and Methods: Consecutive patients with DCSD presented at an academic tertiary care hospital from 2009 to 2019 were identified through retrospective chart review. Patients were categorized into failed radiographic outcomes if C2-7 lordosis <20?, cSVA >4 cm or T1 slope >25? at 3-months postoperatively. For each outcome, univariable association with patient characteristics were first determined using logistic regression, and a prediction model was then constructed.

Results: The study cohort included 177 patients (52% females, mean age: 65.5±12.5 years), with a median clinical follow-up of 361 days. The mean post-operative T1 slope was 32.1±10.6?, C2-7 lordosis was 15.5±6.1?, and C2-7 SVA was 41.1±15.3 mm at 3-months. Pre-operative T1 slope >25? was an independent predictor of failed radiographic outcome at 3-months by 5.3 folds (OR: 5.35, 95%CI: 2.3-12.4, p<0.001). Similarly, pre-operative C2-7 lordotic angle <20? and post-operative kyphotic fusion had a more likelihood of radiographic failure at 3-months by 13-folds (OR: 13.7, 95%CI: 3.72-50.7, p<0.001) and 14-folds (OR: 14.2, 95%CI: 3.78-53.3, p<0.001) respectively. Furthermore, pre-operative SVA >4cm was significantly associated with post-operative radiographic failure at 3-months by 5.7 folds (OR: 5.72, 95%CI: 2.65-12.4, p<0.001).

Conclusion: Our results highlights the importance of pre-operative cervical alignment parameters in surgical planning to prevent postoperative radiographic failure and achieve better outcomes.

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E-Poster #25

Predicting the Heterogeneity of Outcome following Cervical Sensorimotor Complete Spinal Cord Injury: Trajectory Analysis Based on Prospective Dataset of 655 Patients

Blessing Jaja, MD PhD, James Harrop, MD, FAANS, Bizhan Aarabi, MD, Robert Grossman, MD, Christoper Shaffrey, MD, Jetan Badhiwala, MD, Michael Fehlings, MD, PhD, FRCSC, FACS, ***Jefferson Wilson, MD PhD***

Introduction: While the overall prognosis for recovery following traumatic sensorimotor complete cervical spinal cord injury (SCI) remains poor, there exists significant heterogeneity in outcomes at the patient level. Using a novel analytic approach, we aimed to characterize unique temporal patterns of neurological recovery post injury and to identify patient, injury and treatment variables that predict such patterns.

Materials and Methods: Subjects with cervical ASIA Impairment Scale (AIS) grade A SCI were pooled from four prospective longitudinal multicenter studies. Group based trajectory modeling (GBTM) was applied to model trajectories of recovery over the initial 12 months post injury. Measures of neurological function included: Upper Extremity Motor Score, Total Motor Scores and AIS grade improvement. Within the GBTM framework, multinomial logit regression was applied to: 1) identify characteristics associated with recovery trajectories, and; 2) explore association of trajectories with 12-month Functional Independence Measure (FIM) motor score.

Results: The GBTM categorized subjects (n=655) into three distinct trajectories of neurological recovery. These clinical courses included: (1) Marginal recovery trajectory: characterized by minimal or no improvement in motor strength or change in AIS grade status (remained grade A); (2) Moderate recovery trajectory – characterized by low baseline motor scores that improved by approximately 13 points; or AIS conversion of one grade point; (3) Good recovery trajectory – characterized by motor scores in the upper quartile at baseline that improved to near maximum values within three months of injury. Subjects following this trajectory, on average, gained two grade points on the AIS within three months of injury. Subjects following the moderate or good recovery trajectories were of younger age, had more caudally located injuries, a higher degree of preserved motor and sensory function at baseline examination and exhibited a greater extent of motor and sensory function in the zone of partial preservation (ZPP). Lastly, trajectories with better prognosis for neurological recovery had significantly higher mean FIM motor scores at 12 months.

Conclusion: Subjects with cervical complete SCI can be classified into one of three distinct trajectories for neurological recovery, with each trajectory associated with specific acute clinical features. This analysis may serve as a starting point to define unique clinical phenotypes based on potential for recovery, rather than baseline severity of injury alone.

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E-Poster #26

Revision Anterior Cervical Disc Arthroplasty: A National Analysis on the 10-year Prevalence and the Associated Indications, Procedures, and Postoperative Outcomes

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Introduction: Anterior cervical disc arthroplasty (ACDA) is a motion-sparing alternative to anterior cervical discectomy and fusion (ACDF). Numerous studies have demonstrated comparable outcomes and revision rates between these two procedures [1-3]. However, the literature on the outcomes after revision ACDA is sparse. The purpose of this study is to examine the associated indications, procedures, and postoperative outcomes after revision ACDA. No prior study has focused on this population at a national level.

Materials and Methods: A national database was utilized to identify adult (≥18 years) patients who underwent either a primary ACDA or removal of ACDA over a 10-year period (2008-2017). An in-depth assessment of the reasons for revision surgery and the subsequent procedures performed after the removal of ACDA was done by using both Current Procedural Terminology (CPT) and International Statistical Classification of Diseases (ICD-9,10) coding. The 30-day outcomes, including unplanned readmissions and reoperations, after revision surgery was compared among different indications and revision procedures in bivariate analyses. Chi-square/Fisher exact test and t-test/ANOVA were used for categorical and continuous variables, respectively.

Results: From 2008 to 2017, a total of 3,350 elective, primary ACDA cases were performed. During this time, 69 patients had a revision surgery requiring the removal of the ACDA (10-year Prevalence = 2.1%)(Figure 1). Revision patients were older (mean age (±standard deviation) = 48.5±11 years) and more often female (60.9%) than primary cases (age=45.6±10.2, p=0.019; female=46.9%, p=0.022), but the comorbidity burden was similar between these cohorts (revision: CCI=0.7±1.1, ASA>2=26.1% vs primary: CCI=0.52±0.81 p=0.066, ASA>2=21.2% p=0.323). The most common reasons for revision surgery included cervical spondylosis (59.4%) and mechanical complications (27.5%). After removal of ACDA, common procedures performed included anterior cervical fusion with or without decompression (69.6%), combined anterior/posterior fusion/decompression (11.6%), and replacement of ACDA (7.2%) (Table A). The indications for surgery did not vary significantly among the different procedures performed (p=0.318). Short-term postoperative complication rates after revision surgery were significantly higher than those seen after primary cases (Any complications: revision=11.6% vs. primary=0.78%, p<0.001 | Readmission: revision=8.7% vs. primary=1.5%, p<0.001 | Reoperations: revision=5.8% vs. primary=0.66%, p<0.001). Revision cases for mechanical complications had significantly higher overall short-term complications (21.1%) than those who underwent revision surgery for cervical spondylosis (2.4%, p=0.031). In comparison to anterior cervical fusion (2.1%) and replacement of ACDA (0%), those who underwent combined approaches (37.5%) had significantly higher risk for unplanned readmissions (p=0.007)(Table B).

Conclusion: The 10-year prevalence of revision surgery for ACDA is low (2.1%); however, the

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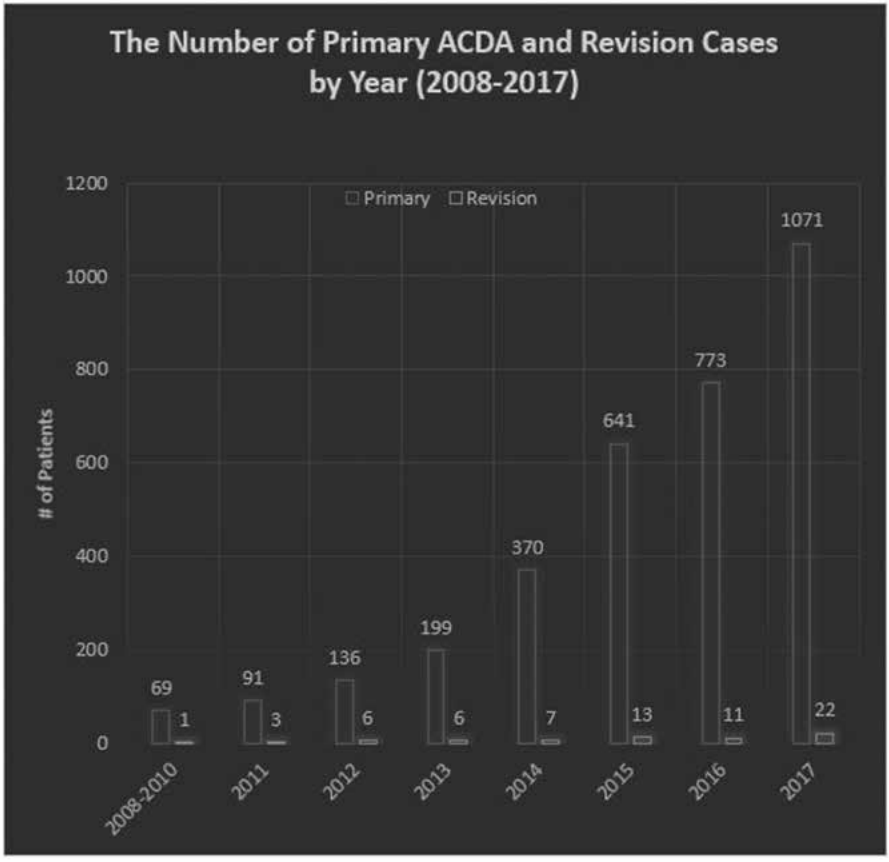
consequence of revision surgery is significant as short-term complication rates are nearly 10-fold greater than those seen after primary cases. Nearly 90% of revision cases were due to either cervical spondylosis or mechanical complications. These indications for surgery did not vary significantly among the different procedures performed. Patients requiring revision surgery for mechanical complications or those who underwent a combined surgical approach were at significantly higher risk for subsequent short-term complications. These findings will be important during the shared-decision making process for patients undergoing primary or revision ACDA.



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Reasons for Revision Surgery by Diagnosis (2008-2017)		
Total N = 69 Patients	**N**	**%**
Cervical Spondylosis	**41**	**59.4%**
With Myelopathy	12	17.4%
Without Myelopathy	20	29.0%
With Radiculopathy	9	13.0%
Mechanical Complications	**19**	**27.5%**
Mechanical Device - Dislocation	1	1.4%
Mechanical Device - Displacement	5	7.2%
Mechanical Device - Other	13	18.8%
Acquired Deformity	**2**	**2.9%**
Trauma	**3**	**4.3%**
Other	**4**	**5.8%**

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Procedures Performed after Removal of ACDA (2008-2017)		
Total N = 69 Patients	**N**	**%**
1-level Removed	64	92.8%
2-levels Removed	5	7.2%
Anterior Cervical Fusion with or without Decompression	**48**	**69.6%**
with decompression	36	52.2%
without decompression	12	17.4%
1-Level	31	44.9%
2-Level	15	21.7%
3-Level	2	2.9%
Combined Anterior and Posterior	**8**	**11.6%**
anterior fusion with posterior decompression	4	5.8%
anterior and posterior fusion with decompression	4	5.8%
Replacement of ACDA	**5**	**7.2%**
Removal of ACDA w/o other documented procedure	**8**	**11.6%**
Other Concomitant Operative Factors		
Corpectomy	7	10.1%
Interbody Device	24	34.8%
Autograft	14	20.3%
Allograft	26	37.7%

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30-Day Outcomes After Revision ACDA		
Any Complications	**8**	**11.6%**
Mortality	**1**	**1.4%**
Wound Complications	2	2.9%
Urinary Tract Infections	1	1.4%
Sepsis/Septic Shock	2	2.9%
Transfusion	2	2.9%
Unplanned Readmission *including Reoperations	**6**	**8.7%**
PE/DVT	1	1.4%
Postoperative Pain	1	1.4%
Unplanned Reoperations	**4**	**5.8%**
Wound Infection	1	1.4%
Hematoma	1	1.4%
Trauma	1	1.4%
Esophageal Rupture	1	1.4%
Extended LOS > 2 Days	**18**	**26.1%**

	Any Complication	P-value	Unplanned Readmission	P-value	Extended LOS > 2 Days	P-value
Diagnosis						
Cervical Spondylosis	2.4%	***0.031***	2.4%	0.054	22.0%	0.937
Mechanical	21.1%		15.8%		21.1%	
Procedure						
Anterior Cervical Fusion with or without Decompression	6.3%	0.187	2.1%	***0.007***	25.0%	0.718
Combined Anterior and Posterior	25.0%		37.5%		37.5%	
Replacement of ACDA	20.0%		0.0%		20.0%	

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E-Poster #27

How Does Ossification of Posterior Longitudinal Ligament Progress in Conservatively Managed Patients?

Sehan Park, MD, *Dong-Ho Lee, PhD, Chang-Ju Hwang, MD, PhD, Jae Hwan Cho, MD, PhD, Choon Sung Lee, MD, PhD, Jae Jun Yang, MD*

Introduction: Although several studies have demonstrated how ossification of the posterior longitudinal ligament (OPLL) progresses after laminoplasty or fusion, its risk factors and incidence of progression in conservatively managed patients remains unclear. Predicting high risk patients of OPLL growth could aid in tailoring patient follow-up strategy. Therefore, this study aims to elucidate the progression of OPLL in conservatively managed patients and determine its risk factors.

Materials and Methods: Medical records and radiographic data of 97 patients who were conservatively managed for OPLL and followed-up for at least 2 years were retrospectively reviewed. The vertical length of the ossified mass was evaluated by measuring the distance between the most proximal and distal points. Patients with vertical growth >2mm were classified as the vertical progression group. Ossified mass thickness was defined as the distance between the posterior cortex of the vertebral body and the posterior margin of the ossified mass, as measured on sagittal CT. Segments with the thickness progression of >1mm were classified as thickness progressed segments, and patients who had at least one progressed segment were classified as the thickness progression group. Based on the characteristics at each disc level, the ossified mass at each segment was classified into four types—type 1, no disc space involvement; type 2, involving disc space but not crossing; type 3, crossing the disc space but not fused; and type 4, completely fused (Figure 1).

Results: Out of 97 patients in total, 27 (27.8%) exhibited progression in vertical direction, 22 (22.7%) in thickness, and 12 (12.4%) in both directions. Of the 244 segments evaluated, 25 (12.4%) showed progression in thickness. Vertical progression was observed in younger patients ($p<0.01$), patients who had longer initial vertical length of the ossified mass ($p=0.04$), and when ossified mass involved C2–C3 ($p<0.01$). Moreover, the progression in thickness was more often observed in patients with ossified mass involving C2–C3 ($p<0.01$). The progression in both directions was observed more often in the mixed-type OPLL (Table 1). The analysis of each segment revealed that progression occurred most often in type 3 segments (18/25, 72.0%), which was statistically significant ($p<0.01$) (Table 2). In type 3 segments, thickness progression was found more frequently in segments for which segmental ROM was ≥5 degrees (10/32, 31.3% vs 8/65, 12.3%, $p=0.04$). Although the initial thickness did not exhibit a marked difference between both groups, the rate of segments whose initial thickness was >5mm was significantly higher in progressed segments (15/25, 60.0% vs. 77/219, 35.2%, $p=0.03$) (Table 2).

Conclusion: This study demonstrates factors that could estimate progression of OPLL in conservatively managed patients. Young age, involvement of C2–C3, and mixed-type OPLL are risk factors for vertical growth, whereas involvement of C2–C3 and mixed-type OPLL are risk factors for progression in thickness. Special attention is needed for segments which has

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morphology of crossing the segment while not fusing (type 3), segmental ROM ≥5o and initial thickness of >5mm since they pose higher risk of OPLL progression. Follow-up strategy of patients with incidental OPLL should be tailored considering these factors.

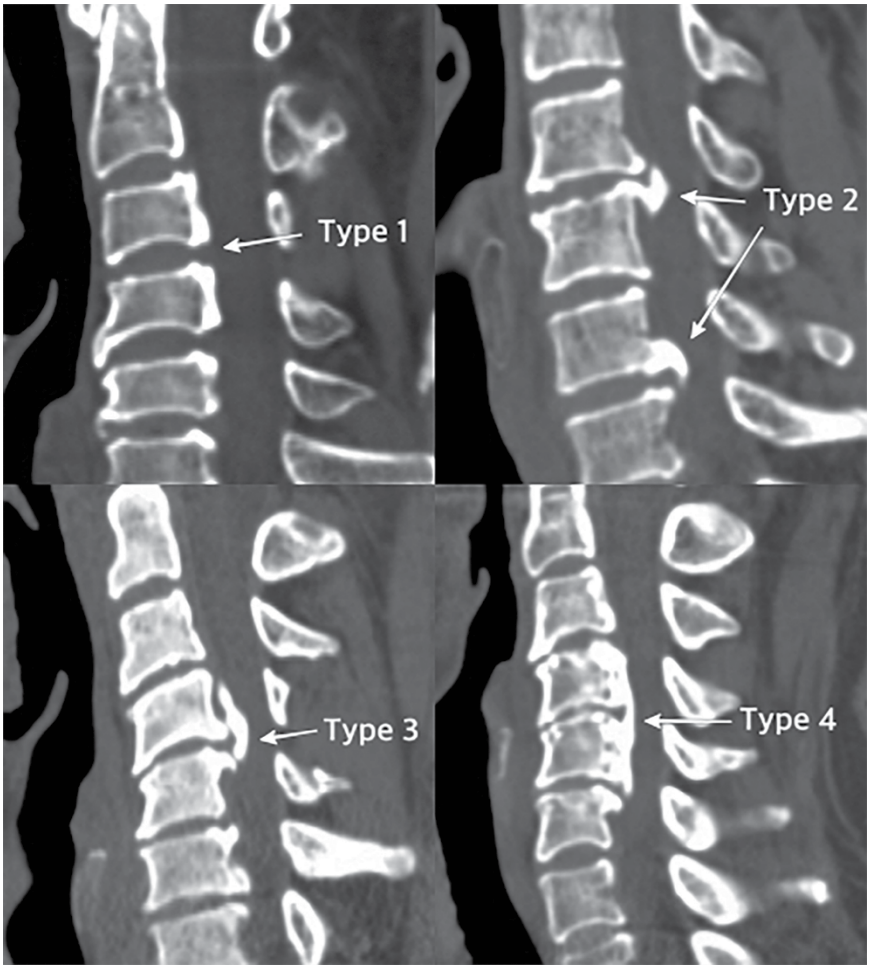

Table 1. Comparison between patients with progression and those without progression

	V-NP group	VP group	*P*	T-NP group	TP group	*P*
	N = 71	*N* = 26		*N* = 75	*N* = 22	
Age (yr)	60.6 ± 9.0	55.0 ± 10.0	< 0.01	59.67 ± 9.7	57.3 ± 9.0	0.31
Sex						
Male	47 (66.2%)	19 (73.1%)	0.62	48 (64.0%)	18 (81.8%)	0.13
Female	24 (33.8%)	7 (26.9%)		27 (36.0%)	4 (18.2%)	
Follow-up (m)	39.4 ± 17.6	39.1 ± 18.1	0.94	38.7 ± 18.0	41.2 ± 16.4	0.57
Cervical alignment	11.9 ± 9.8	10.8 ± 6.2	0.59	11.3 ± 9.0	12.7 ± 8.8	0.51
Cervical ROM	44.3 ± 13.4	39.5 ± 16.8	0.15	43.7 ± 14.3	40.7 ± 15.2	0.40
C2-C3 involvement						
Absent	51 (71.8%)	9 (34.6%)	< 0.01	52 (69.3%)	8 (36.4%)	< 0.01
Present	20 (28.2%)	17 (65.4%)		23 (30.7%)	14 (63.6%)	
Initial length (mm)	46.0 ± 27.4	58.7 ± 26.5	0.04	46.7 ± 28.2	58.4 ± 24.0	0.08
Type						
Continuous	15 (21.2%)	6 (23.1%)		14 (18.7%)	7 (31.8%)	
Segmental	33 (46.5%)	2 (7.7%)	< 0.01	33 (44.0%)	2 (9.1%)	0.03
Mixed	16 (22.5%)	16 (61.5%)		22 (29.3%)	10 (45.5%)	
Localized	7 (9.8%)	2 (7.7%)		6 (8.0%)	3 (13.6%)	

V-NP, vertical non-progression; VP, vertical progression; T-NP, thickness non-progression; TP, thickness progression; N, number; yr, years; m, months; ROM: range of motion

Age, sex, C2-C3 involvement, and type were compared using the chi-squared test

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Table 2. Comparison of thickness between non-progressed and progressed segments

	Non-progression segments $N = 219$	Progression segments $N = 25$	P
Segmental ROM	5.28 ± 3.78	4.32 ± 2.17	0.21
Initial thickness	4.49 ± 1.46	4.95 ± 1.10	0.12
Segmental type			
Type 1	65 (29.7%)	1 (4.0%)	
Type 2	58 (26.5%)	4 (16.0%)	< 0.01
Type 3	79 (36.1%)	18 (72.0%)	
Type 4	17 (7.7%)	2 (8.0%)	
Trabeculation			
No	203 (92.7%)	25 (100.0%)	0.38
Yes	16 (7.3%)	0 (0.0%)	
Initial thickness > 5 mm			0.03
No	142 (64.8%)	10 (40.0%)	
Yes	77 (35.2%)	15 (60.0%)	

N, number; ROM, range of motion

Segmental ROM and initial thickness were compared using the *t*-test

Segmental type, trabeculation, and initial thickness > 5 mm were compared using the chi-squared test

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E-Poster #28

Preoperative PROMIS Physical Function Association with Mental Health Improvement After Anterior Cervical Discectomy and Fusion

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Introduction: In the shift away from patient evaluations that are focused on radiological findings, patient reported outcome measures (PROMs) have an increasing relevance [1-2]. While Anterior Cervical Discectomy and Fusion (ACDF) is one of the most commonly performed ambulatory surgeries, research is limited on the predictive value of Patient-Reported Outcomes Measurement Information System (PROMIS®) scores and their influence on depressive symptoms as measured by the Patient Health Questionnaire-9 (PHQ-9). This study investigates the influence of physical function and their influence on postoperative depressive symptom scores as measured by PHQ-9 among ACDF patients.

Materials and Methods: A prospectively maintained surgical registry was retrospectively reviewed from March 2016-January 2019. Inclusion criteria were primary or revision, ACDF procedures. Patients were grouped by preoperative PROMIS physical function (PROMIS-PF) score (≥ 35.0, < 35.0), with higher scores indicating greater physical function. The 35.0 cut point was established using data from a high-powered study sample that identified the threshold between "fair" and "poor" to be between ≥ 35.0 and <35.0, respectively.1,2 Chi-squared and Student's t-tests assessed categorical and continuous variables (e.g., demographics, perioperative, and postoperative values). A t-test evaluated postoperative improvement in PROMIS-PF scores between subgroups among PROMIS-PF scores and PHQ-9 score improvement at 6-weeks, 12-weeks, 6-month, and 1-year. Linear regression assessed the influence of preoperative PROMIS-PF scores on PHQ-9 score improvement.

Results: The 121 subject cohort was 61.2% male with an average age of 49.6 ± 9.8 years. Patient demographics and baseline characteristic analysis revealed 81 subjects within the preoperative PROMIS-PF ≥ 35.0 subgroup (Table 1). The PROMIS-PF ≥ 35.0 subgroup had a significantly lower mean preoperative PHQ-9 score (6.0 vs. 11.3, $p < 0.001$) compared to the PROMIS-PF < 35.0 group. Compared to the PROMIS-PF ≥ 35.0 group, the PROMIS-PF <35.0 group also had larger improvement of PROMIS-PF scores at 6-weeks (Table 2).No significant difference in postoperative PHQ-9 improvement was observed between subgroups. There was a negative association between preoperative PROMIS-PF scores and improvement in PROMIS-PF scores at the 6-week, 12-week, 6-month, and 1-year (Figure 1A-H). There was a positive association between preoperative PROMIS-PF scores and magnitude of 1-year depressive symptom (PHQ-9) change.

Conclusion: Individuals with lower preoperative PROMIS-PF scores had significantly higher PHQ-9 scores at one-year. Patients with lower preoperative physical function, as evaluated by PROMIS-PF scoring, had greater improvement of mental health at one-year postoperatively. All patients are likely to experience a diminishing of their PHQ-9 score as preoperative PROMIS-PF

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score decreases. Given the current emphasis on multidisciplinary involvement when delivering effective patient care, continuing to develop our understanding regarding preoperative PROMIS-PF scores, ACDF spine surgery, and the possible impact these have on depression is likely to only become more important. Having a keen ability to anticipate treatment and patient needs will likely increase in value as the number of patients seeking both orthopaedic care and mental health care continues to rise.

Table 1. Patient Demographics by PROMIS Score

	Total (n = 121)	**PROMIS ≥ 35 (n=81)**	**PROMIS < 35 (n=40)**	**†p-value**
Age (mean ± SD)	49.6 ± 9.8	50.8± 9.5	47.9 ± 10.0	0.132
Gender (n)				0.854
Female	38.8% (47)	38.3% (31)	40.0% (16)	
Male	61.2% (74)	61.7% (50)	60.0% (24)	
Body Mass Index (n)				0.222
Non-Obese (<30 kg/m^2)	52.9% (64)	56.8% (46)	45.0% (18)	
Obese (≥ 30 kg/m^2)	47.1% (57)	43.2% (35)	55.0% (22)	
Smoking Status (n)				0.569
Non-Smoker	85.1% (103)	86.4% (70)	82.5% (33)	
Smoker	14.9% (18)	13.6% (11)	17.5% (7)	
Insurance Coverage (n)				0.608
Private or WC	98.4% (119)	98.8% (80)	97.5% (39)	
Medicare/Medicaid	1.6% (2)	1.2% (1)	2.5% (1)	
Ageless CCI (mean ± SD)	0.8 ± 0.9	0.8 ± 1.0	0.78 ± 0.8	0.719
Preoperative PHQ-9 (mean ± SD)	7.8 ± 6.8	**6.0 ± 5.5**	**11.3 ± 7.9**	**<0.001**
Preoperative Diagnoses*				
COPD	0.8% (1)	1.2% (1)	0% (0)	0.480
Uncomplicated Diabetes	13.2% (16)	14.8% (12)	10.0% (4)	0.462
Congestive heart failure	0.8% (1)	1.2% (1)	0% (0)	0.490
Hypertension	32.2% (39)	32.1% (26)	32.5% (13)	0.965
Neurologic Disease	0.8% (1)	1.2% (1)	0% (0)	0.480
Arthritis	14.9% (18)	14.8% (12)	15.0% (6)	0.979
Malignancy	2.5% (3)	2.5% (2)	2.5% (1)	0.992

COPD = Chronic Obstructive Pulmonary Disorder; CCI = Charlson Comorbidity Index; SD = Standard Deviation; WC = Workers Compensation

†p-value was calculated using Student's t-test (continuous), Chi-square (categorical), or Fisher's exact test (categorical)

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Table 2. Postoperative Improvement Over Predetermined Time Periods

	Postoperative Improvement mean ± SD (n) PROMIS ≥ 35	Postoperative Improvement mean ± SD (n) PROMIS < 35	†p-value
PROMIS Time Period			
Preoperative	—	—	—
6 week	**0.35 ± 6.9 (56)**	**3.7 ± 5.8 (24)**	**0.042**
12 week	4.0 ± 7.7 (43)	7.7 ± 8.7 (20)	0.090
6 month	6.3 ± 7.1 (41)	7.5 ± 8.0 (18)	0.579
1 year	6.8 ± 7.2 (28)	10.7 ± 6.9 (14)	0.102
PHQ-9 Time Period			
Preoperative	—	—	—
6 week	-2.1 ± 4.8 (74)	-2.3 ± 7.5 (32)	0.820
12 week	-2.1 ± 5.3 (57)	-3.0 ± 5.7 (27)	0.512
6 month	-2.3 ± 4.8 (52)	-2.8 ± 9.3 (25)	0.752
1 year	-2.4 ± 4.7 (31)	-5.0 ± 8.7 (14)	0.202

†p-value was calculated using Student's t-test (continuous)

PHQ-9 = Patient Health Questionnaire-9; PROMIS = Patient-Reported Outcomes Measurement Information System; SD = Standard Deviation

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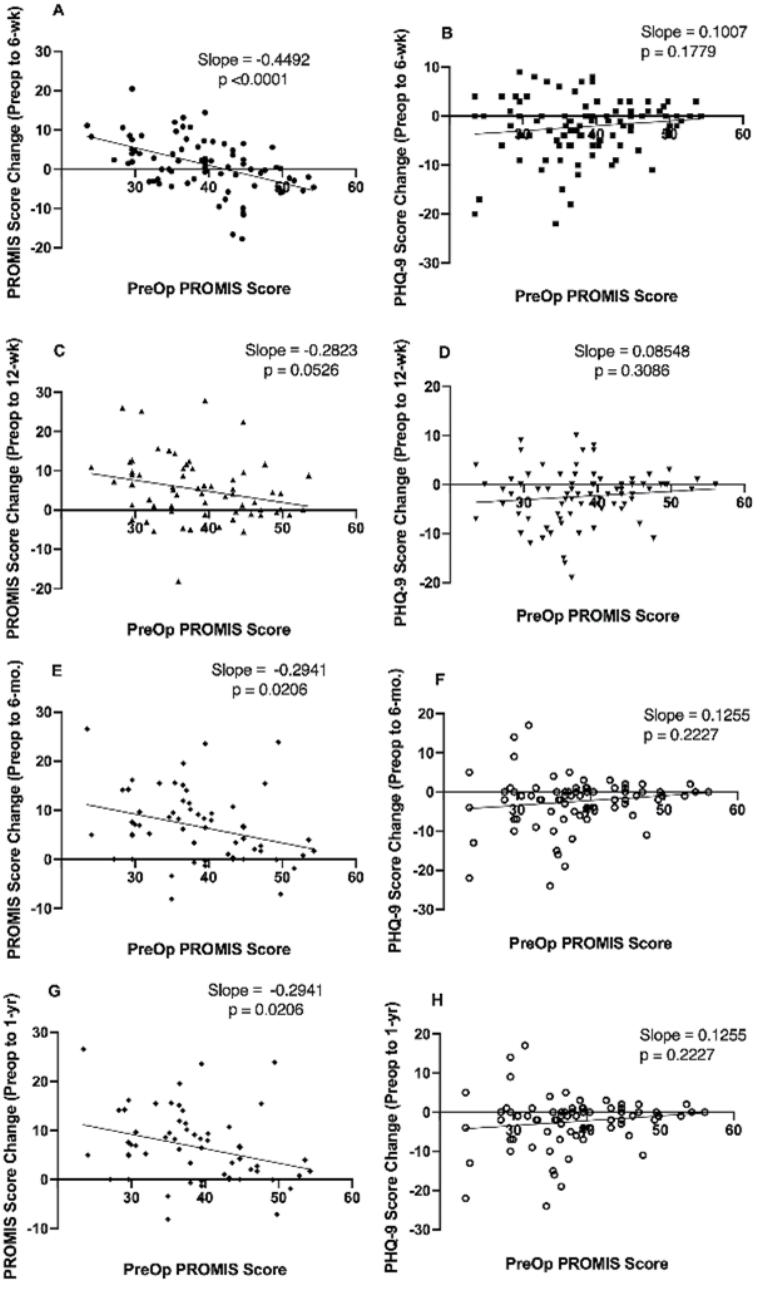

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E-Poster #29

Does Baseline Thoracolumbar Shape Influence Patterns of Cervical Decompensation following Surgical Adult Spinal Deformity Correction?

Peter Passias, MD, *Waleed Ahmad, MS, Renaud Lafage, MS, Virginie Lafage, PhD, Breton Line, BS, Alan Daniels, MD, Christopher Ames, MD, Justin Smith, MD, PhD, Shay Bess, MD, Eric Klineberg, MD, Han Jo Kim, MD*

Introduction: Adult spinal deformity (ASD) surgery is complex and may lead to new-onset cervical malalignment and/or PJK. Roussouly et al. describes variations in baseline thoracolumbar (TL) shape (Types 1-4), which have been shown to differentially influence surgical ASD outcomes. The effect of morphological shape on patterns of post-operative CD development remains underexplored.

Materials and Methods: Operative ASD patients with complete radiographic data at baseline, 6W, 1Y, 2Y, & 3Y intervals were included. Pts were grouped by baseline PI and apex of LL into component types of the Roussouly classification system utilizing pelvic incidence as published by Pizones et al. Pts with no BL CD were post-operatively stratified by Ames CD criteria (TS-CL> 20o, cSVA>40mm), where CD was defined as fulfilling >1 criteria. Follow-up intervals were established post-ASD surgery, with 6W post-op defined as "Early," 6W-1Y "Intermediate," 1-2Y "Late," and 2-3Y "Long." Univariate and Cox regression analyses identified CD conversion rate and PJK rate (<-10o change in UIV and UIV+2) across Roussouly types 1-4.

Results: 266 surgical ASD pts (59.7yrs, 77.4%F) with complete radiographic data were included. By Roussouly classification, 9% were Type 1, 15.8% Type 2, 46.6% Type 3, and 28.6% Type 4. 28.6% of ASD pts converted to post-op CD (Early: 14.3%, Intermediate: 5.3%, Late: 4.1%, Long: 4.9%). There were no significant differences in CD conversion rate across Roussouly types (1: 33.3%; 2: 28.6%; 3: 26.6%; 4: 30.3%, P=0.895). Types 2 (41.7%), 3 (60.6%), and 4 (43.5%) had their peak rates of conversion in the Early (<6w) window compared to other follow-up intervals, whereas Type 1 pts had a peak rate (50%) between 6w-1Y. Type 2 pts had higher rates of later CD conversion (>1 year) than other types (50% vs 28.1%, P=0.135), while Type 1 pts trended higher rates of earlier CD conversion (<1 year) than other types (33.8% vs 12.5%, P=0.220); these patterns did not reach statistical significance. Across Roussouly Types, among patients that converted to CD, Type 4 had significantly higher rates of ++ SRS-Schwab PT and greater TPA at BL(both p<0.05). Type 4 pts had the highest rate of concurrent PJK with CD conversion (60.9%) compared to Type 1 (50%), Type 2 (50%), or Type 3(54.5%) (P>0.05). There were no significant change in ODI, PCS, or SRS total among Roussouly Types in patients that converted to CD (p>0.05). Random forest analysis determined the top surgical (levels fused), radiographic (TS-CL), and demographic (frailty) factors associated with CD conversion.

Conclusion: Baseline thoracolumbar shape as described by the Roussouly classification has a differential effect on timing to CD conversion, though overall rates of CD conversion after TL-ASD correction were similar across Types 1-4. Type 1 patients with a lower apex of lumbar lordosis trended earlier conversion, while Type 2 patients with a higher apex of LL trended conversion beyond 1-year post-op.

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E-Poster #30

Postoperative Complication Rates and Hazards-Model Survival Analysis of Revision Surgery Following Occipitocervical and Atlanto-axial Fusion

Daniel Yang, BS, *Shyam Patel, MD, Kevin DiSilvestro, MD, Neill Li, MD, Daniel Reid, MD, Alan Daniels, MD*

Introduction: Complication rates following occipitocervical and atlanto-axial fusion are high. While methods to fuse the upper cervical spine levels have evolved, complication rates and surgical survivorship of occipitocervical fusion versus atlanto-axial fusion are incompletely understood [1]. Occipitocervical fusion has yet to be compared to atlanto-axial fusion through a controlled analysis, particularly with attention toward indication for surgery [2].

Materials and Methods: The PearlDiver Research Program (www.pearldiverinc.com) was used to identify patients undergoing primary occipitocervical or atlanto-axial fusion between 2011 and 2017. Incidence of each fusion procedure was studied across time. Multivariable logistic regression was used to compare 30-day readmission, 30-day medical complications, and post-operative opioid utilization at 1, 3, 6, and 12 months between cohorts, controlling for age, gender, Charlson Comorbidity Index (CCI), and indication for surgery. Logistic regression of opioid utilization also controlled for preoperative opioid use. Risk of revision was compared through Cox-proportional hazards modelling, Kaplan-Meier survival, and log-rank test. An a value of .05 was set as the level of significance.

Results: Cohorts of 483 occipitocervical fusions and 737 atlanto-axial fusions were examined. From 2008 to 2016, incidence of occipitocervical fusion rose linearly by 55.9% ($p=0.0099$), whereas atlanto-axial fusion rose linearly by 21.6% ($p=0.0232$) (Figure 1). A greater percentage of atlanto-axial fusions were due to trauma (69.9% vs. 50.5%), whereas a greater percentage of occipitocervical fusions were due to degenerative disease (41.6% vs. 29.4%) ($p=0.0161$). After adjusting for age, gender, CCI, and indication for surgery, the independent risk of 30-day readmission was greater in occipitocervical fusion compared to atlanto-axial fusion (aOR=1.45, 95%CI 1.07-1.96, $p=0.0150$) (Table 1). Total 30-day complications were seen in 40.9% of occipitocervical fusion patients compared to 26.3% of atlanto-axial fusion patients (aOR=2.06, $p<0.0001$). Specifically, occipitocervical fusion patients had higher risk of respiratory (aOR=2.06, 95%CI 1.50-2.83, $p<0.0001$), surgical site (aOR=2.59, 95%CI 1.30-5.28, $p=0.0075$), implant-related complications (aOR=2.47, 95%CI 1.20-5.25, $p=0.0155$), and sepsis (aOR=2.53, 95%CI 1.24-5.32, $p=0.0119$). Occipitocervical fusion resulted in higher risk for prolonged opioid use, for example at 6 months (aOR-2.48, $p=0.0009$). Risk of revision following fusion was increased in occipitocervical fusion at 6 months (aOR=1.94, 95%CI=1.12-3.41, $p=0.0194$), 1 year (aOR=2.29, 95%CI=1.38-3.83, $p=0.0015$), and 2 years (aOR=2.47, 95%CI=1.53-4.04, $p=0.0025$). By 2 years, 11.3% of occipitocervical fusions required revision, whereas 5.2% of atlas-axis fusions required revision. Kaplan Meier survival analysis and Cox-proportional hazards demonstrated greater risk of revision following surgery for occipitocervical fusion (log rank: $p<0.0001$, aHR=2.66, 95%CI 1.73-4.10, $p<0.0001$) (Figure 2).

Conclusion: Rates of occipitocervical and atlanto-axial fusion are rising in the United States.

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In this large cohort of 1,220 patients, complication and revision surgery rates were high, with occipitocervical fusion leading to higher complication and revision rates even after controlling for patient characteristics and surgical indication. Spine surgeons should be cautious when considering performance of occipitocervical fusion if atlanto-axial fusion could be performed safely and provide adequate stabilization to treat the same pathology.

Figure 1. Incidence of Atlanto-axial Fusion vs. Occipitocervical Fusion from 2008-2016

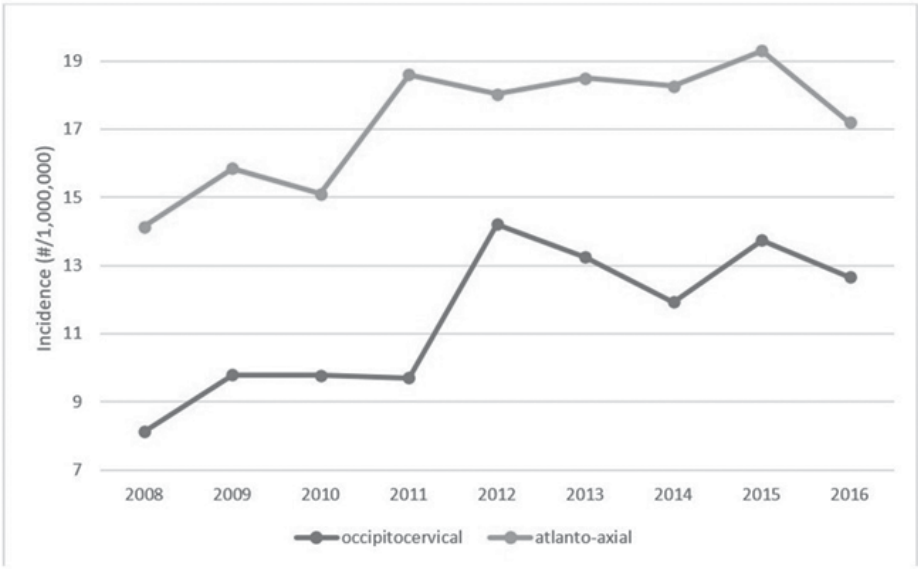

Table 1: Complications following Occipitocervical Fusion vs. Atlanto-axial Fusion

	C1-C2 Fusion		Occiput-C2 Fusion		aOR	95%CI		p-value
	n	%	n	%				
30-day Readmission	139	19.0	120	25.1	1.45	1.07	1.96	**0.0150**
Complications								
30-day complications	192	26.3	196	40.9	2.27	1.73	2.99	**<0.0001**
Respiratory	114	15.6	117	24.4	2.06	1.50	2.83	**<0.0001**
Pneumonia	32	4.4	24	5.0	1.23	0.68	2.20	0.4841
DVT	39	5.3	31	6.5	1.50	0.87	2.56	0.1411
Surgical Site	16	2.2	23	4.8	2.59	1.30	5.28	**0.0075**
Implant	18	2.5	22	4.6	2.47	1.20	5.25	**0.0155**
Sepsis	15	2.1	23	4.8	2.53	1.24	5.32	**0.0119**
Spinal Cord	20	2.7	22	4.6	1.85	0.93	3.70	*0.0796*
Myocardial	*	*	11	2.3	1.98	0.67	6.06	0.2178
Opioid Utilization								
1 Month Preoperatively	154	21.1	120	33.4	--	--	--	--
Postoperatively								
1 Month	52	7.1	48	10.0	1.63	1.03	2.59	**0.0382**
3 Months	42	5.7	44	9.2	1.92	1.17	3.18	**0.0099**
6 Months	33	4.5	42	8.8	2.48	1.45	4.29	**0.0009**
12 Months	24	3.3	29	6.1	2.12	1.15	3.96	**0.0167**

*Multivariable regression adjusted for age, gender, CCI, and indication for surgery. Models for opioid utilization also included preoperative opioid as a covariate.
Bold represents $p<0.05$ considered statistically significant.

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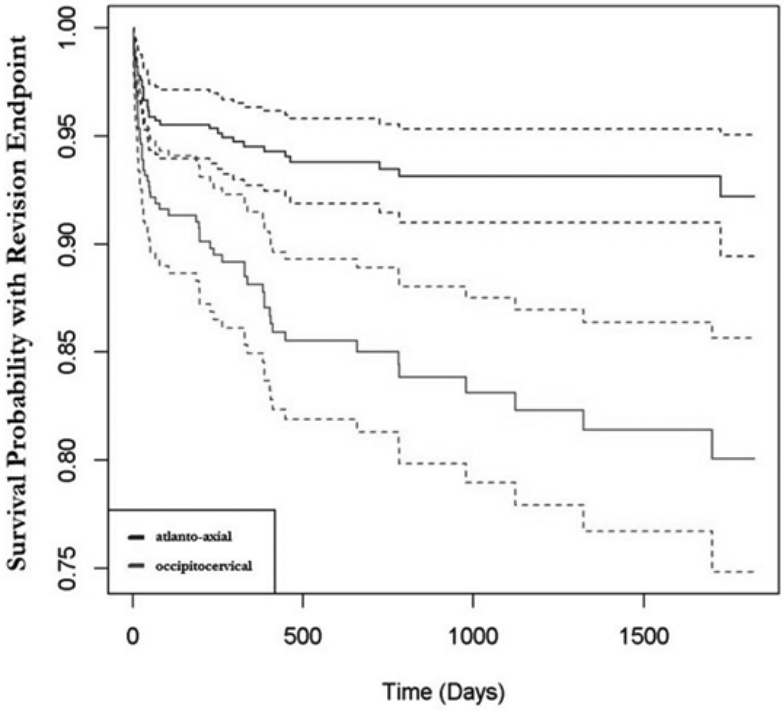
Figure 2. Kaplan-Meier Survival of Atlas-Axis Fusion vs. Occipitocervical Fusion with Endpoint of Revision



E-Poster #31

The Impact of Cervical Disc Arthroplasty vs ACDF on Driving Disability: Post-hoc analysis of a Randomized Controlled Trial with 10-year Follow-up

Deeptee Jain, MD, *K. Daniel Riew, MD, Michael Kelly, MD, Matthew Gornet, MD, J. Kenneth Burkus, MD, Scott Hodges, DO, Randall Dryer, MD, FACS, Jeffrey McConnell, MD, Todd Lanman, MD*

Introduction: Even with assistive automotive technologies that have improved visualization and decreased blind spots, driving is an activity that still requires the ability to turn the neck laterally. Anecdotally, we have found that patients with multi-level fusions often complain about restricted turning motion. The purpose of this study was to compare the effectiveness of cervical disc arthroplasty (CDA) with anterior cervical discectomy and fusion (ACDF) on driving disability improvement at 10-year follow-up after a 2-level procedure.

Materials and Methods: This was a post-hoc analysis of driving disability data from a randomized controlled trial of patients with cervical radiculopathy or myelopathy at two levels, in which patients either underwent CDA or ACDF. The patient self-reported driving disability question from the neck disability index (NDI) questionnaire was rated from 0-5 and obtained preoperatively and up to 10 years postoperatively. The severity of driving disability was categorized into “none” (score 0), “mild” (1 or 2), and “severe” (3, 4, or 5). The score and the severity of driving disability was summarized for each follow-up visit and compared between the treatment groups.

Results: Out of 397 patients (CDA 209, ACDF 188), 148 CDA and 118 ACDF patients had follow up at 10 years. The driving disability scores were not different between the groups preoperatively (CDA: 2.65; ACDF: 2.71, $p = 0.699$). Postoperatively, the driving disability scores in the CDA group were significantly lower than those in the ACDF group at 5 (0.60 vs 1.08, $p = <0.001$) and 10 years (0.66 vs 1.07, $p=0.001$). The mean improvement of driving disability score from preoperative to postoperative in the CDA group was significantly greater than the ACDF group at 10-year follow-up (-1.94 vs -1.63, $p=0.003$). The majority of patients reported severe driving disability (CDA: 56.9%, ACDF: 58.0%, $p=0.968$) before surgery. After surgery, a greater proportion of patients in the CDA group had neck pain-free driving compared with the ACDF group at 5 (63.3% vs 41.8%, $p<0.001$) and 10 years (61.8% vs 41.2%, $p=0.003$).

Conclusion: To our knowledge, this is the first report of the effect of two-level arthroplasty vs ACDF on driving disability with 10-year follow-up. In patients with two-level cervical disc disease with radiculopathy and/or myelopathy, CDA provided greater improvements in driving disability as compared with ACDF at 10-year follow-up. This finding may be attributable to the preservation of motion associated with CDA.

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E-Poster #32

Postoperative SVA >4 cm has no impact on Neck Pain Scores after C2-T2 fusion for myelopathy: Results from a multi-center cohort study

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Introduction: Recent literature has examined the importance of cervical alignment with regards to health related quality of life outcomes. Several cervical alignment parameters have been identified as potential goals for correction of cervical spinal deformities. Of these parameters, the C2-7 SVA has been utilized as a measure of global cervical alignment, and previous work has suggested that achieving a postoperative SVA of 4 cm or less is ideal with regards to patient outcomes. The purpose of this study was to determine the impact of SVA on postoperative neck pain scores after posterior cervical laminectomy and fusion for myelopathy.

Materials and Methods: We performed a retrospective review of a multicenter prospective cohort of patients undergoing posterior cervical laminectomy and fusion from C2-T2 for subaxial cervical stenosis and degenerative cervical myelopathy from 2011-2018. We collected demographic information and assessed cervical alignment on standing radiographs performed preoperatively as well as at 6 months or greater postoperatively. The cohort was divided into 2 groups based on a postoperative SVA of less than 4 cm or 4 cm or greater based on established criteria. We then examined differences between the groups with regards to preoperative and postoperative alignment, demographics, and neck pain scores as measured by the visual analog scale. A univariate analysis was performed to assess for differences between the 2 groups. All statistical analyses were performed with JMP® Pro 14.1.0.

Results: 173 patients were identified for inclusion. In this cohort, 70 patients were identified as having a postoperative SVA less than 4 cm and 103 patients were identified as having an SVA of 4cm or greater. In both groups, the change in SVA showed a worsening of alignment. This was significantly higher in the SVA > 4 cohort compared to the SVA <4 cohort (-11.6 vs -3.3, p<.001). There was also a significantly higher proportion of female patients in the SVA <4 cohort (54.3% vs 30.1%). Otherwise, there were no other significant differences in demographics between the 2 groups (Table 1). Of the 173 patients, 108 patients (62.4%) had VAS neck pain scores recorded at greater than 6 months postoperatively. With regards to VAS neck pain scores, they improved in both groups with long-term follow up (Table 2). There was no significant difference between the cohorts with respect to neck pain scores at any time point. Using the established minimal clinically important difference for VAS neck pain following cervical surgery, we found that 61.9% of the SVA <4 cohort and 52.9% SVA >4 cohort achieved MCID with no significant difference between the groups (p = .432).

Conclusion: The primary goal for posterior cervical laminectomy and fusion in the treatment of degenerative myelopathy is to achieve adequate decompression of the spinal cord and a stable, fused spine. While previous work has established the importance of SVA alignment in treatment

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of cervical deformity, in this multi-center cohort of patients undergoing C2-T2 posterior cervical fusion for degenerative myelopathy, postoperative S VA >4 cm was not associated with a significant difference in long-term patient reported outcomes with regards to neck pain.

TABLE 1: Postop C2 SVA <4 and SVA>4 Cohorts			
Variable	**SVA <4 (n = 70)**	**SVA >4 (n = 103)**	**P value**
Preoperative C2 SVA*	**26.9**	**51.1**	**<.001**
Postoperative C2 SVA	**27.5**	**57.3**	**<.001**
C2 SVA Δ	**-3.3**	**-11.6**	**.007**
Age	63.2	65.5	.124
Sex (Female)	**38 (54.3%)**	**31 (30.1%)**	**.001**
BMI > 35	14 (20.0%)	20 (19.6%)	.091
Smoking	10 (14.3%)	12 (11.8%)	.396
Diabetes	13 (18.6%)	29 (28.4%)	.096
Chronic kidney disease	4 (5.7%)	9 (8.8%)	.327
Chronic steroid use	4 (5.7%)	10 (9.8%)	.252
Inflammatory arthritis	9 (12.9%)	9 (8.9%)	.453

*SVA: Sagittal Vertical Axis, BMI: Body Mass Index

TABLE 2: VAS* neck pain scores			
	SVA <4 (n =41)	**SVA >4 (n =67)**	**P value**
Preoperative baseline	6.1	5.4	.221
Postoperative <3 months	2.1	1.9	.627
Postoperative >6 months	0.83	0.78	.841
% MCID* (ΔVAS-NP* > 4)	26 (61.9%)	37 (52.9%)	.432

*MCID: Minimally Clinically Important Difference, VAS: Visual Analog Score, VAS-NP: Visual Analog Score – Neck Pain

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E-Poster #33

Biomechanical Analysis of Gait and Stability in Preoperative Cervical Spondylotic Myelopathy Patients

Joshua Bell, MD, *Emily Dooley, BS, Lawal Labaran, BA, Shawn Russell, PhD, Hamid Hassanzadeh, MD*

Introduction: Cervical spondylotic myelopathy (CSM) is the most common cause of myelopathy in patients over 55 years and the most common cause of spinal cord dysfunction in the world.[1,2] It can lead to significant functional deficits including loss of fine motor control, proprioception, and gait disturbances. In all, these characteristics provide challenges with ambulation and performing normal acts of daily living. Biomechanical feedback mechanisms compensating for these gait and balance inefficiencies, specifically angular momentum (AM) regulation, have remained largely unexplored.[3] The aim of this study was to 1) determine postural stability and spatiotemporal gait parameters and 2) characterize dynamic stability and variances in AM of preoperative CSM patients compared to healthy controls.

Materials and Methods: Data was collected from 56 subjects: 32 Nurick grade 2 or 3 CSM patients (15M and 17F, age: 59.9 ± 10.4 years, body mass index (BMI): 31.48 ± 6.87 kg/m2)and 24 controls (9M and 15F, age: 56.2 ± 11.2 years, BMI: 27.51 ± 6.70 kg/m2). Inclusion criteria for CSM subjects include patients age 40 to 80 who were undergoing planned decompressive surgery. Able-bodied controls age 40 to 80 were selected that had no previous history of symptomatic spine, musculoskeletal, or neuromuscular pathology. Standing balance trials were performed on a single Bertec force plate, while walking trials were conducted at self-selected pace over a 15m runway and a series of five Bertec force plates. All trials were recorded with 3D motion capture software and Plug-in-Gait Model was then utilized to calculate spatiotemporal gait parameters, and joint kinematics and exported to Matlab for further analysis.

Results: Tilted ellipse area, a measure of center of pressure (CoP) variance and postural stability, was significantly greater among CSM patients (847.54±764.33mm2 vs. 258.18±103.35mm2, $p<0.001$). (see Figure 1) CSM patients had two times as much variance medial-lateral (72.12±51.83mm vs. 29.15±14.95mm, $p=0.001$) and over three times as much anterior-posterior (42.25±55.01mm vs. 9.17±4.83mm, $p=0.001$) compared to controls. Spatiotemporal parameters indicated that CSM patients tending to have slower, shorter, and wider gait compared to controls, while spending a significantly greater amount of time in double support. (see Table 1) Dynamic stability appeared to be significantly alerted in CSM patients. Compensatory AM was significantly increased in all three anatomic planes. (see Figure 3) This was most pronounced in the frontal plane, where whole and upper body AM were approximately double (0.057±0.034 vs. 0.023±0.006, $p<0.001$) and triple (0.007±0.003 vs. 0.022±0.016, $p<0.001$) that of controls respectively.

Conclusion: Preoperative CSM patients showed significant alterations in gait and stability compared to controls. Likewise, AM analysis demonstrates that these patients have increased body excursion to maintain dynamic balance. Increases in frontal plane AM was indicative of CSM patient's wide based, waddling gait. Likewise, a phase shift in increasing compensatory AM in the

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sagittal and traverse planes correlated to a period of prolonged stable double support followed by a delayed initiation of an unstable swing phase. Understanding these deficiencies is crucial in the development of targeted therapies and rehabilitation plans to prevent complications, like falls, and help restore functional capacity in these patients.

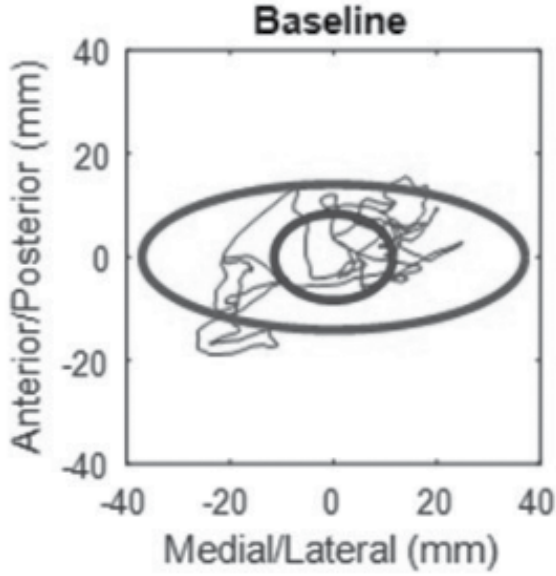

Figure 1. Postural Stability measured through center of pressure (CoP) variance. Representative average CoP path of CSM patients with corresponding ellipse area in red. Representative average ellipse area of controls in shown in blue.

Parameter	Controls	(±St. Dev.)	CSM Patients	(±St. Dev.)	p-value
Stride Length (m)	1.173	0.123	0.956	0.203	<0.001
Cadence (steps/min)	107.374	9.871	96.272	13.478	0.001
Velocity (m/s)	1.050	0.147	0.778	0.213	<0.001
Step Width (mm)	136.863	29.385	190.508	47.738	<0.001
Toe Off (% Gait Cycle)	63.273	1.957	66.611	4.547	0.001
Double Support (% Gait Cycle)	0.267	0.039	0.334	0.090	<0.001

Table 1. Comparison of mean spatiotemporal parameters for control population and CSM patients.

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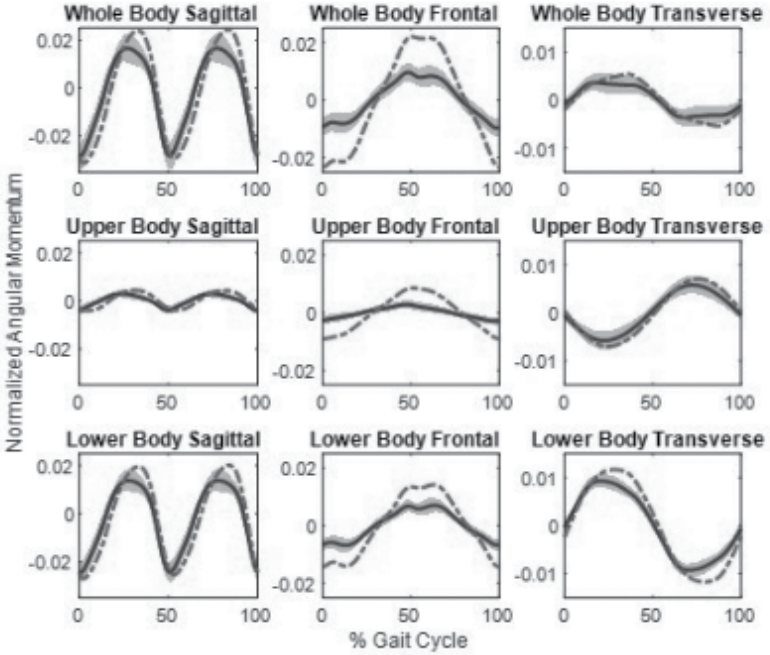

Figure 2. Angular momentum over one gait cycle in the anatomical planes. Control population shown as solid blue line with ±1 S.D. shaded. Mean of CSM patient population shown in dashed red.

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E-Poster #34

Surgical outcome of cervical compressive myelopathy with mild severity -Investigation of patients with preoperative JOA score of 14.5 or above-

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Introduction: Recent clinical practice guidelines for the management of degenerative cervical myelopathy recommend surgical intervention for patients with moderate and severe symptoms. However, there is no established consensus on the indications for surgery in patients with mild cervical myelopathy. The purpose of this study is to comprehensively investigate surgical outcome of mild cervical compressive myelopathy (CCM) using the Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ), which is a patient self-administered questionnaire.

Materials and Methods: This study is a retrospective study conducted at three institutions in Japan. A total of 458 consecutive patients were reviewed from January 2011 to September 2017. All patients underwent surgical decompression for CCM and were followed up at least two years after surgery. We defined mild cervical myelopathy as JOA score of 14.5 or larger according to a prediction formula as follows: modified JOA (mJOA) total = 2.39 + 0.89 × (JOA total), which was proposed by the previous study. Preoperatively and at two years after surgery, patients were evaluated using the JOA score, the visual analog scale (VAS), the functional score of the JOACMEQ, and the choice of each question in the JOACMEQ. Additionally, the effectiveness rate was calculated from the functional score in each domain of the JOACMEQ. Statistical analyzes were performed by the Wilcoxon's signed rank test for the VAS and the test of marginal homogeneity for the choice of each question in the JOACMEQ.

Results: Of 458 patients undergoing cervical decompressive surgery, 65 (14.2%) met the study criteria (average age: 61.2 years, 78.5 % male). The JOA scores were significantly improved postoperatively (15.0 vs. 15.5, $P = 0.005$). The VAS scores for neck (36.3 vs. 27.1, $P = 0.018$), upper limbs (48.3 vs. 29.7, $P < 0.001$), and lower limbs (23.6 vs. 15.8, $P = 0.026$) significantly improved at the 2-year follow-up. The effectiveness rates of each domain in the JOACMEQ were 55.3% in the cervical spine domain, 59.5% in the upper extremity domain, 42.9% in the lower extremity domain, 27.8% in the bladder domain, and 23.1% in the quality of life (QOL) domain. In the assessment of each question in the JOACMEQ, more than half of questions in the domains of cervical spine function, upper extremity function and all the questions in the domain of QOL significantly improved at the 2-year follow-up ($P < 0.05$). Furthermore, there were no choices of the questions that showed deterioration at the 2-year follow-up.

Conclusion: Surgical decompression provided slight but definite functional improvement even in the patients with mild CCM, especially in the domains of cervical spine and upper extremity in the JOACMEQ. While the comparison with conservative treatment would be crucial in the future, the current study revealed the effectiveness of the surgical decompression for mild CCM, suggesting that the surgical treatment can be a potential option for the patients with mild CCM.

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E-Poster #35

Preoperative Functional Status Predicts Postoperative Benefit in Cervical Degenerative Disease

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Introduction: Cervical surgery, particularly anterior cervical discectomy and fusion (ACDF), has been hailed as one of the most successful operations across all disciplines of orthopaedic surgery, yet a substantial number of patients continue to experience pain and disability postoperatively. Many factors play a role in determining a patient's outcome postoperatively, including degree of deformity, neck pain, cord signal, ossification of the posterior longitudinal ligament, duration of symptoms, and advanced age. Historically, surgery has been thought to most benefit those with radicular symptoms, with more limited goals of halting or slowing disease progression in the setting of myelopathy. Whether patients with poor preoperative function experience the same benefit as those with higher levels of function remains unknown. The purpose of this study was to assess whether preoperative functional status can be used to predict clinical benefit following surgery for cervical degenerative disease.

Materials and Methods: Adult patients undergoing surgery for cervical degenerative disease at a single institution between 2016-2018 were prospectively enrolled, completing questionnaires (Short Form-36 [SF-36], Neck Disability Index [NDI], VAS arm/neck, Patient Reported Outcomes Measurement Information System [PROMIS] Pain Interference [PI] and Physical Function [PF]) preoperatively and at 6-months postoperatively. Logistic regression analysis was used to determine the association between preoperative patient-reported outcomes (PROs) and achieving minimal clinically important difference (MCID) or substantial clinical benefit (SCB) postoperatively.

Results: There were 139 patients meeting inclusion criteria, with a mean age of 56.4 years and diagnoses of myelopathy (n=36), radiculopathy (n=48) and myeloradiculopathy (n=49). All outcome measures demonstrated a statistically significant correlation between worse baseline scores and achieving postoperative MCID and SCB. A one-point decrease in preoperative PRO resulted in ORs of achieving MCID for NDI (1.04), SF-36 PCS (1.03), SF-36 MCS (1.04), VAS Arm (1.76), VAS Neck (1.93), PROMIS PI (1.11), and PROMIS PF (1.07). Of patients with preoperative NDI>34, 79% achieved MCID vs. 70% of those with NDI≤34 (p=0.001). On subgroup analysis of patients with radiculopathy, all outcome measures demonstrated statistically significant correlation between worse baseline scores and achieving MCID and SCB, with the exception of MCID for NDI (p=0.263). For patients with myelopathy, the NDI and VAS arm/neck instruments demonstrated significant correlation between worse baseline scores and attaining postoperative MCID/SCB.

Conclusion: Preoperative PROs can predict postoperative benefit for patients undergoing cervical spine surgery, with worse preoperative scores correlating with greater improvement. For those with a high level of preoperative function this may represent a ceiling effect, whereas these findings lend support to the utility of surgery even in the setting of severe disability, challenging

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historical preconceptions about prognosis for this patient population.

NDI Preoperative Score		Improvements Achieved after Surgery		
		MCID	SCB	No Benefit
Better health ↑	0 to 4	0%	0%	100%
	5 to 15	25%	6%	75%
	15 to 24	56%	32%	44%
	25 to 34	71%	61%	29%
Worse health ↓	>34	79%	75%	21%

NDI: Neck Disability Index; MCID: minimal clinically important difference; SCB: substantial clinical benefit

Table 2: Association between Preoperative Outcomes and Postoperative Clinical Benefit, All Patients

Outcome	MCID			SCB		
	OR	95% CI	p value	OR	95% CI	p value
NDI	1.04	1.02, 1.06	**0.001**	1.05	1.03, 1.07	**<0.001**
SF36 PCS	1.03	1.00, 1.05	**0.007**	1.04	1.01, 1.06	**0.001**
SF36 MCS	1.04	1.02, 1.07	**<0.001**	1.05	1.03, 1.07	**<0.001**
VAS Arm	1.76	1.42, 2.18	**<0.001**	2.25	1.69, 3.00	**<0.001**
VAS Neck	1.93	1.54, 2.41	**<0.001**	1.70	1.40, 2.07	**<0.001**
PROMIS PI	1.11	1.05, 1.18	**<0.001**	1.10	1.04, 1.16	**0.001**
PROMIS PF	1.07	1.03, 1.13	**0.003**	1.10	1.04, 1.15	**<0.001**

MCID: minimal clinically important difference; SCB: substantial clinical benefit; NDI: Neck Disability Index; SF36: Short Form 36; PCS: Physical Component Score; MCS: Mental Component Score; VAS: Visual Analog Scale; PROMIS: Patient-Reported Outcomes Measurement Information System; PI: Pain Interference; PF: Physical Function

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Table 3: Association between Preoperative Outcomes and Postoperative Clinical Benefit, Radiculopathy

	MCID			SCB		
	OR	95% CI	p value	OR	95% CI	p value
NDI	1.03	0.98, 1.08	0.263	1.05	1.01, 1.11	**0.030**
SF36 PCS	1.04	1.00, 1.07	**0.037**	1.05	1.02, 1.11	**0.008**
SF36 MCS	1.06	0.91, 1.02	**0.006**	1.06	1.02, 1.11	**0.003**
VAS Arm	1.79	1.24, 2.57	**0.002**	2.41	1.44, 4.01	**0.001**
VAS Neck	2.68	1.46, 4.94	**0.002**	1.80	1.26, 2.83	**0.002**
PROMIS PI	1.17	1.04, 1.33	**0.010**	1.29	1.11, 1.49	**0.001**
PROMIS PF	1.19	1.04, 1.34	**0.008**	1.22	1.07, 1.39	**0.004**

MCID: minimal clinically important difference; SCB: substantial clinical benefit; NDI: Neck Disability Index; SF36: Short Form 36; PCS: Physical Component Score; MCS: Mental Component Score; VAS: Visual Analog Scale; PROMIS: Patient-Reported Outcomes Measurement Information System; PI: Pain Interference; PF: Physical Function

Table 4: Association between Preoperative Outcomes and Postoperative Clinical Benefit, Myelopathy

	MCID			SCB		
	OR	95% CI	p value	OR	95% CI	p value
NDI	1.04	1.01, 1.08	**0.025**	1.05	1.01, 1.09	**0.014**
SF36 PCS	1.03	0.99, 1.06	0.118	1.05	1.00, 1.09	**0.028**
SF36 MCS	1.04	0.99, 1.09	0.089	1.04	1.00, 1.10	0.075
VAS Arm	3.71	1.52, 9.03	**0.004**	6.60	1.22, 35.88	**0.029**
VAS Neck	2.55	1.43, 4.55	**0.001**	1.68	1.18, 2.40	**0.004**
PROMIS PI	1.08	0.98, 1.18	0.110	1.03	0.94, 1.12	0.546
PROMIS PF	1.10	1.00, 1.19	0.051	1.10	1.00, 1.22	0.054

MCID: minimal clinically important difference; SCB: substantial clinical benefit; NDI: Neck Disability Index; SF36: Short Form 36; PCS: Physical Component Score; MCS: Mental Component Score; VAS: Visual Analog Scale; PROMIS: Patient-Reported Outcomes Measurement Information System; PI: Pain Interference; PF: Physical Function

E-Poster #36

Hybrid Technique for Multilevel Anterior Decompression with Corpectomy and Discectomy Shows Higher Fusion and Lower Reoperation Rates Than Anterior Cervical Discectomy and Fusion with Minimum 5 year Follow-up

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Introduction: Cervical spondylitic myelopathy and multilevel radiculopathy can lead to significant morbidity. Surgical intervention often includes multiple levels of decompression and stabilization to address areas of stenosis and deformity while minimizing complications. Concerns regarding consecutive multilevel corpectomy have led some anterior-only approaches to utilize hybrid decompression, with corpectomy and adjacent discectomies while retaining intervening vertebral body support. The additional morbidity of a corpectomy over discectomy has led others to recommend multilevel anterior cervical discectomy and fusion (ACDF). Previous studies have examined short term follow-up, but less is known about long term outcomes when comparing hybrid decompression versus multilevel ACDFs.

Materials and Methods: All patients undergoing 3-5 level anterior cervical spine decompression and fusion with or without corpectomy from 2003-2015 at a single center were retrospectively reviewed. Patients with minimum 5-year follow-up and adequate imaging to assess fusion were included. Excluded were patients with corpectomy alone or with posterior hardware or halo fixation. Demographic patient data and implant related data was collected. Fusion was assessed with flexion-extension radiographs with less than 1 mm motion between spinous processes or by bridging bone on computed tomography scans. Lordosis was measured on lateral radiographs from C2-C7 preoperatively, postoperatively, and at final follow-up. Reoperation at the index levels or for adjacent segment disease, subsidence, or graft or interbody-related complications were recorded. Statistical analyses with Fisher's exact test and student t-test were performed to compare hybrid and ACDF groups.

Results: Thirty-eight patients with hybrid decompression and fusion had average 7.7 years follow-up (range 5-14). Twenty-six patients underwent corpectomy with adjacent ACDF, and 14 underwent corpectomy with 2 adjacent ACDFs. In the ACDF group, 12 patients had 3-4 level ACDF with average 10.5 years follow-up (range 5-16). Fusion rate was 89% for hybrid patients, with the only pseudoarthroses occurring at ACDF sites within the construct; fusion occurred in 50% of patients with multilevel ACDF ($p=0.0073$). Cervical lordosis improved from preoperatively by an average of 9 degrees in hybrid patients and 14 degrees in ACDFs at final follow-up ($p=0.19$). Regarding additional surgery, fewer hybrid patients had reoperation for nonunion (3% vs 33%, $p=0.0093$). Adjacent segment degeneration requiring additional surgery was performed in 10% of hybrid patients and 12% of ACDF patients ($p=1.00$).

Conclusion: Hybrid decompression and fusion has a higher fusion rate and lower reoperation rate for nonunion compared with multilevel ACDF for cervical spine pathology. To our knowledge, this is the longest follow-up study comparing hybrid and ACDF constructs of patients treated with anterior techniques only. Concerns regarding morbidity of corpectomy must be balanced against the risk of increased pseudoarthrosis. Hybrid decompression with corpectomy and discectomy provides favorable results that last into the longer term when treating multilevel cervical pathology.

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E-Poster #37

Baseline differences in patients undergoing anterior versus posterior surgery for cervical myelopathy: an analysis from the Quality Outcomes Database

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Introduction: Surgical intervention for cervical myelopathy may utilize either an anterior or posterior approach. The baseline differences between patient populations undergoing these two approaches are unclear. The object of this study is to describe baseline differences in patients undergoing anterior versus posterior surgery for cervical myelopathy using a prospectively-collected, multi-institutional, neurosurgery-specific dataset.

Materials and Methods: The cervical module of the NeuroPoint Quality Outcomes Database (QOD) was queried for patients treated with either anterior or posterior cervical surgery. We excluded patients who did not have symptoms of myelopathy. Demographic, comorbidity, socioeconomic, and patient-reported outcome (PRO) measures were compared between patients undergoing anterior approach versus posterior approach.

Results: Of the patients in the cervical QOD registry, 986 had symptoms of myelopathy. There were 677 patients (68.4%) who underwent anterior surgery vs. 309 patients (31.2%) who underwent posterior surgery. Anterior approach patients were significantly younger (mean age 58.8 ± 11.7 vs. 64.8 ± 10.5 years, $p<0.001$), had less comorbidity burden (ASA grade ≥3: 45.9% vs. 56.4%, $p=0.003$), less severe myelopathy (mean modified Japanese Orthopaedic Association score 12.3 ± 2.7 vs. 11.3 ± 3.0, $p<0.001$; motor deficit present in 57.6% vs. 65.4%, $p=0.021$), lower unemployment (46.8% vs. 69.1%, $p<0.001$), and significantly fewer segments fused (mean 1.8 ± 0.8 segments vs. 3.5 ± 1.7, $p<0.001$). No differences were observed for gender, race, education level, smoking status, individual comorbidities, EQ-5D, or NDI.

Conclusion: Significant differences exist between baseline characteristics of patients undergoing anterior versus posterior surgery for cervical myelopathy.

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E-Poster #38

Development of Advanced Cervical Deformity Frailty Index for Preoperative Risk Stratification.

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Introduction: The preoperative risk stratification in the Cervical Deformity (CD) patients undergoing posterior fusion is important for accurate prediction of outcomes following surgery. Although the CD frailty index (CD-FI) and modified CD-FI were developed but are clinically impractical due to a large number of factors for calculation. To develop a simplified FI for CD patients undergoing posterior fusion surgery.

Materials and Methods: CD patients (C2-7 lordosis>10°, C2-7 SVA>4cm, or C2-7 Cobb>10°) >18 years with preoperative modified CD-FI factors. Bivariate Pearson correlation assessed relationships between component deficits of modified CD-FI and overall modified CD-FI score. The significant factors contributing to modified CD-FI score were included in multiple stepwise regression models. The deficits from the model with the largest R2 were included, and the mean score of all deficits calculated, resulting in the advanced CD-FI score from 0 to 1. Patients were stratified by advanced CD-FI into: Not Frail (NF: 0, 35.9%), Pre-Frail (PF: 0-0.2, 25.8%), Frail (>0.2-0.6, 25.8%) Severely Frail (SF: >0.6, 12.6%).

Results: Statistical analysis included 199 patients (65.5±12.5 years, 50.8% females). Multiple stepwise linear regression model identified 5-factors as responsible for 91% of the variation in the modified CD-FI; these parameters were used to construct the advanced CD-FI. Overall, the mean advanced CD-FI was 0.28±0.29. Compared with the NF and PF patients, frail and SF patients had more postoperative medical complications (0.01) and surgical wound infection (p=0.05). Frail patients had 1-fold higher risk (OR:1.04,95%CI:1.006-1.06,p=0.003) of postoperative C2-7 SVA>4 cm. Furthermore, there exists 4.2-folds higher likelihood of DJK (OR:4.2,95%CI:1.17-15.7,p=0.02) in patients who are frail.

Conclusion: Increased frailty, as assessed by advanced CD-FI, is associated with increased risk of postoperative medical and surgical complications along with radiographic failure. This suggests the clinical utility of the advanced CD-FI in the pre-operative risk stratification.

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E-Poster #39

Tandem Stenosis Patients Undergoing Primary Cervical Operations are at an Increased Risk for Poor Perioperative Outcomes

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Introduction: Tandem spinal stenosis [TS] refers to spinal canal diameter narrowing in at least 2 regions of the spine, most commonly the lumbar and cervical regions. This entity can be an asymptomatic radiographic finding, or it can present with severe cervical myelopathy and stenosis-associated lower-extremity symptoms. Tandem spinal stenosis may impact surgeon decision-making when planning cervical spine surgery. The purpose of this study was to patients with tandem stenosis who underwent underwent a cervical spine procedure prior to addressing the lumbar.

Materials and Methods: Surgical cervical spine patients≥ 18yrs were isolated in the single-center Comprehensive Spine Quality Database(Quality). Patients diagnosed with cervical myelopathy[CM] and lumbar stenosis[LS] were identified. Univariate tests assessed differences in baseline patient-related, radiographic and surgical factors between CM and LS and those with both [TS]. Regression with stepwise model selection was employed to explore predictors of TS patients with a poor outcome (extended LOS>7days with occurrence of a perioperative complication).

Results: 867 operative cervical spine patients (54.6yrs, 44%F, 29kg/m2, mean CCI 1.12) included (122 CM, 286 LS, and 213 TS). In the present cohort, 79.4% of patients who had a diagnosis of LS had TS, while 57.3% of patients with a diagnosis of CM had TS. Baseline radiographic parameters were not different between TS, LS, and CM groups, $p>0.050$. TS patients were significantly older (60yrs), underwent more posterior(29.1%) and combined(10.3%) approaches($p<0.001$) compared to CM or LS patients. TS patients also had significantly more levels fused(3.02), total operative time (211min), EBL (251.6ccs), and LOS (3.4days, extended: 45.5%) over LS and CM patients, all $p<0.001$. The UIV for TS patients was around C3 (significantly higher), with a smaller Fluoroscopy dosage(5.3mGy vs 9.9mGy), greater use of Lactated Ringers (2324mL), all $p<0.001$. TS patients had greater intraoperative (2.8% vs 0.6%, $p<0.001$) and 30-day complications (16%, $p<0.050$). Neurological complications was the smallest in the LS only group, which tripled with addition of CM in the TS patient (7%, $p=0.010$). Of the patients with a diagnosis of TS, 26/213 patients(12.2%) incurred a poor perioperative outcome. Stepwise regression determined that the following combination of variables significantly predicted a poor outcome in TS patients: CCI, diabetes, preoperative ++ SRS-Schwab PI-LL, major C2-S1 angle, and undergoing a combined approach ($R2=0.506$, $p=0.039$).

Conclusion: Primary cervical operative patients with TS were found to have increased neurologic complications and extended length of hospital stay. Cervical surgeons should be wary of patients who present with concomitant stenosis of the lumbar and cervical spine in preoperative planning.

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E-Poster #40

Temporary Internal Fixation for Treatment of Symptomatic Odontoid Pseudarthrosis

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Introduction: Nonunion is a frequent complication following D' Alonzo Type 2 odontoid fractures. The treatment of symptomatic nonunion commonly involves C1-2 arthrodesis, resulting in loss of rotational range of motion (ROM). Temporary internal fixation without fusion has been described for acute fractures, however previous reports of this technique in patients with pseudarthrosis involved a technically demanding anterior / posterior procedure with exploration and debridement of the fibrous nonunion. In this study, we describe a posterior only temporary internal fixation and report our series of four patients.

Materials and Methods: Patients with symptomatic nonunion after a type 2 odontoid fracture were evaluated for surgery after failure of conservative therapy. These patients underwent a posterior only surgery involving temporary internal fixation at C1-2. Fixation was achieved via C1 lateral mass and C2 pedicle screws. Patients were rigidly orthosed post-operatively and followed with surveillance CT scans at 1 month and 3 months. Once consolidation of the pseudarthrosis was achieved on CT, instrumentation was then removed via a posterior approach. Neck ROM movements under sedation were used to break up any soft tissue adherences prior to closure.

Results: In the period from 2015 to 2020, four patients presented with symptomatic pseudarthrosis after attempts at non-operative intervention. These patients underwent posterior spinal internal fixation and post-operative orthosis. All four patients went on to achieve bony fusion by 1 year post-op. Instrumentation was removed in 3 patients. One patient, an 81 year old female, opted against removing her instrumentation to avoid a second surgery. All patients had resolution of pain after internal fixation, without recurrence of pain after removal of instrumentation. Table 1.

Conclusion: We describe the use of temporary internal fixation for the treatment of symptomatic nonunion after type 2 odontoid fracture. While previous attempts at this treatment paradigm involved both anterior and posterior procedures, posterior only internal fixation without direct repair of the nonunion may also be a reasonable option to preserve rotational ROM.

Age / sex	Mechanism of trauma	Time to diagnosis	Characteristics of pseudarthrosis	Time to surgery	Complications	Radiographic result	Time to Odontoid bone union	Duration of internal fixation (until removal of instrumentation)	Rotation retained after ROI
81 F	Ground level fall	0 months	Non displaced, 2 mm gap, b/l pars fracture	9 months	Mild left hand weakness	Successful bone union	3 months	Refused removal	N/A
78 F	Ground level fall	5 months	Non displaced, 2 mm gap, b/l pars fracture	8 months	None	Successful bone union	2 months	5 months	Right: 45 degrees Left: 30 degrees
18 M	Blunt trauma	0 months	Non displaced, 2 mm gap	6 months	None	Successful bone union	3 months	4 months	Right: 30 degrees Left: 40 degrees
61 F	Auto accident	2 months	Non displaced, 4 mm gap	5 months	None	Successful bone union	10 months	12 months	Right: 20 degrees Left: 25 degrees

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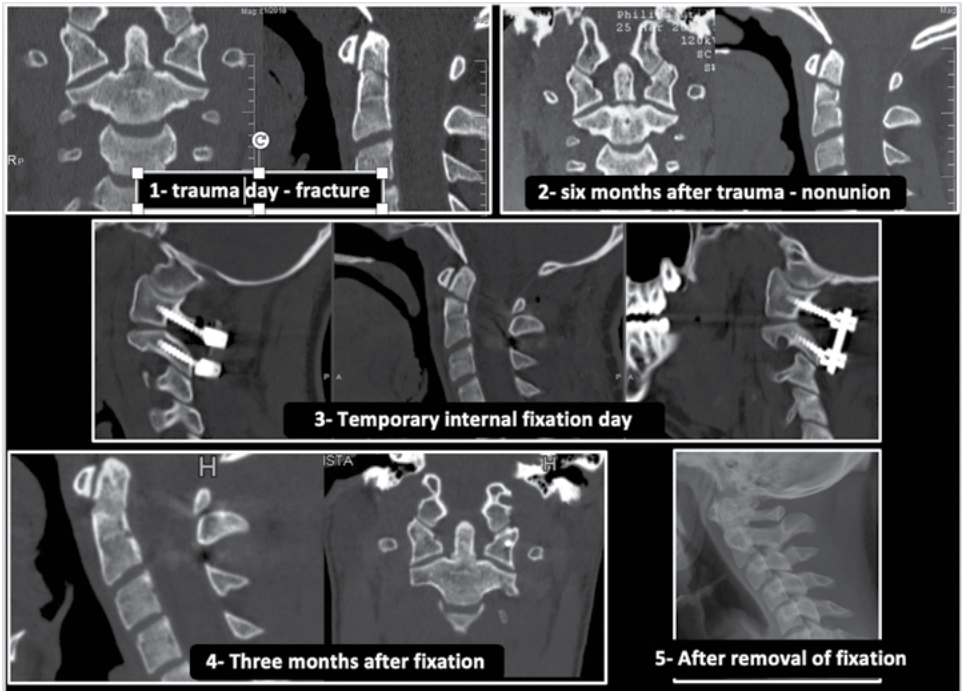

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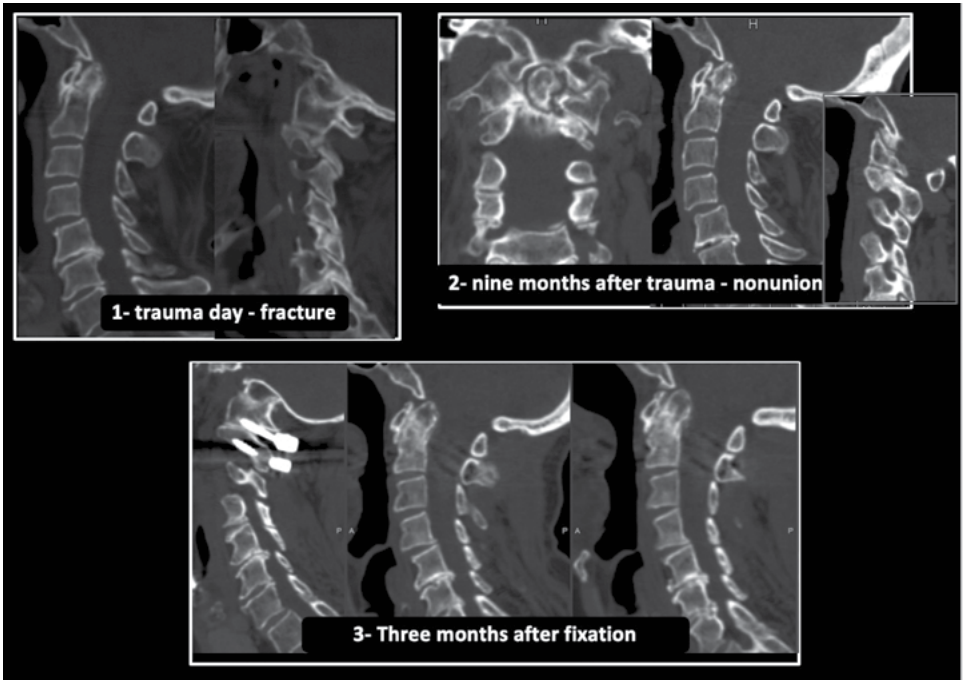

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E-Poster #41

C5 palsy secondary to nerve root injury associated with frictional heat generated by a high-speed drill during cervical surgery

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Introduction: Although nerve root palsy such as C5 palsy is known to occur after cervical surgery, the exact cause remains debatable, and various mechanisms are considered possible contributors to this common postoperative adverse event. These include perioperative nerve root injury, nerve root traction secondary to a posterior shift of the spinal cord, ischaemia, reperfusion injury, and various spinal cord disorders. Recent studies have reported that heat generated by high-speed drills may precipitate nerve root injury resulting in motor palsy (1,2). We evaluated the temperature around the nerve root during drilling of the lamina and histopathologically evaluated nerve root injury immediately, as well as 3, and 7 days postoperatively.

Materials and Methods: This basic science study was performed in New Zealand white rabbits. Nerve roots were exposed to frictional heat generated during high-speed drilling of the lamina in a live rabbit model. Drilling of the lamina was continued for 60 seconds at a stable pressure (2 N, Figure1). Concomitant saline irrigation during drilling was performed using saline at room temperature (RT group, n=30) or chilled saline (chilled group, n=30). A third group included rabbits who did not undergo irrigation (without irrigation [W/O] group, n=30). We measured temperatures around the nerve root using a specially ordered soft wire thermometer (Figure 2). Nerve root specimens were obtained immediately, as well as 3 and 7 days postoperatively, and we performed histopathological examination using Luxol fast blue and haematoxylin and eosin stains. Rabbits showing laminar perforation during drilling were excluded from the analysis to eliminate the effect of drill-induced direct injury.

Results: The mean temperature around the nerve root was 52.0°C (38.0°C–75.5°C) after 60 seconds of drilling in the W/O group. Nerve root injuries occurred in one of 13 (7.7%) rabbits immediately, in 3 of 14 (21.4%) rabbits 3 days and in 11 of 25 (44.0%) rabbits 7 days postoperatively (p value for tendency=0.019, Cochran-Armitage trend test). The temperature around the nerve root was significantly lower in the RT group than in the W/O group (mean 46.5°C [34.5°C–66.9°C], p <0.001). However, room temperature saline did not significantly reduce nerve root injury (10 of 26 rabbits, 38.5%, odds ratio (OR) 0.96, 95% confidence interval (CI) 0.516–1.785, p=0.563). Meanwhile, the temperature around the nerve root was significantly lower in the chilled group than in the W/O group (mean 39.0°C [35.3°C–52.3°C], p <0.001) along with a lower rate of nerve root injury (2 of 21 rabbits, 9.5%, OR 0.13, 95% CI 0.02–0.703, p=0.010).

Conclusion: Frictional heat generated by high-speed drills can precipitate histopathologically proven nerve root injury. We observed that such injury progressively worsened postoperatively, similar to the course of C5 palsy. This study highlights that surgeons should be mindful of the risk of thermal nerve root injury, particularly during extended drilling.

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Figure 1 Diagrammatic representation of the surgical system

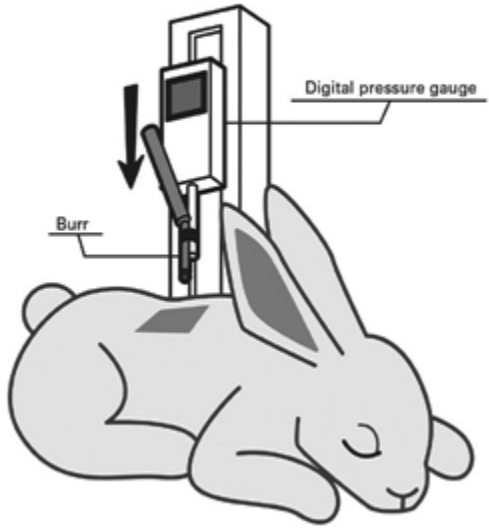
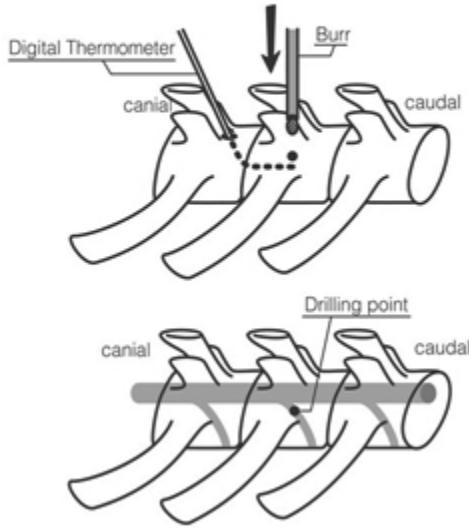


Figure 2 Diagrammatic representation of thermal evaluation of rabbits performed in the study



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E-Poster #42

When Not to Operate in Spinal Deformity: Identifying Subsets of Patients with Simultaneous Clinical Deterioration, Major Complications, and Reoperation

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Introduction: Due to the complexity and invasiveness of deformity correction, poor outcomes are often associated. Currently, it is unknown what factors predict an outcome which operation may not be warranted (reoperation, major complications, clinical deterioration). The purpose of this study was to investigate what patient factors justify determining a patient ineligible for a deformity correction.

Materials and Methods: Patients>18yrs undergoing surgery for ASD(scoliosis≥20°, SVA≥5cm, PT≥25°, or TK≥60°). An unsatisfactory outcome was defined by the following categories met at 2Y: (1) clinical: deteriorating in ODI at 2Y f/u (2) complications/reop: having a reoperation and major complication were deemed unacceptable for surgery (NoOp). Baseline demographic, clinical and radiographic information were utilized through univariate/multivariate analyses to assess predictive factors of NoOp patients in adult spinal deformity patients. Multivariate regression with backward model selection was employed to create a model for when not to operate.

Results: 633 ASD patients (59.9 years, 79%F, 27.7 kg/m2, CCI: 1.74) were included. By approach, 0.6% were anterior, 69.7% posterior and 29.5% combined approaches, with a total number of levels fused as 7.5±2.1. Baseline severe Schwab modifier incidence (++): 39.2% PI-LL, 28.8% SVA, 28.9% PT. 15.5% of patients deteriorated in ODI by 2 years, while 7.6% underwent a reoperation and had a major complication. This categorized 11 (1.7%) of patients in the total cohort as NoOp. NoOp patients had were more comorbid in terms of arthritis (73%) heart disease (36%) and kidney disease (18%), $p<0.001$. Surgically, NoOp patients had an overall greater EBL (4431ccs), underwent more osteotomies (91%), specifically Ponte(36%) and Three Column Osteotomies(55%), which occurred more at L2(91%). NoOp patients underwent more PLIFs (45%) and had more blood transfusion units (2641ccs), all $p<0.050$. The multivariate regression predicting the NoOp ASD group determined a combination of a baseline DRAM score in the 75th percentile, having arthritis and kidney disease, a baseline right lower extremity motor score ≤3, cSVA >65mm, C2 slope >30.2°, CTPA >5.5° for an R2 value of 0.535 ($p<0.001$).

Conclusion: When addressing adult spine deformities, a negative outcome of clinical deterioration, major complications, and reoperations is exceedingly rare, but does occur. This tends to occur in severely comorbid patients with major baseline psychological distress scores, poor neurologic function and concomitant cervical malalignment.

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E-Poster #43

How Does Surgical Approach Affect Outcomes Following Cervical Spine Trauma in the Elderly?

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Introduction: Both anterior - anterior cervical discectomy and fusion (ACDF) and posterior - posterior cervical fusion (PCF)] approaches are commonly used to treat traumatic injuries of the cervical spine. Some evidence exists to suggest that ACDF may be superior in younger patients with studies demonstrating shorter hospital stays and fewer complications. However, there is data paucity of studies comparing outcomes between these surgical approaches in elderly patients with cervical spine injuries. With a rapidly aging population in the United States and the corresponding increase in spine trauma in this population, this topic is of increasing importance. Outcome studies comparing ACDF to PCF in the elderly are important to inform surgical management of elderly patients with spinal injury. This study aims to determine if there are outcome differences of ACDF versus PCF in elderly patients – particularly with regard to complication rates and hospital admission length.

Materials and Methods: Patient demographics, comorbidities, and long-term outcomes were collected into a deidentified institutional spine trauma database. Elderly patients (65+) were age-matched and divided into ACDF and PCF groups. There were no statically significant difference in the ISS score, injury pattern, or rate of concurrent polytrauma, or comorbidities between these groups ($P > 0.05$). Surgical and medical morbidity variables that were evaluated include surgical site and hospital acquired infections, DVT, PE, stroke, pneumonia, and myocardial infarction. A combination of Pearson and t-tests were used to assess correlation between approach and preexisting comorbidities as well as correlations between approach and outcomes (estimated blood loss during surgery, hospital stay length, death during admission, and time to death).

Results: A total of 40 patients, 19 anterior and 21 posterior, were included with an average age of 69.8 and 76.6, respectively. There was a significant difference in average age between these cohorts ($P<.001$). Of intraoperative variables, there was a significantly greater average blood loss ($P < 0.01$) in the PCF group. However, there was no correlation between approach and length of stay ($P = 0.97$), medical ($P = 0.58$) or surgical ($P = 0.30$) complication, in-hospital mortality ($P = 0.52$), or death within one year ($P = 0.79$).

Conclusion: In this cohort, there was no significant difference in morbidity or mortality between ACDF and PCF. Estimated blood loss was found to be significantly lower with patients who underwent ACDF, but this did not translate to a difference in complications or hospital stay. Therefore, our data suggests that ACDF remains a safe option in the appropriate elderly patient with fractures amenable to anterior fixation. However, the benefits of ACDF over PCF may not be as pronounced as in younger populations. Future study, including larger multi-center studies focusing on patient reported outcomes may help elucidate additional differences between the two approaches in this population.

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Table 1

	Anterior Approach (ACDF)	Posterior Approach (PSF)	P-Value
N	19	21	
Average Estimated Blood Loss (mL)	148.42	443.00	*0.000378476
Average Length of Stay (days)	9.63	9.57	0.976691536
Surgical Complications	1	0	0.298623206
Medical Complications	6	5	0.58265728
1-Year Mortality	3	4	0.786529392

*,P-value<0.05

E-Poster #44

Impact of Preoperative Weakness and Duration of Symptoms on Health-Related Quality-of-Life Outcomes Following Anterior Cervical Discectomy and Fusion

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Introduction: The majority of patients with pre-operative upper extremity weakness show improvements in motor function after anterior cervical discectomy and fusion (ACDF). While numerous studies have examined both the extent and time course to which motor function can be expected to improve, few have shown that improvements in motor function translate to better Health-Related Quality-of-Life Outcomes (HRQOL). The purpose of this study is to examine the effect of preoperative weakness and duration of symptoms on HRQOL outcomes in patients who underwent anterior cervical discectomy and fusion.

Materials and Methods: A retrospective cohort study was conducted with patients who underwent an ACDF procedure over a 2-year period. Patient demographics, surgical case characteristics, motor strength exams, and HRQOL outcomes (Short Form-12 Physical (PCS-12) and Mental (MCS-12) Composite Scores, Neck Disability Index (NDI), and Visual Analogue Scale (VAS) Arm and Neck) were collected. Means and categorical variables were compared using t-test, Mann-Whitney U test, Wilcoxon Rank sum test and chi-squared test where appropriate. Multivariate linear regression analysis was performed to determine the effect of the preoperative weakness on patient-reported outcomes.

Results: 276 patients were identified. 46 patients (16.5%) showed evidence of preoperative weakness, 45 (97.8%) of which showed subsequent postoperative motor recovery after ACDF. All patients reported significant improvements in all HRQOL outcomes. Patients with preoperative weakness reported significantly worse preoperative VAS Arm (6.9 vs. 5.2; p: 0.01) and VAS Neck (6.1 vs. 4.8; p: 0.02) scores. Compared to patients without preoperative weakness, patients with preoperative weakness reported significantly more improvement in NDI (β: -10.9; p: 0.001) and VAS Neck (β: -1.5; p: 0.02) scores (Table 1). Patients with symptoms for longer than 12 months showed significantly less improvement in NDI (β: 12.4; p: 0.047) and VAS Arm (β: 2.0; p: 0.03) compared to those with symptoms for less than 12 months (Table 2).

Conclusion: Patients with preoperative weakness generally had worse pain and HRQOL measures preoperatively and showed greater potential for improvement after ACDF. Patients with a shorter duration of preoperative weakness had greater potential for improvement in HRQOL measures after ACDF compared to those with longer duration of symptoms. ACDF is an effective procedure to improve strength and HRQOL measures across all patient groups under appropriate indications.

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Table 1 Patient-reported outcomes at minimum 1-year follow-up stratified by presence or absence of preoperative weakness

		No Preoperative Weakness (n = 231)	Preoperative Weakness (n = 45)	p-value[1,2]	Regression Analysis[3]
PCS-12					
	Pre-Op	31.3 [25.6, 37.5]	30.9 [23.6, 39.3]	0.99	β: 0.6 [-4.4, 3.1] p: 0.74
	Post-Op	42.1 [32.2, 49.5]	39.9 [33.4, 48.9]	0.72	
	Δ-value	9.6 [1.7, 17.3]	11.7 [2.6, 15.5]	0.97	
	p-value[2]	< 0.001*	< 0.001*		
MCS-12					
	Pre-Op	47.2 [36.5, 56.5]	52.5 [41.3, 58.5]	0.14	β: 1.0 [-5.7, 3.6] p: 0.66
	Post-Op	53.1 [42.7, 59.7]	56.5 [44.6, 60.6]	0.36	
	Δ-value	4.9 [-3.2, 13.5]	6.7 [0.2, 11.0]	0.83	
	p-value[2]	< 0.001*	< 0.001*		
NDI					
	Pre-Op	37.0 [24.0, 48.0]	44.0 [27.3, 62.5]	0.07	β: -10.9 [-17.3, -4.5] p: 0.001*
	Post-Op	25.0 [14.0, 40.0]	19.5 [8.5, 35.0]	0.09	
	Δ-value	-11.0 [-21.0, -1.0]	-15.0 [-24.0, -6.0]	0.03*	
	p-value[2]	< 0.001*	< 0.001*		
VAS Arm					
	Pre-Op	5.2 [3.5, 7.3]	6.9 [5.1, 8.3]	0.01*	β: -0.9 [-1.9, 0.2] p: 0.12
	Post-Op	1.0 [0.0, 2.7]	1.6 [0.7, 2.9]	0.10	
	Δ-value	-3.7 [-5.6, -1.9]	-4.1 [-6.3, -2.9]	0.27	
	p-value[2]	< 0.001*	< 0.001*		
VAS Neck					
	Pre-Op	4.8 [3.1, 7.1]	6.1 [4.3, 8.3]	0.02*	β: -1.5 [-2.7, -0.3] p: 0.02*
	Post-Op	2.1 [0.7, 4.1]	1.8 [0.3, 3.8]	0.76	
	Δ-value	-2.5 [-3.9, -0.8]	-3.4 [-4.8, -2.3]	0.02*	
	p-value[2]	< 0.001*	< 0.001*		

[1] Independent-samples t-test or Mann-Whitney U test
[2] Paired-sample t-test or Wilcoxon Rank sum test
[3] Multiple linear regression controlling for age, gender, BMI > 40, CCI
* Significance established at $p < 0.05$
PCS-12: Physical Component of SF-12, MCS-12: Mental Component of SF-12, NDI: Neck Disability Index, VAS: Visual Analog Scale

Table 2 Patient-reported outcomes stratified by duration of symptoms among patients with preoperative weakness

		< 12 months (n = 31)	≥ 12 months (n = 14)	p-value[1,2]	Regression Analysis[3]
PCS-12					
	Pre-Op	31.3 [25.0, 39.9]	29.8 [20.5, 37.2]	0.46	
	Post-Op	42.5 [34.9, 52.2]	36.8 [28.5, 42.8]	0.08	β: -3.7 [-12.4, 5.1] p: 0.40
	Δ-value	11.7 [2.8, 16.2]	10.5 [-1.8, 15.3]	0.40	
	p-value[2]	< 0.001*	0.01*		
MCS-12					
	Pre-Op	55.8 [46.5, 59.8]	39.3 [26.1, 48.7]	< 0.001*	
	Post-Op	58.1 [49.3, 62.6]	46.7 [31.2, 54.7]	0.02*	β: 6.3 [-2.2, 14.9] p: 0.14
	Δ-value	5.5 [0.0, 9.0]	9.5 [0.3, 13.8]	0.26	
	p-value[2]	0.03*	0.03*		
NDI					
	Pre-Op	46.0 [28.0, 62.0]	39.0 [24.0, 74.0]	0.80	
	Post-Op	15.0 [6.5, 35.5]	25.0 [16.0, 35.0]	0.18	β: 12.4 [1.4, 26.1] p: 0.047*
	Δ-value	-21.0 [-41.0, -8.5]	-11.0 [-14.0, -3.5]	0.04*	
	p-value[2]	< 0.001*	0.01*		
VAS Arm					
	Pre-Op	7.1 [5.6, 8.7]	5.3 [3.9, 7.3]	0.03*	
	Post-Op	1.2 [0.0, 3.7]	2.1 [1.5, 2.9]	0.31	β: 2.0 [0.2, 3.6] p: 0.03*
	Δ-value	-4.5 [-7.0, -3.1]	-3.3 [-4.4, -1.2]	0.02*	
	p-value[2]	< 0.001*	0.01*		
VAS Neck					
	Pre-Op	7.0 [3.5, 8.5]	5.4 [4.7, 8.4]	0.87	
	Post-Op	1.4 [0.0, 5.2]	1.8 [1.1, 3.2]	0.89	β: -0.9 [-3.3, 1.4] p: 0.42
	Δ-value	-3.3 [-4.6, -2.0]	-4.0 [-5.9, -2.8]	0.29	
	p-value[2]	0.001*	0.01*		

[1] Independent-samples t-test or Mann-Whitney U test
[2] Paired-sample t-test or Wilcoxon Rank sum test
[3] Multiple linear regression controlling for age, gender, BMI > 40, CCI
* Significance established at p < 0.05
PCS-12: Physical Component of SF-12, MCS-12: Mental Component of SF-12, NDI: Neck Disability Index, VAS: Visual Analog Scale

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E-Poster #45

Radicular Symptoms after Anterior Cervical Discectomy and Fusion

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Introduction: Although ACDF is one of the most effective treatments for patients with cervical myelopathy and radiculopathy, postoperative radiculopathy can persist or occur de novo. To the best of our knowledge, few reports have addressed this aspect of ACDF. In this study, we aimed to analyze the incidence and characteristics of postoperative radiculopathy after ACDF and to ascertain the risk factors contributing to it.

Materials and Methods: We retrospectively reviewed patients who underwent ACDF done by one academic spine surgeon for degenerative pathologies with follow-ups at 6 weeks, 6 months, and 1 year after surgery. At each follow-up period, the presence of radicular symptoms, including sensory disturbance, muscular weakness, and radicular pain were identified by chart review. Patients were dichotomized into no-radiculopathy vs. radiculopathy, with the latter defined by radicular symptoms on at least one follow-up. Data included demographics, diagnosis, duration of symptoms before surgery, EBL, surgical levels, complications, and postoperative symptoms. C2-C7 SVA and index level flex-ex interspinous process distance, for fusion status (<1mm), were evaluated pre/postop.

Results: A total of 60 patients were included. The incidence of radicular symptoms was 26/60 (43%), 16/60 (27%), and 14/60 (23%) at 6 weeks, 6 months, and 1 year after surgery, respectively, and the most prevalent symptom was sensory disturbance (Figure 1). There were 10, 36, and 39 patients with preoperative constant numbness, muscular weakness, and radicular pain, respectively. Patients with preoperative constant numbness had more postoperative sensory disturbance than those with intermittent numbness at any follow-up (70% vs. 28%; P=0.027, 60% vs. 22%; P=0.046, and 60% vs. 19%, P=0.020 at 6 weeks, 6 months, and 1 year, respectively). Most patients with preop muscular weakness improved by 6 weeks postop, and none of those who had preop radicular pain complained of radicular pain at 6 and 12 months, irrelevant of fusion status (Figure 2). Patients in the radiculopathy group were older (63.5 vs. 57.9, P=0.042); otherwise, there was no difference between the two study groups concerning patient demographics, operative data, or radiographic measurements. Multivariate analysis revealed the duration of symptoms before surgery correlated with the risk of postoperative radicular symptoms (OR = 1.02; P=0.023) (Table 1).

Conclusion: The incidence of radiculopathy after ACDF was approximately 40% at 6 weeks and 25% at 6 months and 1 year after surgery. The most common persistent symptom was sensory disturbance with muscular weakness and radicular pain far lower. Preop constant numbness was more associated with postoperative numbness, whereas intermittent numbness, muscular weakness and radicular pain mostly recovered by 6 months after surgery. The duration of symptoms before surgery was associated with a persistence of postoperative radiculopathy, whereas spinal alignment and fusion status did not. Patients should be warned that preoperative constant numbness is likely to persistent in >60% of cases and prolonged duration of numbness

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portends a poor prognosis.

Figure 1a: Bar graph showing Kappa value, sensitivity, and specificity of 4 questions when the criterion of extra graft bridging bone on CT scan was used to define fusion status.

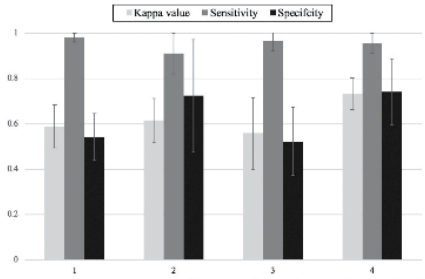


Figure 1b: Bar graph showing a comparison of the sensitivity, specificity, intra, and inter reliability of the studies.

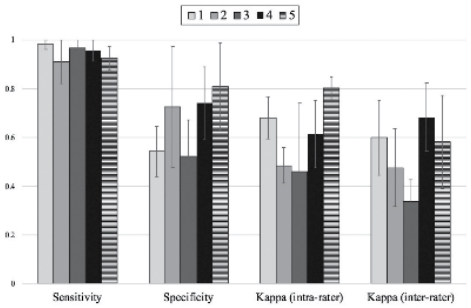
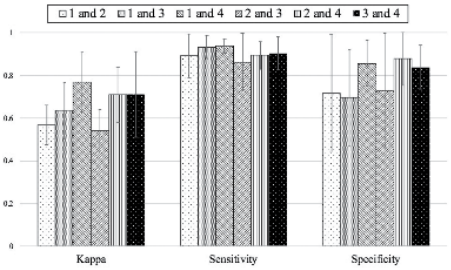


Figure 1c. A bar graph showing the inter-rater reliability, sensitivity, and specificity for a combination of two radiographic criteria in diagnosing fusion status compared to consensus opinion using CT.



	Kappa	Sensitivity	Specificity
1 and 2	0.5686	0.893	0.7184
1 and 3	0.6362	0.9332	0.6954
1 and 4	**0.7706**	**0.94**	**0.8568**
2 and 3	0.5422	0.8626	0.7302
2 and 4	**0.7102**	**0.8946**	**0.8782**
3 and 4	**0.7114**	**0.905**	**0.839**

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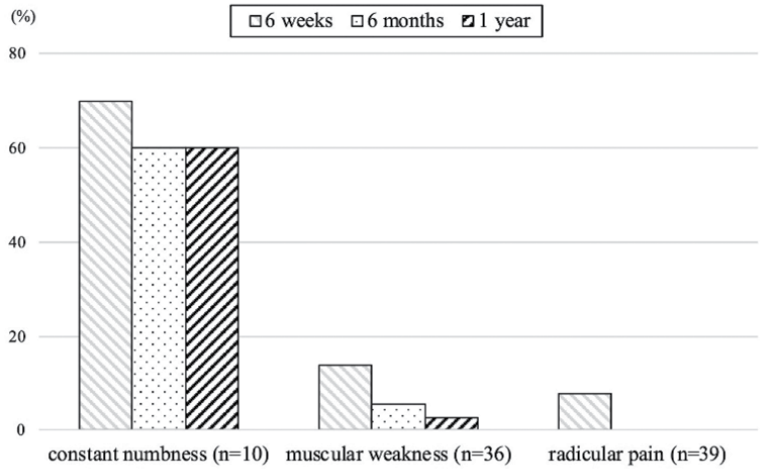
Figure 2. Graph showing postoperative sensory disturbance, muscular weakness, and radicular pain in patients with preoperative constant numbness, muscular weakness, and radicular pain, respectively. More than half of the patients with preop constant numbness had postop sensory disturbance. On the other hand, most patients with preop muscular weakness and radicular pain improved postoperatively.



E-Poster #46

Failure Mechanisms and Revision Strategies for DJK Following Cervical Deformity Correction

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Introduction: Cervical deformity (CD) surgery can markedly improve a patient's life quality. Distal junctional kyphosis (DJK) is a common complication of cervical deformity surgery. Severe DJK can erode corrections and postoperative cervical malalignment has been correlated with poor health outcomes (HRQL). Although studies have identified risk factors for DJK, the mechanisms and revision strategies for severe DJK (sDJK) are not well understood. This study aims to investigate if revisions for severe DJK can restore satisfactory alignment and improve clinical outcomes.

Materials and Methods: A retrospective review of a prospective database of operative CD patients was analyzed. Fusions below L4 were excluded. Severe DJK was defined as a postoperative change >20° (LIV to LIV-2). Those with LIV to LIV-2 <20° were defined as noDJK. sDJK patients were compared to those without in terms of demographic factors, surgical factors, revisions and HRQL at baseline and 1 year, using t-tests and X2 tests for continuous and categorical variables, respectively. Mechanisms of sDJK and sDJK revision strategies were described.

Results: 163 patients included (mean age 61.32, 61.11% F). sDJK occurred in 16 (9.8%) with mean maximum DJK angle of -31.96°?9.6°. Osteoporosis (p=0.02) and Neuromuscular disease (p=0.001) were more likely in sDJK. There were no significant differences in % smokers, BMI and CCI (all p>.05). sDJK patients had more posterior levels fused and more caudal posterior and anterior LIV (all p<.05). sDJK patients had a higher rate of Smith-Petersen osteotomy (56.30% vs. 20.40%, p=0.001). There was no significant difference in HRQL change at 3, 6 and 12 months between cohorts. The revision rate was 37.5% for sDJK and 11.6% for noDJK (p=0.005). 64% of sDJK had a bony failure (78% LIV; 22% LIV-1), 21% had screw pull-out of LIV, 14% had ligamentous failure (Fig 1). For noDJK, 31% were revised for neurological deficits, 25% for infection, and 19% for prominent hardware.The mean additional levels fused in sDJK revisions were 8.3?5.5. One sDJK patient required a 2nd revision. Post revision, mean C2 slope was 39.3°?10.3° and cSVA was 45.2?13.2.

Conclusion: Post CD surgery, sDJK occured at 9.8%. Bony failure was the most common DJK mechanism, often occurring at the LIV. Strategies for revision include longer fusions with mean of 8.3 additional levels, however, revisions for severe DJK frequently do not result in optimal cervical alignment.

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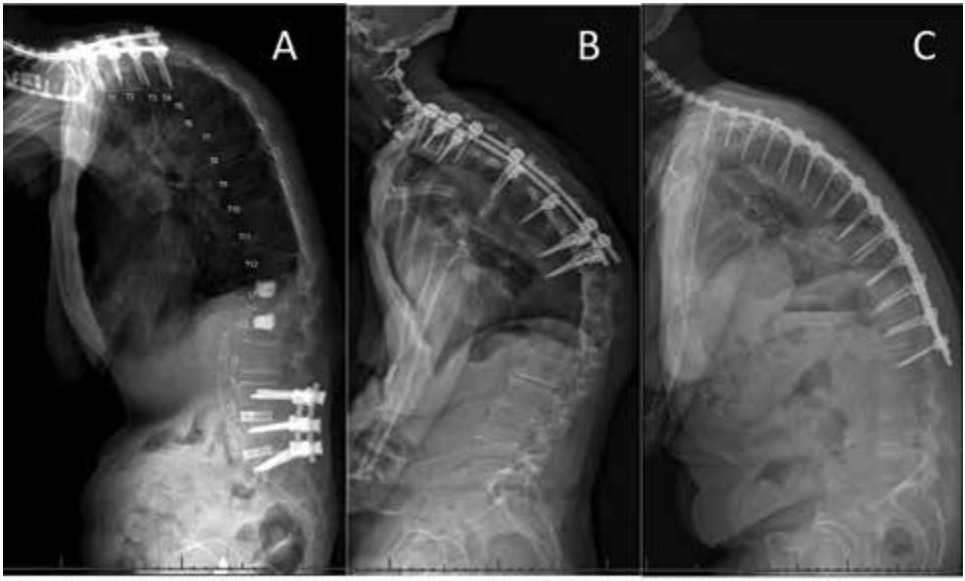

Figure 1: Failure mechanisms observed for sDJK: A) Fracture proximate to LIV, B) Ligamentous failure, C) Screw pull-out

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E-Poster #47

Higher Baseline Function Portends Worse Outcomes after Anterior Cervical Discectomy and Fusion

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Introduction: Defining the minimal clinically important difference (MCID) for a given surgery and patient-reported outcomes measure (PROM) may have more clinical utility than identifying statistically significant changes in outcomes after surgery. Multiple validated PROMs exist to evaluate outcomes after anterior cervical discectomy and fusion (ACDF). We set out to calculate and determine risk factors for not meeting the MCID in the population undergoing ACDF at one institution.

Materials and Methods: We performed a retrospective review of all patients undergoing ACDF with at least one year of follow up. Data collected included general demographics, body mass index (BMI), medical and psychological co-morbidities, alcohol or tobacco use, chronic steroid use or immunosuppression, and number of surgical levels. Radiographic variables were measured on all patients pre- and post-operatively, including the C2 sagittal vertical axis (SVA), global cervical lordosis, and segmental lordosis. Outcomes measures included the Neck Disability Index (NDI), RAND survey, EuroQual-5D (EQ-5D) and single assessment numeric evaluation (SANE). The MCID for each PROM was calculated and analyzed using a previously published technique.

Results: Results for each PROM are reported individually. There were no preoperative differences in demographics or radiographic parameters between the MCID and non-MCID groups except for two factors, as noted in Tables 1 and 2. There were no differences in any overall preoperative PROMs, except as noted below for the EQ-5D non-MCID group. The non-MCID groups had worse overall outcomes for all tested PROMs. Seventy-two patients had complete RAND data for analysis. Twenty-six (36%) did not meet MCID. Patients in the non-MCID group reported significantly better preoperative heavy (19.7 vs 8.3, $p=0.05$) and moderate activity (40.8 vs 20.5, $p=0.04$). Improvements in NDI, EQ-5D and SANE were significantly smaller in the non-MCID group ($p<0.01$, respectively). Twenty-two patients did not meet MCID for EQ-5D (29.7%, N=74). There was significantly better self-reported sleep and lower pain in the non-MCID group ($p<0.05$, respectively). We found significantly higher ability to perform daily activities ($p=0.03$) and significantly lower pain preoperatively in the non-MCID group (1.7 vs 2.2, $p=0.03$). The non-MCID group had a significantly higher SANE preoperatively (69.3 vs 81.9, $p=0.01$), and significantly smaller improvements in the overall NDI, RAND and SANE after surgery. Twenty patients did not meet the MCID for NDI (27.0%, N=74). There was significantly lower preoperative pain intensity in the non-MCID group (1.6 vs 2.2, $p=0.01$). Again, patients reported significantly smaller improvements in NDI, RAND and SANE in the non-MCID group.

Conclusion: Based on multiple validated legacy PROMs, we found that patients with higher preoperative function and less pain were more likely to not meet the MCID for ACDF. Patients in the non-MCID group for each PROM experienced significantly smaller improvements in all

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measured composite areas, and had significantly lower postoperative outcomes scores. Our findings suggest that there may be a functional level beyond which ACDF does not yield clinically important improvements in patient-reported symptoms.

TABLE 1 Demographics - NDI			
Variable	MCID not met (n = 19)	MCID met (n = 55)	P value
Age	52.2	52.8	.850
Sex (Female)	8 (42.1%)	29 (52.7%)	.595
BMI*	30.4	29.9	.789
Diabetes	4 (21.1%)	15 (27.3%)	.763
Hypertension	8 (42.1%)	23 (41.8%)	.617
Hyperlipidemia	7 (36.8%)	21 (38.2%)	.643
Autoimmune d/o	1 (5.3%)	10 (18.2%)	.269
Osteoporosis	1 (5.3%)	8 (14.6%)	.432
Chronic steroid	4 (21.1%)	8 (14.6%)	.613
Immunosuppression	1 (5.3%)	4 (7.3%)	.618
Revision surgery	0 (0.0%)	3 (5.5%)	.565
Anxiety	1 (5.3%)	3 (5.5%)	.704
Depression	7 (36.8%)	18 (32.7%)	.783
Alcohol abuse	**5 (26.3%)**	**4 (7.3%)**	**.043**
Smoking	0 (0.0%)	5 (9.1%)	.216
Levels			
One level	10 (52.6%)	21 (38.2%)	.462
Two level	6 (31.6%)	26 (47.3%)	
Three level	3 (15.8%)	8 (15.6%)	

BMI* Body Mass Index

TABLE 2 Radiographic Parameters - EQ-5D			
Variable	MCID not met (n = 21)	MCID met (n =53)	P value
C2 SVA preop	**35.8**	**23.8**	**.017**
C2 SVA postop	**35.3**	**25.7**	**.0122**
C2 SVA Δ	0.4	-2.72	.524
C2-7 lordosis preop	7.3	13.0	.177
C2-7 lordosis postop	11.0	14.8	.218
C2-7 lordosis Δ	3.70	1.61	.565
Regional lordosis preop	3.01	4.41	.402
Regional lordosis postop	8.80	8.38	.839
Regional lordosis Δ	5.79	3.66	.370

E-Poster #48

Frailty is a better predictor of mortality and perioperative complications compared to age alone after surgery for Degenerative Cervical Myelopathy; an ambispective study of 41,369 patients from the NSQIP database 2010-2018.

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Introduction: Much controversy exists regarding the safety and efficacy of surgery for Degenerative Cervical Myelopathy (DCM) in the elderly age group (Wilson et al 2019, Severino et al 2019). The use of frailty indices for risk evaluation in DCM surgery has not been established. The objectives of the study was to determine significant predictors of perioperative complications and mortality after DCM surgery with regards to age and physiological reserve measured by the modified frailty indices 5-point and 11-point (MFI5, MFI11).

Materials and Methods: The NSQIP inpatient sample database records from 2010-2018 were interrogated for adult patients who underwent surgery with a diagnosis of DCM based on ICD9/ICD 10 codes (721.1, 722.71, M47.12, M50*). MFI11 and MFI5 scores were calculated using previously published conventions matching variables within the NSQIP database volume. Outcomes of Mortality, major complication, readmission <30 days, reoperation <30 days and length of stay were calculated for each patient and compared initially with univariate analysis. A multivariable regression model was used to test the effect of age alone or MFI5/MFI11 on each outcome variable, adjusting for surgical approach, gender and number of levels operated.

Results: 41,369 patients were included, mean age 56.6[56.5-56.7], 46% were female. Anterior was the most common approach (80%), with 3% combined anterior/posterior. On univariate analysis, age and MFI5/MFI11 were significantly correlated with mortality, major complication, unplanned readmission, reoperation within 30 days, length of hospital stay and discharge destination other than home ($p<0.05$ for each, see Table 2). Increasing frailty for both MFI5/MFI11 demonstrated increasing risk for each outcome, and the effect size for frailty ("Frail" & "Severely Frail" patients) was higher compared to age. The multivariable regression model confirms that the MFI5 score is a stronger predictor of all outcome variables compared to age as a continuous variable ($p<0.05$, see Table 3).

Conclusion: In one of the largest studies on perioperative complications in DCM, Frailty indices appear to be stronger predictors of adverse events compared to age alone. This has important implications in the pre-operative assessment and counselling of patients undergoing surgery for DCM.

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Table 1 - Patient Demographics	
Age mean (95% CI)	56.6 [56.5-56.7]
-distribution (n):	
18-30	627
30-40	3728
40-50	8858
50-60	12427
60-70	9966
70-80	4745
80-90	931
90+	87
Gender	
- Male	22,191 (54%)
- Female	19,167 (46%)
Ethnicity	
- White	30778 (74%)
- Black/African American	5260 (13%)
- Asian	897 (2.1%)
- American Indian	222 (0.5%)
- Native Hawaiian / Pac Island	141 (0.4%)
- Unknown	4071 (10%)
Approach (where defined)	
- Anterior	27380 (80%)
- Posterior	5945 (17%)
- Combined	962 (3%)
Distribution of Frailty	
MFI5	
- Not frail	18482 (45%)
- Pre-frail	14904 (36%)
- Frail	6816 (16%)
- Severely Frail	1167 (3%)
MFI11	
- Not frail	4650 (40%)
- Pre-frail	4406 (37%)
- Frail	2239 (19%)
- Severely Frail	463 (4%)

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Table 2 - Univariate Analysis
(all results OR [95%CI], * designates significant at the <0.05 level)

	Mortality	Major Complication (Pneumonia, DVT/PE, MI, Cardiac Arrest, Wound infection/dehiscence, Sepsis, CVA)	Unplanned Readmission	Reoperation	Length of Hospital Stay
Age	1.09 [1.08-1.11]*	1.06 [1.05-1.06]*	1.05[1.03-1.07]*	1.07[0.99-1.04]	0.062[0.058-0.067]*
MFIS					
-Pre-frail	4.89 [2.72-8.79]*	2.40 [2.06-2.80]*	1.30 [0.71-2.40]	0.57 [0.22-1.51]	0.82 [0.70-.94]*
- Frail	8.37 [4.58-15.32]*	3.80 [3.22-4.48]*	3.40 [1.89-6.12]*	2.71 [1.26-5.86]*	1.67 [1.52-1.82] *
-Severely Frail	27.70 [14.29-53.69]*	11.63 [9.44-14.33]*	6.37 [2.80-14.50]*	8.57 [3.41-21.52] *	3.74 [3.42-4.06]*
MFI11					
-Pre-frail	4.45 [1.68-11.81]*	1.87 [1.45-2.41]*	1.11 [0.59-2.09]	0.49 [0.18-1.28]	0.80 [0.47-1.13]*
- Frail	7.11[2.62-19.29]*	2.84 [2.17-3.72]*	2.75 [1.51-5.01] *	1.92 [0.88-4.22]	1.83 [1.42-2.24] *
-Severely Frail	20.51[6.98-60.26]*	7.39 [5.30-10.31]*	3.74 [1.56-8.95]*	4.68 [1.77-12.38]*	4.39 [3.61-5.16] *

Table 3 - Multivariable Analysis
(all results OR [95%CI], * designates significant at the <0.05 level)

	Mortality	Major Complication (Pneumonia, DVT/PE, MI, Cardiac Arrest, Wound infection/dehiscence, Sepsis, CVA)	Unplanned Readmission	Reoperation	Length of Hospital Stay
Age	1.08 [1.05-1.10] *	1.04 [1.03-1.05] *	1.02 [0.99-1.04]	0.98 [0.95-1.02]	0.021 [0.015-0.026] *
MFIS					
-Pre-frail	2.07 [1.09-3.92] *	1.48 [1.24-1.77] *	0.80 [0.35-1.80]	0.54 [0.15-1.87]	0.31 [0.17-0.45] *
- Frail	3.19 [1.64-6.17] *	2.27 [1.87-2.75] *	2.67 [1.27-5.63] *	2.87 [1.06-7.83] *	0.92 [0.74-1.09] *
-Severely Frail	10.84 [5.28-22.30] *	5.83 [4.54-7.48] *	3.47 [1.18-10.21] *	10.71 [3.57-32.17] *	2.84 [2.47-3.21] *

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E-Poster #49

In vivo kinematic responses of the human cervical spine during walking

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Introduction: Knowledge of cervical spine motion is critical for understanding cervical pathology and for improving treatment methods. Although walking is the most commonly performed human motor activity, spinal kinematics during walking has been less investigated, and no data has been reported on the cervical segmental kinematics during walking. In this study, we investigated in vivo dynamic cervical motion and intervertebral disc deformation during walking. It was hypothesized that the cervical spine is loaded at a higher frequency than lower limb joints such as the knee and hip during gait.

Materials and Methods: Eight asymptomatic female subjects (ages: 28 ~ 46 years) were included in this study. For each subject, optical markers were placed on the neck and the heels (Fig. 1). Motions of the optical markers and cervical spine were simultaneously captured using a motion analysis system (120 Hz) and a dual fluoroscopic imaging system (30 Hz), when each subject walked on a treadmill integrated with force plates (Fig. 1). Using 2D-3D registration algorithms, the 3D models of C1-T1 cervical vertebrae segmented from CT images were matched to the vertebral profiles on dual fluoroscopic images (Fig. 1), such that the positions and alignments of vertebrae in 3D space were determined. Motions of the cervical spine were synchronized to those of the markers on the heels and neck by optimization, and validated by reaction force data (Fig. 2). Using intervertebral kinematics of each segment, we calculated disc deformations in the left-right (LR), anterior-posterior (AP), and proximal-distal (PD) directions at the disc center sites.

Results: The frequency of the cervical PD translation (1.6 ± 0.1 Hz) was twice that of the gait cycle (0.8 ± 0.1 Hz), due to the strikes of left and right feet against the ground. The overall ranges of motion (ROMs) of the entire (C2-T1) cervical spine were 5.0±3.1º in flexion-extension rotation, 3.4±1.0º in lateral-bending rotation, and 5.8±2.1º in the axial-twisting rotation during walking. As presented in Table 1, each intervertebral disc (measured at the disc center location) dynamically deformed in its axial direction in a range of 16.2±5.7% ~ 23.7±8.7%, which was similar to the ranges of shear deformations ($p > 0.05$, except for the C7-T1 disc).

Conclusion: Our data show that that each cervical segment was more frequently loaded during walking, compared with other joints such as the knee and hip. Since contemporary surgical treatments using spinal fusion or total disc arthroplasty restrict intervertebral axial translations, larger and more frequent impact during human locomotion may be exerted to the adjacent segments after implantation, causing dynamic overloading of adjacent segments. Our study suggests that future disc prosthesis design should incorporate innovative mechanisms that allow the axial intervertebral motion at the treated segment levels to mitigate the development of adjacent segment degeneration.

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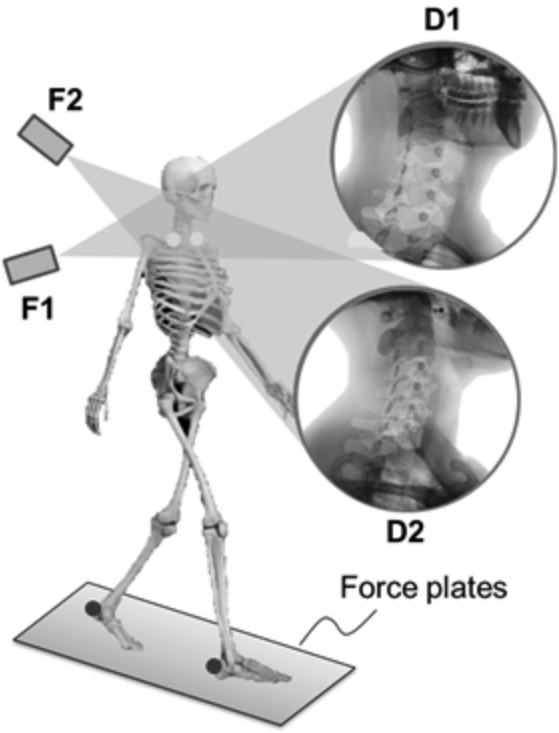

Fig. 1: Three types of measurements performed simultaneously, including dual fluoroscopic imaging of the cervical spine, motion track of neck (green) and heel (blue) reflective markers, and measurement of loads exerted by left/right feet on force plates.

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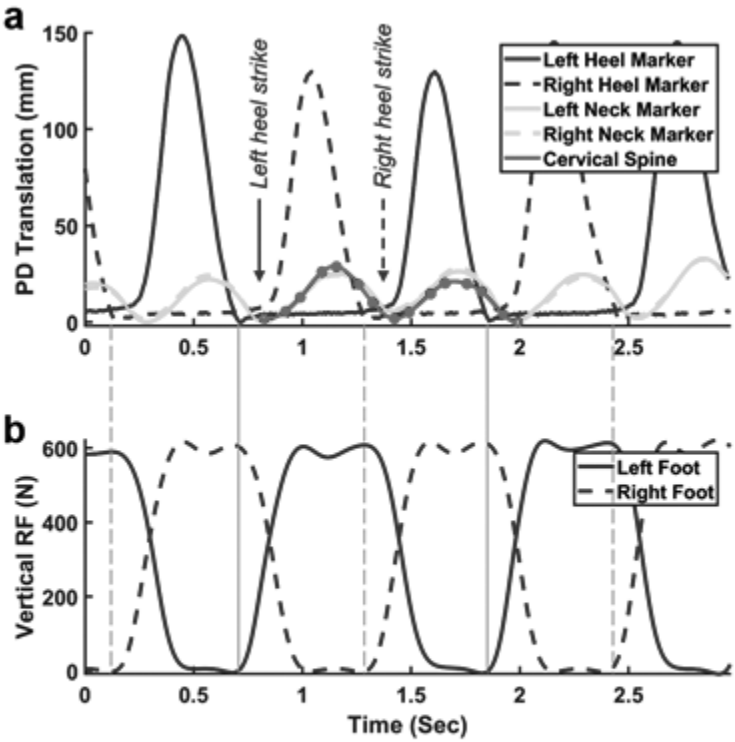

Fig. 2 (*right*): (**a**) The representative proximal-distal (PD) translations of heel/neck markers and the cervical spine (represented by the PD translation of T1 in 3D space), when a subject walked on the treadmill. (**b**) The corresponding vertical reaction forces (RFs) of the left and right feet.

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Table 1: The ranges (%) of the PD, LR, and AP disc deformations measured at the disc center site at each segment during gait.

	PD Deformation Range (a)	LR Deformation Range (b)	AP Deformation Range (c)
C2-C3 (1)	23.7±8.7	29.0±9.6	30.7±10.3
C3-C4 (2)	21.4±7.7	19.7±6.0[1]	18.2±6.8[1]
C4-C5 (3)	18.3±7.2	16.3±6.9[1]	16.6±9.2[1]
C5-C6 (4)	16.2±5.7	20.4±7.0	19.2±9.4
C6-C7 (5)	17.2±5.6	21.2±9.2	16.5±6.5[1]
C7-T1 (6)	20.2±10.5[b]	43.0±14.8[2-5]	34.1±21.2[2-5]

Note: 1) The PD, LR, and AP deformations are represented by letter a~c. Significant differences ($p < 0.05$) in pairwise comparisons of disc deformations in different directions are indicated by superscript letters. 2) The discs from proximal to distal levels are represented by numbers 1~6. Significant differences ($p < 0.05$) in pairwise comparisons of disc deformations at different segments are indicated by superscript numbers.

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E-Poster #50

Changes in cervical spinal alignment after thoracolumbar corrective surgery in adult patients with adolescent idiopathic scoliosis

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Introduction: Corrective surgery of spinal deformity has been shown to affect cervical spinal alignment. However, the changes in cervical spinal alignment after surgery for adult idiopathic scoliosis has not been sufficiently studied. The purpose of this study is to examine factors influencing cervical spine alignment after corrective surgery of adult idiopathic scoliosis.

Materials and Methods: We examined 85 cases of adult idiopathic scoliosis that received posterior fixation surgery at a single facility with a minimum follow-up of 2 years. All patients were diagnosed with adolescent idiopathic scoliosis during their teenage years but did not receive any prior surgery. Patient clinical characteristics were collected, and health-related quality of life (HRQOL) was assessed by SRS-22. Sagittal plane parameters including those for cervical alignment before surgery and 2 years after surgery were evaluated. Cervical deformity (CD) was defined as one of the following cases: 1) T1 tilt minus C2-C7 angle > 20 °, 2) C2-C7 SVA > 40 mm, 3) C2-C7 angle < -10 ° (Figure 1). According to the cervical alignment at final follow-up, the subjects were divided into those with and without CD based on the defined criteria, and statistically relevant factors were analyzed.

Results: There were 19 cases (22.4%) in the postoperative CD group and 66 cases (77.6%) in the non-CD group. The average age at the operation was significantly lower in the CD group (26.5 vs. 31.4, $p = 0.03$). In the CD group, the average preoperative T1 tilt was smaller (1.1 ° vs. 12.5 °, $p < 0.01$), and the C2-C7 angle was kyphotic (-16.1 ° vs. 3.0 °, $p < 0.01$). In addition, the average kyphotic angle at thoracic spine (T5–T12) was lower in the CD group preoperatively (12.5° vs. 19.5°, p=0.04) and postoperatively (15.2° vs. 20.8°, p=0.04) (Figure 2). HRQOL outcomes were comparable between the groups. Of the patients with preoperative CD, 51.5% (n=17) maintained their deformity at the final follow-up, and preoperative C2–C7 angle was lower than those who converted to non-CD following surgery (n=16) (-17.0° vs. -10.3°).

Conclusion: From the present study, we found that more than half of the patients with preoperative CD maintained their cervical malalignment even after corrective surgery for adult idiopathic scoliosis. Patients with postoperative CD presented cervical kyphotic and thoracic hypokyphotic alignments before surgery. Although the postoperative CD did not adversely affect the HRQOL, careful follow-up observation is necessary for these young patients because cervical malalignment has the potential to lead to cervical degeneration.

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Figure 1

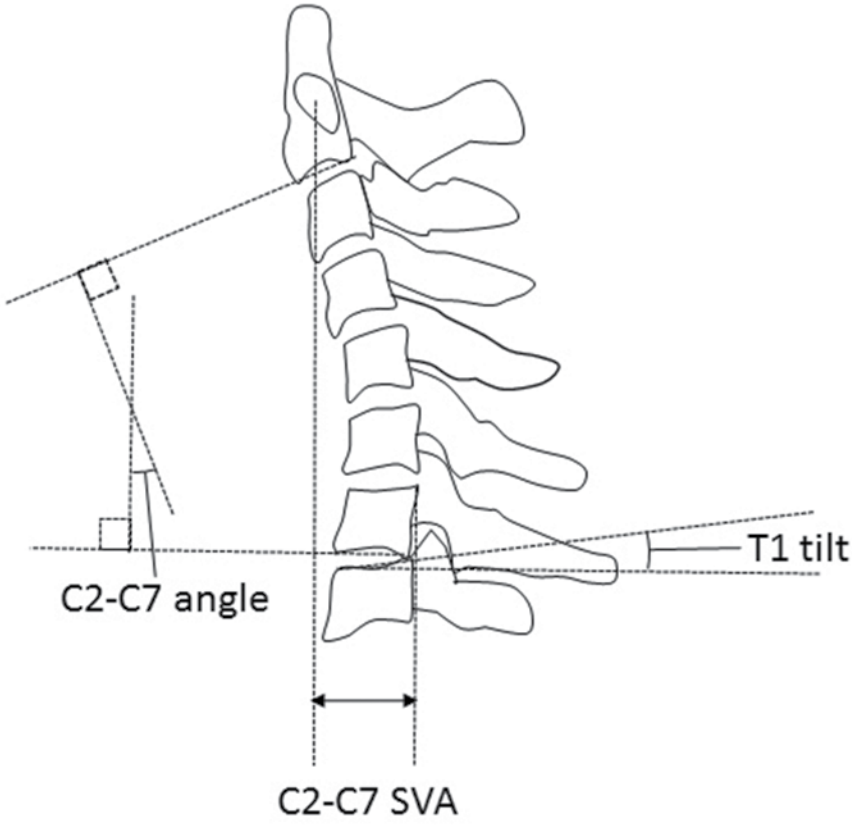

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Figure 2. Comparison of radiographic parameters two years after surgery between postoperative CD and non-CD groups.

	Postoperative CD (n=19)	Postoperative non-CD (n=66)	p-value
C2–C7 angle (°)	**−17.3±11.8**	**11.3±14.2**	**<0.01**
C2–C7 SVA (mm)	**16.9±7.2**	**12.3±9.5**	**0.03**
T1 tilt (°)	**6.2±10.7**	**15.4±11.5**	**<0.01**
T1 tilt – C2–C7 angle (°)	**23.5±6.4**	**4.2±8.6**	**<0.01**
C7–S1 SVA (mm)	−26.7±23.9	−8.0±52.0	0.13
Thoracic kyphosis (°)	**15.2±10.4**	**20.8±10.3**	**0.04**
Cobb angle (°)	22.0±9.8	24.3±11.0	0.41
Sacral slope (°)	32.5±9.5	33.7±9.0	0.63
Pelvic tilt (°)	16.8±6.7	16.4±8.2	0.87
Pelvic incidence (°)	49.3±8.1	50.1±9.5	0.73
Lumbar lordosis (°)	45.3±14.3	43.7±18.2	0.37

CD: cervical deformity; SVA: sagittal vertical axis

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