49TH

FORTY-NINTH ANNUAL MEETING

OF THE

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

ABSTRACT BOOK

49th Annual Meeting
December 1-4, 2021

26th Instructional Course
November 29 – December 1, 2021

On-Demand Annual Meeting and Instructional Course
December 6, 2021 – January 31, 2022

John M. Rhee, MD, *President*

Samuel K. Cho, MD & Steven C. Ludwig, MD • *Annual Meeting Program Co-Chairs*

Brian K. Kwon, MD, PhD, FRCSC & Neill M. Wright, MD • *Instructional Course Program Co-Chairs*

www.csrs.org

Hands On Surgical Techniques Course

July 21-23, 2022 Indiana Spine Group, Carmel, Indiana

Future Instructional Courses

Nov. 16, 2022 Manchester Grand Hyatt, San Diego, CA
Nov. 30, 2023 The Cosmopolitan of Las Vegas, NV

Future Annual Meetings

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

In support of improving patient care, this activity has been planned and implemented by Amedco LLC and Cervical Spine Research Society (CSRS). Amedco LLC is jointly accredited by the Accreditation Council for Continuing Medical Education (ACCME), the Accreditation Council for Pharmacy Education (ACPE), and the American Nurses Credentialing Center (ANCC), to provide continuing education for the healthcare team.

Live Annual Meeting: Amedco LLC designates this live activity for a maximum of 19.75 *AMA PRA Category 1 Credits*™.

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www.csrs.org/meetings/instructional-course/icl21-cme-acc

www.csrs.org/meetings/am21/am21-cme-acc

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The materials presented at this Continuing Medical Education activity are made available for educational purposes only. The material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement or opinion of the faculty that may be helpful to others who face similar situations. The presentation material in this book is included as received from program participants. We apologize for any oversight, deletion, or misspelling. Any such occurrences were unintentional.

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
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Table of Contents

CERVICAL SPINE RESEARCH SOCIETY

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About CSRS

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.

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John M. Rhee, MD	President
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Thomas E. Mroz, MD	Member
Themistocles S. Protopsaltis, MD	Member

49th Annual Meeting Schedule

Wednesday, December 1

2:00pm-8:30pm	Registration Open	Atrium Lobby
3:00pm-4:30pm	Resident and Fellow Pre-Conference Session	A601
7:30pm-8:30pm	Welcome Reception for Attendees	Atrium Lobby

Thursday, December 2

6:30am-8:30am	Breakfast	Atrium Lobby
6:30am-6:30pm	Registration Open	Atrium Lobby
7:00am-5:00pm	Scientific Program – Annual Meeting	Atrium A
9:00am-11:00am	Guest Breakfast	Pulse Loft
9:15am-6:30pm	Exhibit Hall Open	Atrium BC
9:24am-9:54am	Coffee Break in Exhibit Hall	Atrium BC
11:30am-1:00pm	Industry Lunch Workshops	
3:10pm-3:40pm	Coffee Break in Exhibit Hall	Atrium BC
5:00pm-6:30pm	Reception in Exhibit Hall for All Attendees	Atrium BC
7:00pm-9:00pm	Industry Dinner sponsored by NuVasive	

Friday, December 3

6:30am-8:30am	Breakfast	Atrium Lobby
6:30am-5:30pm	Registration Open	Atrium Lobby
7:00am-5:00pm	Scientific Program – Annual Meeting	Atrium A
9:00am-11:00am	Guest Breakfast	Pulse Loft
9:30am-1:30pm	Exhibit Hall Open	Atrium BC
9:41am-10:11am	Coffee Break in Exhibit Hall	Atrium BC
12:10pm-1:20pm	Members' Business Meeting & Lunch	A602
12:10pm-1:20pm	Lunch for Non-Members in Exhibit Hall	Atrium BC
3:28pm-3:52pm	Coffee Break	Atrium Lobby

Saturday, December 4

7:00am-9:00am	Breakfast	Atrium Lobby
7:00am-10:00am	Registration Open	Atrium Lobby
8:00am-12:55pm	Scientific Program – Annual Meeting	Atrium A
9:00am-11:00am	Guest Breakfast	Pulse Loft
9:41am-9:56am	Coffee Break	Atrium Lobby
12:47pm-12:55pm	Close of Meeting	Atrium A

All times are listed in Eastern Time (ET).
Sessions marked with a icon are available on-demand December 6, 2021 – January 31, 2022.
Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

49TH

Forty-Ninth Annual Meeting

of the

CERVICAL SPINE RESEARCH SOCIETY

FOUNDED 1973

Live-Virtual November 29-30, 2021
In-Person December 2-4, 2021
On-Demand December 6, 2021 – January 31, 2022

President John M. Rhee, MD

Scientific Program Chairs Samuel K. Cho, MD • Steven C. Ludwig

Program Committee Alexander C. Ching, MD • Matthew W. Colman, MD
Clinton J. Devin, MD • Ben J. Garrido, MD • Regis W. Haid, MD, FAANS • Craig A. Kuhns, MD
Sergio A. Mendoza-Lattes, MD • Justin W. Miller, MD • Ahmad Nassr, MD
Daniel K. Park, MD • Jeffrey A. Rihn, MD • Carlo Santaguida, MD, FRCSC
Jason W. Savage, MD • Arjun S. Sebastian, MD, MSc • Brian W. Su, MD
Barrett I. Woods, MD • Elizabeth M. Yu, MD • John M. Rhee, 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.

Monday
11/29/2021

8:00am-9:00am LIVE

Session I: CSRS Asia Pacific - Cervical Deformity, Uncommon but Challenging Cases

Moderator(s): Yu Sun, MD

8:00am-8:02am	CSRS Welcome *John Rhee, MD*
8:02am-8:05am	Introduction *Yu Sun, MD*
8:05am-8:15am	Post-infectious Deformity *Shanmuganathan Rajasekaran, PhD*
8:15am-8:25am	Neuromuscular Deformity *Kyung-Soo Suk, MD*
8:25am-8:35am	Congenital Cervical Deformity *Feifei Zhou, MD*
8:35am-8:45am	Dropped Head Syndrome *Hiroshi Miyamoto, MD*
8:45am-9:00am	Discussion

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Tuesday
11/30/2021

8:00am-9:00am LIVE

Session II: CSRS Europe - A Great Case Due to the Right Decision

Moderator(s): Heiko Koller, MD, PhD

8:00am-8:02am	CSRS Welcome *John Rhee, MD*
8:02am-8:05am	Introduction *Heiko Koller, MD, PhD*
8:05am-8:12am	Case Presentation I *Tobias Pitzen, MD*
8:12am-8:15am	Discussion
8:15am-8:25am	Case Presentation II *Petr Vachata, MD*
8:25am-8:26am	Discussion
8:26am-8:33am	Case Presentation III *Jorg Klekamp, MD*
8:33am-8:37am	Discussion
8:37am-8:44am	Case Presentation IV *Deszoe Jeszensky, MD*
8:44am-8:48am	Discussion
8:48am-8:55am	Case Presentation V *Luis Carelli, MD*
8:55am-9:00am	Discussion

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Thursday
12/2/2021

6:30am-8:30am — **Atrium Lobby**

Breakfast

6:30am-6:30pm — **Atrium Lobby**

Registration Open

7:00am-8:24am — **Atrium A**

Session 1: Abstracts - Outcomes Pt. I
Moderator(s): S. Tim Yoon, MD, PhD; Ra'Kerry Rahman, MD

7:00am-7:10am	CSRS Welcome *Program Co-Chairs, Samuel K. Cho, MD; Steven C. Ludwig, MD*
7:10am-7:11am	Introduction *S. Tim Yoon, MD, PhD; Ra'Kerry Rahman, MD*
7:11am-7:16am	PRESENTATION #1 Impact of Depression Severity on Patient Reported Outcomes Following Multilevel Anterior Cervical Discectomy and Fusion *Elliot DK. Cha, MS*
7:16am-7:21am	PRESENTATION #2 No Difference in Clinical Outcomes When Instrumenting Across the Cervicothoracic Junction in Multilevel Posterior Cervical Fusion *Gregory R. Toci, BS*
7:21am-7:26am	PRESENTATION #54 Evaluating the paradigm shift from anterior cervical decompression and fusion to posterior muscle-preserving selective laminectomy - a single center study of degenerative cervical myelopathy *Eddie de Dios, MD*
7:26am-7:31am	PRESENTATION #4 Is it better to stop at C2 or C3/4 in elective posterior cervical decompression and fusion? *Scott L. Zuckerman, MD*
7:31am-7:36am	PRESENTATION #58 Surgical Apgar Score and Controlling Nutritional Status Score are significant predictors of major complications after cervical spine surgery *Kousei Miura, MD, PhD*
7:36am-7:47am	Discussion

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7:47am-7:52am	PRESENTATION #6 Which traditional functional outcome measures and their specific components are most affected by proper re-alignment and clinical improvement in Adult Cervical Deformity Surgery? *Peter G. Passias, MD*
7:52am-7:57am	PRESENTATION #55 Does diabetes affect the surgical outcomes in cases with cervical ossification of the posterior longitudinal ligament? *Momotaro Kawai, MD*
7:57am-8:02am	PRESENTATION #8 Prediction of complications after anterior cervical spinal fusion: a machine learning-driven approach *Akash A. Shah, MD*
8:02am-8:07am	PRESENTATION #9 Social Media Posts pertaining to Anterior Cervical Discectomy and Fusion (ACDF) Surgery: A Cross-Sectional Analysis of Patient and Surgeon Perceptions *Peter Swiatek, MD*
8:07am-8:12am	PRESENTATION #10 Comparison of Clinical and Radiographic Outcomes After C3 Laminoplasty versus C3 Laminectomy *Lee A. Tan, MD*
8:12am-8:24am	Discussion

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Thursday
12/2/2021

8:24am-9:24am **Atrium A**

Symposia 1: Digital Transformation During the Pandemic: How Did COVID-19 Change the Practice of Cervical Spine Surgery?
Moderator(s): Neill Wright, MD; Alpesh Patel, MD, MBA

8:24am-8:25am	Introduction *Neill Wright, MD; Alpesh Patel, MD, MBA*
8:25am-8:30am	Global Perspectives - United States *Rick Sasso, MD*
8:30am-8:35am	Global Perspectives - Europe *Heiko Koller, MD, PhD*
8:35am-8:40am	Global Perspectives - Asia Pacific *Yoon Ha, MD, PhD*
8:40am-8:47am	Discussion
8:47am-8:53am	DEBATE - Is Telemedicine Here to Stay? Yes, It's Awesome *W. Ryan Spiker, MD*
8:53am-8:59am	DEBATE - Is Telemedicine Here to Stay? No, It's Worthless *Andrew Hecht, MD*
8:59am-9:05am	Discussion
9:05am-9:11am	Using the Telemedicine Platform - How to Perform a Virtual Cervical Physical Examination *Gregory Schroeder, MD*
9:11am-9:17am	Using the Telemedicine Platform - How Telemedicine Improved My Ability to Care for Cervical Spine Patients *Sheeraz Qureshi, MD, MBA*
9:17am-9:24am	Discussion

9:15am-6:30pm **Atrium BC**

Exhibit Hall Open

9:24am-9:54am **Atrium BC**

Coffee Break

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9:54am-11:18am **Atrium A**

Session 2: Abstracts - Top Reviewed "Sweet Sixteen" Pt. I

Moderator(s): Louis Amorosa, MD; Daniel Sciubba, MD

9:54am-9:55am	Introduction *Louis Amorosa, MD; Daniel Sciubba, MD*
9:55am-10:00am	PRESENTATION #11 Cervical Disc Replacement for Radiculopathy versus Myeloradiculopathy. An MCID Analysis. *Ram K. Alluri, MD*
10:00am-10:05am	**FIRST PLACE RESIDENT/FELLOW RESEARCH AWARD** PRESENTATION #12 The influence of timing of surgical decompression for acute spinal cord injury: a pooled analysis of individual patient data in 1,548 cases *Jetan H. Badhiwala, MD, PhD*
10:05am-10:10am	**THIRD PLACE RESIDENT/FELLOW RESEARCH AWARD** PRESENTATION #13 Comparison of Clinical Guidelines for Reimbursement for Intra-Operative Neuromonitoring During Spine Surgery in the United States *Daniel Berman, MD*
10:10am-10:15am	**FIRST PLACE BASIC SCIENCE AWARD** PRESENTATION #14 Posterior Cervical Spinal Fusion Assemblies Intended to Cross the Cervicothoracic Junction: A Mechanical Analysis *David B. Bumpass, MD*
10:15am-10:20am	PRESENTATION #15 Comparative effectiveness of surgical approaches for cervical myelopathy: quality of life assessments from the CSM-S trial *Zoher Ghogawala, MD, FACS*
10:20am-10:34am	Discussion
10:34am-10:39am	**THIRD PLACE BASIC SCIENCE AWARD** PRESENTATION #16 Cervical Total Disc Replacement: Available Implant Size Matters *Richard D. Guyer, MD*

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10:39am-10:44am	**SECOND PLACE RESIDENT/FELLOW RESEARCH AWARD** PRESENTATION #17 Simulated Bundled Payments for Four Common Surgical Approaches to Treat Cervical Spondylotic Myelopathy: A Consideration to Break the Clinical Equipoise *Nikhil Jain, MD*
10:44am-10:49am	**SECOND PLACE BASIC SCIENCE AWARD** PRESENTATION #18 Do Inflammatory Cytokines Affect Patient Outcomes after ACDF? *Brian A. Karamian, MD*
10:49am-10:54am	PRESENTATION #19 Discharge to Rehabilitation Predicts Greater Morbidity in Patients Undergoing Posterior Cervical Decompression and Fusion *Austen D. Katz, MD*
10:54am-11:05am	PRESENTATION #20 Cervical Laminectomy with Instrumented Fusion is Associated with a Higher Incidence of Postoperative C5 Palsy Compared to Cervical Laminoplasty with Reconstruction: Single Surgeon and National Inpatient *Jinseong Kim, BS*
11:05am-11:18am	Discussion

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Thursday
12/2/2021

1:05pm-2:05pm **Atrium A**

Symposia 2: Pearls of Wisdom for a Successful Research Study
Moderator(s): Zoher Ghogawala, MD, FACS; Wellington Hsu, MD

1:05pm-1:07pm	Introduction *Zoher Ghogawala, MD, FACS; Wellington Hsu, MD*
1:07pm-1:14pm	Designing Research Questions - Study Considerations Leading to Success or Failure *Wellington Hsu, MD*
1:14pm-1:21pm	Knowing How and When to Pivot in a Research Project *Zoher Ghogawala, MD, FACS*
1:21pm-1:28pm	Clinical Trials - Organization and Getting the Message Out to the Right People *Michael G. Fehlings, MD, PhD, FRCSC, FACS*
1:28pm-1:33pm	Lessons Learned from Past and Current CSRS-Funded Studies - C12 Fusion vs. Bracing *Christopher Kepler, MD*
1:33pm-1:38pm	Lessons Learned from Past and Current CSRS-Funded Studies - 5-yr ASD Incidence After TDA Study *Pierce Nunley, MD*
1:38pm-1:43pm	Lessons Learned from Past and Current CSRS-Funded Studies - Steroids for Dysphagia *Sanford Emery, MD, MBA*
1:43pm-2:05pm	Discussion

2:05pm-3:10pm **Atrium A**
This event will not be recorded.

12th Annual Henry H. Bohlman Presidential Guest Lecture - Jeff Foxworthy, Comedian

3:10pm-3:40pm **Atrium BC**

Coffee Break

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Thursday
12/2/2021

3:40pm-4:56pm **Atrium A**

Session 3: Abstracts - Deformity; Diagnositcs and Imaging; Biologics and Bone Graft

Moderator(s): Elizabeth Yu, MD; Barrett Woods, MD

3:40pm-3:41pm	Introduction *Elizabeth Yu, MD; Barrett Woods, MD*
3:41pm-3:46pm	PRESENTATION #21 Understanding the Effects of Three-Column Osteotomies on Regional and Global Alignment in patients with Moderate to Severe Cervical Deformity *Rushikesh S. Joshi, BS*
3:46pm-3:51pm	PRESENTATION #22 Proximal and Distal Reciprocal Changes Following Cervical Deformity Malalignment Correction *Renaud Lafage, MS*
3:51pm-3:56pm	PRESENTATION #23 When Does the Construct Need to Extend to the Thoracic Spine in Patients Undergoing Correction for Cervical Deformity? *Virginie C. Lafage, PhD*
3:56pm-4:01pm	PRESENTATION #24 Durability and Failure Mechanisms of Cervical Deformity Correction Surgery *Themistocles S. Protopsaltis, MD*
4:01pm-4:06pm	PRESENTATION #25 Identifying T1 Slope Thresholds for Optimal Functional and Clinical Outcomes in Cervical Deformity Correction *Peter G. Passias, MD*
4:06pm-4:18pm	Discussion
4:18pm-4:23pm	PRESENTATION #26 Comparison of MRI-based Vertebral Bone Quality (VBQ) Score with Bone Mineral Density Measured by Quantitative Computer Tomography (QCT) in Patients undergoing Cervical Spinal Surgery *Manuel Moser, MD*
4:23pm-4:28pm	PRESENTATION #27 Paraspinal Sarcopenia Predicts Worse Patient Reported Outcomes Following Posterior Cervical Fusion *Zachariah Pinter, MD*

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4:28pm-4:33pm	PRESENTATION #28 What are the Post-operative Consequences of Intraoperative Neuromonitoring Changes during Cervical Spine Surgery *Shalin Shah, DO*
4:33pm-4:38pm	PRESENTATION #29 Impact of inhalational anesthetic agents on the baseline monitorability of upper extremity motor evoked potentials (MEPs) during cervical spine surgery: A review 16,559 procedures *W. Bryan Wilent, PhD*
4:38pm-4:43pm	PRESENTATION #30 Is the Use of rh-BMP associated with Increased Incidence of Cancer? *Nida Fatima, MD*
4:43pm-4:56pm	Discussion

5:00pm-6:30pm **Atrium BC**

Reception for All Attendees

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Friday
12/3/2021

6:30am-8:30am — **Atrium Lobby**

Breakfast

6:30am-5:30pm — **Atrium Lobby**

Registration Open

7:00am-8:30am — **Atrium A**

Session 4: Abstracts - Epidemiology, Etiology, and Natural History; Basic Science
Moderator(s): Erik Olsson, MD; Clinton Devin, MD

7:00am-7:05am — CSRS Welcome
Program Co-Chairs, Samuel K. Cho, MD; Steven C. Ludwig, MD

7:05am-7:06am — Introduction
Erik Olsson, MD; Clinton Devin, MD

7:06am-7:11am — PRESENTATION #69
Single-level Cervical Disc Replacement Using a PEEK-on-Ceramic Implant: Results of a Multicenter FDA IDE Trial with 24-month Follow-up
Richard D. Guyer, MD

7:11am-7:16am — PRESENTATION #31
Cervical Myelopathy and Hip Fractures: Co-incidence, Epidemiology, and Costs of Care
Edward Baldwin, III, MD

7:16am-7:21am — PRESENTATION #32
Racial and social determinants of health disparities in patient presentation for cervical spine surgery: census tract level disparities reveal greater preoperative morbidity and worse POD 90 patient reported outcomes
Sarthak Mohanty, BS

7:21am-7:26am — PRESENTATION #33
No Difference in Reoperation Rates in Posterior Cervical Fusions Stopping at C7 versus T1/T2 for Adjacent Segment Disease (Operative ASD): A cohort of 875 Patients - Part 1
Kern H. Guppy, MD, PhD

7:26am-7:31am — PRESENTATION #34
Physical Examination Findings of Patients With Myelopathy and Diabetes Mellitus
Mena G. Kerolus, MD

All times are listed in Eastern Time (ET).
Sessions marked with a icon are available on-demand December 6, 2021 – January 31, 2022.
Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

7:31am-7:36am	PRESENTATION #35 Do Favorable Short-term Patient Reported Outcomes after ACDF Predict Loss to One- and Two-Year Follow-Up? *Hannah A. Levy, BS*
7:36am-7:41am	PRESENTATION #36 The Impact of Social Determinants of Health (SDOH) on 30- and 90-Day Readmission Rates Following Spine Surgery *Comron Saifi, MD*
7:41am-7:52am	Discussion
7:52am-7:57am	PRESENTATION #37 Safety Evaluation of Hydroxyapatite-Demineralized Bone Matrix Composite Scaffold for Spinal Fusion *Wellington K. Hsu, MD*
7:57am-8:02am	PRESENTATION #38 Computed Tomography Osteoabsorptiometry (CT-OAM) Evaluation of Subchondral Bone Mineral Density in Cervical Endplates and Uncovertebral Joints: Implications for Subsidence and Clinical Practice *Athan G. Zavras, BA*
8:02am-8:07am	PRESENTATION #39 Novel In Vivo Imaging System of Grafted Human iPS Cell-Derived Neuron Activity after Spinal Cord Injury *Kentaro Ago, MD*
8:07am-8:12am	PRESENTATION #40 Long-term Selective Stimulation of Transplanted Neural Stem/Progenitor Cells for Spinal Cord Injury Improves Locomotor Function Mediated by Increased Synaptic Transmission *Momotaro Kawai, MD*
8:12am-8:17am	PRESENTATION #41 Chemical control of grafted human iPSC derived neurons demonstrated the contribution of graft neuronal activity to the recovery following spinal cord injury *Takahiro Kitagawa, MD*
8:17am-8:30am	Discussion

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

Friday
12/3/2021

8:30am-9:41am **Atrium A**

Symposia 3: Deformity Consideration for the Everyday Cervical Degenerative Conditions

Moderator(s): Langston Holly, MD; Praveen Mummaneni, MD

8:30am-8:32am	Introduction *Langston Holly, MD; Praveen Mummaneni, MD*
8:32am-8:42am	Patient with Myelopathy/Radiculopathy Doesn't Have Perfect Alignment - Do They Really Need a Cervical Deformity Correction? *John Rhee, MD*
8:42am-8:52am	How to Prevent Iatrogenic Deformity *Regis Haid, MD, FAANS*
8:52am-9:02am	Choice of UIV *Stuart Hershman, MD*
9:02am-9:12am	Choice of LIV and When to Cross the CT Junction *Lee Tan, MD*
9:12am-9:22am	When Should I Include or Exclude an Adjacent Segment Disc *Andrew Dailey, MD, FAANS*
9:22am-9:41am	Discussion

9:30am-1:30pm **Atrium BC**

Exhibit Hall Open

9:41am-10:11am **Atrium BC**

Coffee Break

10:11am-10:50am **Atrium A**

Presidential Address

10:11am-10:20am	Introduction *James Harrop, MD, FAANS*
10:20am-10:50am	Presidential Address *John Rhee, MD*

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

Friday
12/3/2021

10:50am-12:06pm **Atrium A**

Session 5: Abstracts - Biomechanics; Complications

Moderator(s): P. Justin Tortolani, MD; Daniel Sciubba, MD

10:50am-10:51am Introduction
P. Justin Tortolani, MD; Daniel Sciubba, MD

10:51am-10:56am PRESENTATION #42
Longitudinal Changes in Adjacent Segment Disc Deformation After Cervical Arthrodesis
William J. Anderst, PhD

10:56am-11:01am PRESENTATION #43
Finite Element Modeling to Determine the Effect of a Hybrid Construct Adjacent to a Cervical Disc Arthroplasty
Jamie L. Baisden, MD

11:01am-11:06am PRESENTATION #44
In Vivo Deformation Patterns of Craniocervical Ligaments during Dynamic Head Axial Rotation
Thomas D. Cha, MD

11:06am-11:11am PRESENTATION #45
Supplemental Fixation of Lateral Mass Screws: A Strategy to Improve Posterior Cervical Fusion Fixation Strength
Robert M. Havey, MS

11:11am-11:16am PRESENTATION #46
Biomechanical Analysis of 3-level ACDF Construct Using a Finite-element Cervical Spine Model
Lee A. Tan, MD

11:16am-11:21am PRESENTATION #47
Adjacent Level Kinematics Following One- and Two-Level Anterior Cervical Disectomy and Fusion
William J. Anderst, PhD

11:21am-11:26am PRESENTATION #48
In Vivo Kinematics of the Head-Neck Complex during Dynamic Head Axial Rotation
Thomas D. Cha, MD

11:26am-11:33am Discussion

11:33am-11:38am PRESENTATION #49
Delayed Upper Aerodigestive Tract Perforation from Anterior Cervical Spine Hardware: Treatment and Swallowing Outcomes
Catherine R. Carlile, MD

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11:38am-11:43am	PRESENTATION #50 The Effect of Undercorrection on Distal Junctional Kyphosis in Adult Cervical Deformity Patients *Oscar Krol, BA*
11:43am-11:48am	PRESENTATION #51 Failure in Cervical Total Disc Arthroplasty: Single Institution Experience, Systematic Review of the Literature, and Proposal of a Novel TDA Failure Classification System *Athan G. Zavras, BA*
11:48am-12:06pm	Discussion

12:10pm-1:20pm **A602**

Members' Business Meeting & Lunch

12:10pm-1:20pm **Atrium BC**

Lunch for Non-Members in Exhibit Hall

All times are listed in Eastern Time (ET).
Sessions marked with a icon are available on-demand December 6, 2021 – January 31, 2022.
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Friday
12/3/2021

1:25pm-2:06pm **Atrium A**

Session 6: Meeting Previews; Awards - Paper & E-Poster Awards Presentations, Lifetime Achievement Award
Moderator(s): John Rhee, MD; Jeffrey Coe, MD

1:25pm-1:31pm	Introduction and Honoring of Dr. Whitesides *John Rhee, MD*
1:31pm-1:36pm	Meeting Preview - CSRS 50th Annual Meeting and 27th Instructional Course in San Diego, CA *Jean-Jacques Abitbol, MD*
1:36pm-1:41pm	2022 Meeting Preview - CSRS Europe *Heiko Koller, MD, PhD*
1:41pm-1:46pm	2022 Meeting Preview - CSRS Asia Pacific *Yu Sun, MD*
1:46pm-1:51pm	Awards - Recognition of 2021 Paper and E-Poster Awards *Jeffrey Coe, MD*
1:51pm-1:56pm	Lifetime Achievement Award - Introduction *John Rhee, MD*
1:56pm-2:06pm	Lifetime Achievement Award - Acceptance Speech *Ronald Apfelbaum, MD*

2:06pm-3:28pm **Atrium A**

Session 7: Abstracts - Outcomes Pt. II
Moderator(s): Daniel Park, MD; Gurvinder Deol, MD

2:06pm-2:07pm	Introduction
2:07pm-2:12pm	PRESENTATION #52 Cervical Stiffness Disability Index (CSDI): Validation of a Novel Scoring System Quantifying the Effect of Post-Arthrodesis Cervical Stiffness on Patient Quality of Life *Andrew S. Jack, MD, MSc, FRCSC*
2:12pm-2:17pm	PRESENTATION #53 Influence of preoperative smoking status on clinical outcomes of laminoplasty in patients with degenerative cervical myelopathy: a prospective study *Guoyan Liang, MD*
2:17pm-2:22pm	PRESENTATION #3 Trends in 2 Year Outcomes of a Prospective Consecutively Enrolled Single-Center Adult Cervical Deformity Series: Optimal Realignment Correlates with Superior Outcomes *Bassel G. Diebo, MD*

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2:22pm-2:27pm	PRESENTATION #55 Long Term Associations Between Current Smoking Status and Outcome After Elective Cervical Spine Surgery *Gordon Preston, DO*
2:27pm-2:32pm	PRESENTATION #56 Comparison of Laminoplasty and Posterior Fusion Surgery for Cervical Ossification of the Posterior Longitudinal Ligament: Data from a Prospective Multicenter Research Organization regarding Ossification of the Spinal Ligament *Hiroaki Nakashima, MD, PhD*
2:32pm-2:37pm	PRESENTATION #57 Highest Achievable Outcomes for Patients Undergoing Cervical Deformity Corrective Surgery by Frailty *Virginie C. Lafage, PhD*
2:37pm-2:50pm	Discussion
2:50pm-2:55pm	PRESENTATION #5 Preoperative Diagnosis of a Mental Health Disorder is Associated with Increased Postoperative Rates of Dysphagia after Anterior Cervical Spine Surgery *Athan G. Zavras, BA*
2:55pm-3:00pm	PRESENTATION #59 What is the fate of pseudarthrosis detected 2 years after anterior cervical discectomy and fusion? Results of a minimum of 5-years follow-up *Dong-Ho Lee, MD, PhD*
3:00pm-3:05pm	PRESENTATION #60 The associations between radiological and neurological findings of degenerative cervical myelopathy: Radiological analysis based on kinematic CT myelography and evoked potentials of spinal cord *Masahiro M. Funaba, MD*
3:05pm-3:10pm	PRESENTATION #61 Analysis of Clinical Deterioration Following Adult Cervical Deformity Realignment Surgery: Two Year Outcomes of a Consecutive, Prospectively Enrolled Database *Oscar Krol, BA*
3:10pm-3:15pm	PRESENTATION #62 Restored inhibitory signaling via AAV-mediated KCC2 upregulation recruits microglia to reorganize spinal neural circuits *Michael G. Fehlings, MD, PhD, FRCSC, FACS*
3:15pm-3:28pm	Discussion

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

Friday
12/3/2021

3:28pm-3:52pm **Atrium Lobby**

Coffee Break

3:52pm-5:00pm **Atrium A**

Symposia 4: Master Debate Series I

Moderator(s): Darrel Brodke, MD

3:52pm-3:55pm	Introduction and Case Presentation I *Darrel Brodke, MD*
3:55pm-4:05pm	DEBATE - Cervical Disc Disease with Myelopathy: ACDF *Sanford Emery, MD, MBA*
4:05pm-4:15pm	DEBATE - Cervical Disc Disease with Myelopathy: CDR *K. Daniel Riew, MD*
4:15pm-4:26pm	Discussion
4:26pm-4:29pm	Case Presentation II *Darrel Brodke, MD*
4:29pm-4:39pm	DEBATE - 3-Level CDD: ACDF *John Heller, MD*
4:39pm-4:49pm	DEBATE - 3-Level CDD: Hybrid Approach *Vincent Traynelis, MD*
4:49pm-5:00pm	Discussion

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Sessions marked with a icon are available on-demand December 6, 2021 – January 31, 2022.
Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

Saturday
12/4/2021

7:00am-9:00am — **Atrium Lobby**

Breakfast

7:00am-10:00am — **Atrium Lobby**

Registration Open

8:00am-8:56am — **Atrium A**

Session 8 - Abstracts - Top Reviewed "Sweet Sixteen" Pt. II
Moderator(s): Christopher Witiw, MD, MS; Timothy Moore, MD

8:00am-8:10am — CSRS Welcome
Program Co-Chairs, Samuel K. Cho, MD; Steven C. Ludwig, MD

8:10am-8:11am — Introduction
Christopher Witiw, MD, MS; Timothy Moore, MD

8:11am-8:16am — **SECOND PLACE CLINICAL RESEARCH AWARD**
PRESENTATION #63
Predictive Factors for the Aggravation of Cervical Alignment after Posterior Cervical Foraminotomy
Hyung Rae Lee, MD

8:16am-8:21am — PRESENTATION #64
Surgical Treatment of Single level Cervical Radiculopathy: A Comparison of Anterior Cervical Decompression and Fusion (ACDF) vs. Cervical Disc Arthroplasty (CDA) vs. Posterior Cervical Foraminotomy
Kedar Padhye, MD

8:21am-8:26am — PRESENTATION #65
Surgical and Radiographic Outcomes in Patients with High T1 and C2 Slopes
Themistocles S. Protopsaltis, MD

8:26am-8:31am — **FIRST PLACE CLINICAL RESEARCH AWARD**
PRESENTATION #66
No Difference in Reoperation Rates in Posterior Cervical Fusions Stopping at C7 versus T1/T2 for Nonunions (Operative Nonunions): A cohort of 875 Patients - Part 2
Jacob H. Fennessy, MD

8:31am-8:36am — **THIRD PLACE CLINICAL RESEARCH AWARD**
PRESENTATION #67
Racial Disparities in Patients Undergoing Anterior Cervical Discectomy and Fusion: A Multi-Site Study
Comron Saifi, MD

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

8:36am-8:41am	PRESENTATION #68 Stand-Alone Cages versus Cage and Plate Constructs for Primary One- and Two-level Anterior Cervical Discectomy and Fusion: A Prospective Randomized Controlled Trial *Athan G. Zavras, BA*
8:41am-8:56am	Discussion

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

8:56am-9:31am **Atrium A**

Session 9: CSRS Past Research Grant Awards & Presentations

Moderator(s): Wellington Hsu, MD

8:56am-9:02am	Introduction and Recognition of 2021 Research Grant Award Winners *Wellington Hsu, MD*
9:02am-9:04am	The Role of Calcitonin Gene-Related Peptide in Intervertebral Disc Neurogenic Inflammation: A Potential Therapeutic Target for Discogenic Pain *Jose Canseco, MD*
9:04am-9:06am	Analysis of the Human Serum Proteome in Cervical Radiculopathy Patients to Predict Who Will Fail Conservative Treatment and Require Surgery *Steven Pressciutti, MD*
9:06am-9:08am	Discussion
9:08am-9:10am	Morphological, Biochemical and Biomechanical Characterization of Human Cervical Endplate in Degenerated Disc *Nathan Buchweitz, PhD Student*
9:10am-9:12am	Discussion
9:12am-9:14am	Is Vaporized Nicotine as Detrimental to Spinal Fusions as Cigarette Smoke? *Jesse Bible, MD*
9:14am-9:16am	Treatment of Spinal Cord Injury With Bone Marrow Mesenchymal Stem Cell Derived Exosomes *Ankit Mehta, MD*
9:16am-9:18am	A Multi-Disciplinary Approach to Reduce Chronic Opioid Use Prior to Elective Cervical Spine Surgery *Andrew Pugely, MD*
9:18am-9:20am	Quantitative Histomorphological Characterization of Human Cervical Nerve Roots to Determine the Relationship with Postoperative C5 Palsy *P. Justin Tortolani, MD*
9:20am-9:22am	Exploring Prognostic Brain Biomarkers for Cervical Myelopathy: A Resting-State Functional MRI Multicenter Study *Takashi Kaito, MD, PhD*
9:22am-9:24am	Randomized Trial of Opioid vs. Non-Opioid Postoperative Pain Regimens After Anterior Cervical Discectomy and Fusion *Amir Abtahi, MD*

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

9:24am-9:26am	3D Printed 2D Piezoelectric Materials to Deliver Stem Cells for Bone Repair and Regeneration *Wellington Hsu, MD*
9:26am-9:28am	Radiographic Evaluation of the Cervical Neck Surgical Approach and Its Relationship with BMI and Operative Characteristics Following ACDF. *Michael Nolte, MD*
9:28am-9:30am	Prediction of Admission Costs Following Anterior Cervical Discectomy and Fusion Utilizing Machine Learning *Anirudh Gowd, MD*
9:30am-9:31am	Discussion

9:31am-9:41am **Atrium A**

Presidential Farewell & Induction of New President

9:31am-9:36am	Passing of the Medallion *John Rhee, MD*
9:36am-9:41am	Induction of New President *James Harrop, MD, FAANS*

9:41am-9:56am **Atrium Lobby**

Coffee Break

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

Saturday
12/4/2021

9:56am-10:56am **Atrium A**

Symposia 5: Master Debate Series Pt. II

Moderator(s): Chris Shaffrey, MD; Michael Daubs, MD

9:56am-9:58am	Introduction *Chris Shaffrey, MD; Michael Daubs, MD*
9:58am-10:07am	DEBATE - Traumatic Cervical Facet Fractures without Disclocation: I fix them *Erica Bisson, MD, MPH*
10:07am-10:16am	DEBATE - Traumatic Cervical Facet Fractures without Disclocation: I put them in a collar *Addisu Mesfin, MD*
10:16am-10:27am	Discussion
10:27am-10:36am	DEBATE - In an Awake, Alert, Cooperative Patient with a Cervical Disclocation: Closed Reduction Always and then OR *Carlo Bellabarba, MD*
10:36am-10:45am	DEBATE - In an Awake, Alert, Cooperative Patient with a Cervical Disclocation: OR and Forget About the Closed Reduction *Vincent Traynelis, MD*
10:45am-10:56am	Discussion

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

10:56am-12:47pm **Atrium A**

Session 10: Abstracts - Motion Preservation; Trauma; Other

Moderator(s): Lee Riley, III, MD; Comron Saifi, MD

10:56am-10:57am	Introduction *Lee Riley, III, MD; Comron Saifi, MD*
10:57am-11:02am	PRESENTATION #84 The impact of anterior spondylolisthesis and kyphotic alignment on dynamic changes in spinal cord compression and neurological status in cervical spondylotic myelopathy: A radiological analysis involving kinematic CT myelography and *Takuya Sakamoto, MD*
11:02am-11:07am	PRESENTATION #70 Range of Motion on Flexion and Extension at Long-Term Follow-Up After Cervical Total Disc Arthroplasty: A Systematic Review and Meta-Analysis *Athan G. Zavras, BA*
11:07am-11:12am	PRESENTATION #71 Evaluation of Gait and Functional Stability in Preoperative Cervical Spondylotic Myelopathy Patients *Hamid Hassanzadeh, MD*
11:12am-11:17am	PRESENTATION #72 Skip laminoplasty as a novel posterior decompression technique to decrease interlaminar fusion and preserve cervical range of motion *Jun Hee Lee, MD*
11:17am-11:22am	PRESENTATION #73 Neuroimaging Biomarkers Correlate With Disease Severity In Degenerative Cervical Myelopathy *Muhammad Ali Akbar, MD*
11:22am-11:27am	PRESENTATION #74 Early Surgical Decompression Enhances Motor Recovery in Traumatic Cervical ASIA A Spinal Cord Injury Patients: Analysis of Prospective, Multicentre Data in 420 Cases *Ali Moghaddamjou, MD*
11:27am-11:37am	Discussion
11:37am-11:42am	PRESENTATION #75 Internet Video-Based Patient Education on ACDF and CTDR: A Quantitative Analysis of Content and Quality *Edward DelSole, MD*

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Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

11:42am-11:47am	PRESENTATION #76 Risk Factors for MCID Drop-Off in Patients Undergoing Anterior Cervical Discectomy and Fusion *Conor P. Lynch, MS*
11:47am-11:52am	PRESENTATION #77 Incidence of Noncontiguous Cervical Injury in Patients with Thoracic Spine Fractures *Patrick Curtin, MD*
11:52am-11:57am	PRESENTATION #78 International Validation of the AO Spine Subaxial Injury Classification System: The Importance of Methodology *Brian A. Karamian, MD*
11:57am-12:02pm	PRESENTATION #79 Survival Rates in Atlanto-occipital Dissociation: A Look at the Past 20 Years *Gautham Prabhakar, MD*
12:02pm-12:12pm	Discussion
12:12pm-12:17pm	PRESENTATION #80 Radiological factors associated with the severity of corticospinal tract dysfunctions for cervical spondylotic myelopathy: An analysis of the central motor conduction time and kinematic CT myelography *Masahiro M. Funaba, MD*
12:17pm-12:22pm	PRESENTATION #81 Enoxaparin promotes functional recovery after spinal cord injury by antagonizing PTPR sigma *Sadayuki Ito, MD*
12:22pm-12:27pm	PRESENTATION #82 Surgical outcome of cervical and thoracic extramedurally spinal tumor *Akinobu Suzuki, MD*
12:27pm-12:32pm	PRESENTATION #83 Laminectomy Alone versus Laminectomy with Fusion for Degenerative Cervical Myelopathy - a Long-term Study of a National Cohort *Eddie de Dios, MD*
12:32pm-12:47pm	Discussion

12:47pm-12:55pm **Atrium A**

Close of meeting from CSRS Program Co-Chairs

Program Co-Chairs, Samuel K. Cho, MD; Steven C. Ludwig, MD

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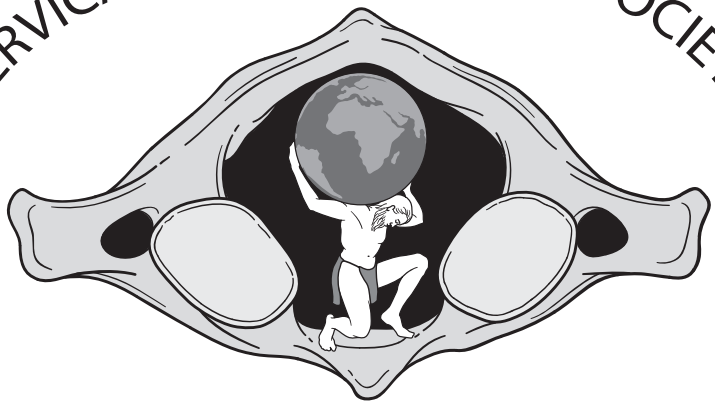
Sessions marked with a icon are available on-demand December 6, 2021 – January 31, 2022.
Sessions marked with a LIVE icon are available virtual-live on date and time listed in the session title.

CERVICAL SPINE RESEARCH SOCIETY



FOUNDED 1973

Alphabetical Participant Disclosure List

Name	Disclosure
Abitbol, Jean-Jacques (MD)	No Relevant Financial Relationships
Abtahi, Amir (MD)	No Relevant Financial Relationships
Ago, Kentaro (MD)	Research Grant Site Principal Investigator relationship with General Insurance Association of Japan
Akbar, Muhammad Ali (MD)	No Relevant Financial Relationships
Aleem, Ilyas (MD, MS, FRCSC)	No Relevant Financial Relationships
Alluri, Ram (MD)	No Relevant Financial Relationships
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
Amorosa, Louis (MD)	No Relevant Financial Relationships
Anderst, William (PhD)	Research Grant Overall Principal Investigator relationship with Smith & Nephew; Research Grant Overall Principal Investigator relationship with Paragon28; Consultant relationship with Facebook Technologies
Arnold, Paul (MD)	No Relevant Financial Relationships
Arpey, Nicholas (MD)	No Relevant Financial Relationships
Badhiwala, Jetan (MD, PhD)	No Relevant Financial Relationships

Alphabetical Participant Disclosure List

Name	Disclosure
Bae, Hyun (MD)	Research Grant Site Principal Investigator relationship with Medtronic; Research Grant Site Principal Investigator relationship with Mesoblast; Research Grant Site Principal Investigator relationship with Simplify Medical; Research Grant Site Principal Investigator relationship with Intrisic Therapeutics, Inc.; Fellowship Funding relationship with Medtronic; Fellowship Funding relationship with Nuvasive; Consultant relationship with DePuy J&J; Consultant relationship with Nuvasive; Consultant relationship with Stryker; Consultant relationship with Zimmer Biomet; Patent Holder relationship with Nuvasive; Patent Holder relationship with DePuy J&J; Patent Holder relationship with Stryker; Stock Shareholder relationship with DePuY J&J; Stock Shareholder relationship with Medtronics; Stock Shareholder relationship with Prosidyan; Invested relationship with Surgery Center, 90210 Surgery CenterMedical
Baisden, Jamie (MD)	Training relationship with Stryker
Balas, Michael (MD(C))	No Relevant Financial Relationships
Baldwin, Edward (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; Scientific/Medical Advisory Board Member relationship with Difusion
Bible, Jesse (MD)	No Relevant Financial Relationships
Bisson, Erica (MD, MPH)	Consultant relationship with Stryker; Consultant relationship with MiRus
Brodke, Darrel (MD)	Consultant relationship with CTL Amedica; Consultant relationship with Orthofix
Buchweitz, Nathan (PhD Student)	No Relevant Financial Relationships
Bumpass, David (MD)	Consultant relationship with Medtronic; Research Grant Site Principal Investigator relationship with Medtronic; Stock Shareholder relationship with NuShores LLC
Canseco, Jose (MD)	No Relevant Financial Relationships
Carelli, Luis (MD)	Consultant relationship with Medtronic; Consultant relationship with NuVasive; Consultant relationship with Stryker; support of fellowship training relationship with Vertical; speaker relationship with Gross; scientific support relationship with Grünetal; Scientific/Medical Advisory Board Member relationship with Brazilian Spine Society; Scientific/Medical Advisory Board Member relationship with Craniovertebral Junction Spine Society
Carlile, Catherine (MD)	No Relevant Financial Relationships
Carlson, Bayard (MD)	No Relevant Financial Relationships

Name	Disclosure
Cha, Elliot (MS)	No Relevant Financial Relationships
Cha, Thomas (MD)	Consultant relationship with Stryker; Consultant relationship with Nuvasive; Research Grant Overall Principal Investigator relationship with Bio2; Research Grant Site Principal Investigator relationship with NIH; Research Site Investigator relationship with Gordon and Betty Moore Foundation; Fellowship Support relationship with K2M, OMEGA, Nuvasive; Consultant relationship with Stryker, Nuvasive, Bio2; Research Grant Site Principal Investigator relationship with NIH. Gordon and Betty Moore Foundation; Fellowship support relationship with Nuvasive, OMEGA
Chan, Andrew (MD)	Research support relationship with Orthofix Medical, Inc.
Chapman, Jens (MD)	Consultant relationship with Globus Medical; Fellowship Support relationship with Stryker; Fellowship Support relationship with DePuy Synthes; Fellowship Support relationship with SeaSpine
Chen, Huajiang (MD)	No Relevant Financial Relationships
Chen, Xiong-sheng (MD)	No Relevant Financial Relationships
Chiba, Yusuke (MD, PhD)	No Relevant Financial Relationships
Ching, Alexander (MD)	Consultant relationship with globus; Consultant relationship with Nuvasive; Consultant relationship with Depuy Spine
Cho, Samuel (MD)	Consultant relationship with Globus; Consultant relationship with Stryker; Royalty relationship with Globus
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)	Consultant relationship with K2M / Stryker; Consultant relationship with Alphatec Spine; Consultant relationship with Orthofix; Consultant relationship with Spinal Elements; Research Grant Site Principal Investigator relationship with CSRS; Fellowship Support relationship with AO Spine
Crawford, Charles (MD)	Product Development relationship with Alphatec; Consultant relationship with Depuy-Synthes; Consultant relationship with Medtronic; and Product Development relationship with Nuvasive
Curtin, Patrick (MD)	No Relevant Financial Relationships
Czerwinski, Alyssa	No Relevant Financial Relationships
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

Alphabetical Participant Disclosure List

Name	Disclosure
Dailey, Andrew (MD, FAANS)	Consultant relationship with Zimmer Biomet; Research Grant Site Principal Investigator relationship with K2M/Stryker
Daubs, Michael (MD)	Consultant relationship with DePuy Synthes; Research relationship with Pfizer; Deputy Editor relationship with The Spine Journal; Chair relationship with AOSpine North America; Director-Elect relationship with American Board of Orthopaedic Surgery
de Dios, Eddie (MD)	No Relevant Financial Relationships
DelSole, Edward (MD)	Speakers Bureau relationship with DePuy/Synthes
Deol, Gurvinder (MD)	Royalty relationship with Nuvasive; Royalty relationship with Globus; Consultant relationship with Alphatec; Consultant relationship with Cerapedics
Devin, Clinton (MD)	Research Grant Site Principal Investigator relationship with Stryker Spine; Consultant relationship with Balanced Back; Consultant relationship with Stryker Spine; Stock Shareholder relationship with Balanced Back
Diebo, Bassel (MD)	No Relevant Financial Relationships
DiMaria, Stephen (BS)	No Relevant Financial Relationships
Elliott, Iain (MD)	No Relevant Financial Relationships
Elysee, Jonathan (BS)	No Relevant Financial Relationships
Emery, Sanford (MD, MBA)	Local PI on grant for lumbar fusion study relationship with Medtronic
Fatima, Nida (MD)	No Relevant Financial Relationships
Fehlings, Michael G. (MD, PhD, FRCSC, FACS)	President and Founder relationship with Inteligex
Fennessy, Jacob (MD)	No Relevant Financial Relationships
Foxworthy, Jeff	No Relevant Financial Relationships
Funaba, Masahiro (MD)	No Relevant Financial Relationships
Furlan, Julio (MD, MBA, MSc, PhD)	No Relevant Financial Relationships
Garrido, Ben (MD)	Consultant relationship with ATEC
Geoghegan, Cara (BS)	No Relevant Financial Relationships
Gerlach, Erik (MD)	No Relevant Financial Relationships
Gerling, Michael (MD)	Consulting relationship with RTI; na relationship with Integrity
Ghanayem, Alexander (MD)	No Relevant Financial Relationships
Ghogawala, Zoher (MD, FACS)	No Relevant Financial Relationships
Gokaslan, Ziya (MD)	No Relevant Financial Relationships
Goldstein, Jeffrey (MD)	Consultant relationship with Globus Medical; na relationship with NuVasive; na relationship with Surgalign; Scientific/Medical Advisory Board Member relationship with Augmedics
Gowd, Anirudh (MD)	No Relevant Financial Relationships
Grauer, Jonathan (MD)	Publishing role relationship with North American Spine Society

Name	Disclosure
Groves Sausser, Lindsey	No Relevant Financial Relationships
Guppy, Kern (MD, PhD)	No Relevant Financial Relationships
Guyer, Richard (MD)	Speakers Bureau relationship with Simplify Medical; Consultant relationship with Nuvasive; Consultant relationship with Orthofix; Consultant relationship with Aesculap; Consultant relationship with Centinel
Ha, Yoon (MD, PhD)	No Relevant Financial Relationships
Haid, Regis (MD, FAANS)	Consultant relationship with NuVasive; Royalties (IP) relationship with NuVasive; Stock Shareholder relationship with NuVasive; Royalties (IP) relationship with Globus Medical; Stock Shareholder relationship with Globus Medical; Royalties (IP) relationship with Medtronic; Stock Shareholder relationship with SpineWave; Stock Shareholder relationship with Remedy Health Media (formerly Vertical Health/SpineUniverse)
Harrop, James (MD, FAANS)	Scientific/Medical Advisory Board Member relationship with Depuy Spine; Speakers Bureau relationship with Globus spine; Speakers Bureau relationship with Stryker; Scientific Advisory Board relationship with Abbvie; Scientific Advisory Board relationship with Spiderwort; Scientific Advisory Board relationship with Ethicon
Hassanzadeh, Hamid (MD)	Consultant relationship with Nuvasive; Research Grant Site Principal Investigator relationship with Orthofix; Research Grant Site Principal Investigator relationship with SKK/Rho; Research Grant Site Principal Investigator relationship with Pfizer; Research Grant Site Principal Investigator relationship with Medtronic; Consultant relationship with DePuy
Havey, Robert (MS)	other relationship with DePuy
Hecht, Andrew (MD)	Consultant relationship with Medtronic Spine; Scientific/Medical Advisory Board Member relationship with Clinical Spine Surgery; Scientific/Medical Advisory Board Member relationship with Orthopaedics Today; Scientific/Medical Advisory Board Member relationship with Spine Surgery Today; Consultant relationship with Atlas Spine; Consultant relationship with Zimmer Spine
Heller, John (MD)	Royalties and stock ownership relationship with Medtronic; Consultant relationship with Medtronic
Hershman, Stuart (MD)	No Relevant Financial Relationships
Holly, Langston (MD)	Patent Holder relationship with Medtronic
Horák, Tomáš (MD)	No Relevant Financial Relationships
Horáková, Magda (MD)	No Relevant Financial Relationships

Alphabetical Participant Disclosure List

Name	Disclosure
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 Wright Medical
Ito, Sadayuki (MD)	No Relevant Financial Relationships
Jack, Andrew (MD, MSc, FRCSC)	No Relevant Financial Relationships
Jadczak, Caroline (BS)	No Relevant Financial Relationships
Jain, Nikhil (MD)	No Relevant Financial Relationships
Jamieson, Alysha (BS)	No Relevant Financial Relationships
Jeszensky, Deszoe (MD)	No Relevant Financial Relationships
Joshi, Rushikesh (BS)	No Relevant Financial Relationships
Kaito, Takashi (MD, PhD)	No Relevant Financial Relationships
Kakadiya, Ghanshyam (MBBS, MS, DNB)	No Relevant Financial Relationships
Kang, James (MD)	Scientific/Medical Advisory Board Member relationship with OnPoint Surgical; Stock Shareholder relationship with ALung; Stock Shareholder relationship with Cardiorobotics
Karamian, Brian (MD)	No Relevant Financial Relationships
Katz, Austen (MD)	No Relevant Financial Relationships
Kawai, Momotaro (MD)	Research Grant Site Principal Investigator relationship with The General Insurance Association of Japan; Research Grant Site Principal Investigator relationship with AOSpine
Kelly, Michael (MD)	Grant relationship with Depuy Synthes
Kepler, Chris (MD)	Research Grant Site Principal Investigator relationship with RTI; Royalty Agreement relationship with Inion; Research Grant Site Principal Investigator relationship with NIH
Kepler, Christopher (MD)	No Relevant Financial Relationships
Kerolus, Mena (MD)	No Relevant Financial Relationships
Khan, Safdar (MD)	No Relevant Financial Relationships
Kim, Han Jo (MD)	Consultant relationship with Zimmerbiomet; Consultant relationship with K2M- Styrker; Consultant relationship with Alphatec
Kim, Jinseong (BS)	No Relevant Financial Relationships
Kim, Jun (MD)	No Relevant Financial Relationships
Kitagawa, Takahiro (MD)	Research Grant Site Principal Investigator relationship with General Insurance Association of Japan
Klekamp, Jorg (MD)	No Relevant Financial Relationships
Koller, Heiko (MD, PhD)	Consultant relationship with DepuySynthes; Scientific/Medical Advisory Board Member relationship with DSS

Name	Disclosure
Krol, Oscar (BA)	No Relevant Financial Relationships
Kuhns, Craig (MD)	Design Team Member relationship with ATEC; Design Team Member relationship with Nuvasive; Design Team Member relationship with Spineology
Kwon, Brian (MD, PhD, FRCSC)	Scientific/Medical Advisory Board Member relationship with Versapeutics; Scientific/Medical Advisory Board Member relationship with NervGen
Lafage, Renaud (MS)	Stock Shareholder relationship with Nemaris
Lafage, Virginie (PhD)	Consultant relationship with Globus Medical; lectures relationship with Depuy Synthes Spine; lectures relationship with Implanet; Consultant relationship with Nuvasive
Lawrence, Brandon (MD)	Corporate Board Member relationship with Medtronic; Corporate Board Member relationship with AO Spine North America
Lee, Dong-Ho (MD, PhD)	No Relevant Financial Relationships
Lee, Hyung Rae (MD)	No Relevant Financial Relationships
Lee, Joon (MD)	No Relevant Financial Relationships
Lee, Jun Hee (MD)	No Relevant Financial Relationships
Lee, Sang Hun (MD)	Consultant relationship with DePuy Synthes; Consultant relationship with Medtronic
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
Levy, Hannah (BS)	No Relevant Financial Relationships
Liang, Guoyan (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; Scientific/Medical Advisory Board Member relationship with Nuvasive
Lynch, Conor (MS)	No Relevant Financial Relationships
Maki, Satoshi (MD, PhD)	No Relevant Financial Relationships
Mehta, Ankit (MD)	No Relevant Financial Relationships
Mendoza-Lattes, Sergio (MD)	Consultant relationship with Globus Medical
Mesfin, Addisu (MD)	Speakers Bureau relationship with Depuy; Consultant relationship with Medtronic; Fellowship Grant Support relationship with Globus

Alphabetical Participant Disclosure List

Name	Disclosure
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; Consultant relationship with Stryker; Research Grant Site Principal Investigator relationship with Centinel Spine
Miller, Justin (MD)	No Relevant Financial Relationships
Minamide, Akihito (MD, PhD)	No Relevant Financial Relationships
Miura, Kousei (MD, PhD)	No Relevant Financial Relationships
Miura, Masataka (MD)	No Relevant Financial Relationships
Miyamoto, Hiroshi (MD)	No Relevant Financial Relationships
Moghaddamjou, Ali (MD)	No Relevant Financial Relationships
Mohan, Shruthi (BS)	No Relevant Financial Relationships
Mohanty, Sarthak (BS)	No Relevant Financial Relationships
Monsour, Meredith (BS)	No Relevant Financial Relationships
Moore, Timothy (MD)	Speakers Bureau relationship with Globus Medical
Moriguchi, Yu (MD, PhD)	No Relevant Financial Relationships
Moser, Manuel (MD)	No Relevant Financial Relationships
Mroz, Thomas (MD)	royalties relationship with stryker
Mummaneni, Praveen (MD)	Consultant relationship with Depuy Synthes; Consultant relationship with Globus; Consultant relationship with Stryker; Stock Shareholder relationship with Spinicity/ISD; author relationship with Thieme Publishers; author relationship with Springer Publisher; Research Grant Site Principal Investigator relationship with ISSG; Research Grant Site Principal Investigator relationship with NREF; Research Grant Site Principal Investigator relationship with AO Spine
Mundis, Gregory (MD)	Consultant relationship with nuvasive; Scientific/Medical Advisory Board Member relationship with nuvasive; fellowship support relationship with nuvasive; Consultant relationship with Seaspine; Scientific/Medical Advisory Board Member relationship with Seaspine; Consultant relationship with Viseon; Scientific/Medical Advisory Board Member relationship with Carlsmed; Consultant relationship with Carlsmed
Naghdi, Neda (PhD)	No Relevant Financial Relationships
Nakashima, Hiroaki (MD, PhD)	No Relevant Financial Relationships
Nassr, Ahmad (MD)	Research Grant Site Principal Investigator relationship with Premise Spine; Fellowship director relationship with AO Spine NA; Research Grant Site Principal Investigator relationship with AO Spine NA

Name	Disclosure
Nolte, Michael (MD)	No Relevant Financial Relationships
Nunley, Pierce (MD)	Research Grant Site Principal Investigator relationship with Zimmer Biomet; Speakers Bureau relationship with Zimmer Biomet; Consultant relationship with Zimmer Biomet
Olsson, Erik (MD)	Consultant relationship with Seaspine Orthopedics
Padhye, Kedar (MD)	No Relevant Financial Relationships
Park, Daniel (MD)	Consultant relationship with Aegis spine; Consultant relationship with Stryker; Consultant relationship with Arthrex; Consultant relationship with Solco
Park, Jin Hoon Park (MD, PhD)	No Relevant Financial Relationships
Park, Sehan (MD)	No Relevant Financial Relationships
Passias, Peter (MD)	Consultant relationship with Medicrea; Consultant relationship with SpineWave; Speakers Bureau 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 Terumo; Consultant relationship with Royal Biologics
Patel, Alpesh (MD, MBA)	Scientific/Medical Advisory Board Member relationship with nView; Deputy Editor relationship with Journal of American Academy of Orthopaedic Surgeons; Consultant relationship with Alphatec; Consultant relationship with Nuvasive; Consultant relationship with Nuvasive; Consultant relationship with Depuy Synthes; Scientific/Medical Advisory Board Member relationship with Kuros Biosciences; Deputy Editor relationship with Journal of American Academy of Orthopaedic Surgery; Consultant relationship with Zimmer Biomet; Investor relationship with TDI Inc; Investor relationship with Endoluxe; Investor relationship with Nocimed; Investor relationship with Cytonics; Consultant relationship with CTL Amedica; Consultant relationship with CTL Amedica; Consultant relationship with Johnson and Johnson; Consultant relationship with Alphatec
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; Royalties relationship with SI Bone
Pinter, Zachariah (MD)	No Relevant Financial Relationships
Pitzen, Tobias (MD)	No Relevant Financial Relationships
Prabhakar, Gautham (MD)	No Relevant Financial Relationships
Pressciutti, Steven (MD)	No Relevant Financial Relationships
Preston, Gordon (DO)	No Relevant Financial Relationships

Alphabetical Participant Disclosure List

Name	Disclosure
Protopsaltis, Themistocles (MD)	Consultant relationship with Medtronic; Consultant relationship with Globus; Consultant relationship with NuVasive; Consultant relationship with Medicrea; Consultant relationship with Altus; Consultant relationship with SpineAlign; Consultant relationship with Stryker K2M
Pugely, Andrew (MD)	No Relevant Financial Relationships
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; 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 (Past relationship); 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 (Past relationship); Speaker address relationship with RTI Surgical Inc. (Past relationship); 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; Professional Society Member relationship with Lumbar Spine Research Society; Consultant, Royalties relationship with Stryker K2M; Private investments relationship with Vital 5 (Past relationship); Private investments relationship with Tissue Differentiation Intelligence
Radcliff, Kris (MD)	Design of a lumbar cortical screw system relationship with Globus Medical; Teaching and educational course participation relationship with Stryker; Consultant relationship with 4 Web Medical; Stock Shareholder relationship with 7D Surgical; Consultant relationship with Orthoson; Consultant relationship with Orthofix; Research Grant Site Principal Investigator relationship with Simplify Medical; Research Grant Site Principal Investigator relationship with Orthofix; Research Grant Site Principal Investigator relationship with Biocomposites

Name	Disclosure
Rahman, Ra'Kerry (MD)	No Relevant Financial Relationships
Rajan, Prashant (MD)	No Relevant Financial Relationships
Rajasekaran, Shanmuganathan (PhD)	No Relevant Financial Relationships
Redmond, Kristin (MD)	Research Grant Site Principal Investigator relationship with Elekta AB; Data Safety Monitoring Board relationship with BioMimetix; Research Grant Overall Principal Investigator relationship with Accuray; Research Grant Site Principal Investigator relationship with Novocure
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
Riew, K. Daniel (MD)	Patent Holder relationship with Biomet; Consultant relationship with Nuvasive; Consultant relationship with Happe Spine; Stock Shareholder relationship with Axiomed; Stock Shareholder relationship with Expanding Orthopedics; Stock Shareholder relationship with Spineology; Stock Shareholder relationship with Spinal Kinetics; Stock Shareholder relationship with Amedica; Stock Shareholder relationship with Vertiflex; Stock Shareholder relationship with Benvenue; Stock Shareholder relationship with Paradigm Spine; Corporate Board Member relationship with NASS
Rihn, Jeffrey (MD)	Deputy Editor relationship with The Spine Journal; Consultant relationship with Globus medical
Riley, Lee (III, MD)	Scientific/Medical Advisory Board Member relationship with Change Healthcare
Saela, Stephen (MD)	No Relevant Financial Relationships
Saifi, Comron (MD)	Consultant relationship with Nuvasive; Consultant relationship with GS Medical; Stock Shareholder relationship with Vertera/Nuvasive; Stock Shareholder relationship with Huxley Medical; NuVasive acquisition of Vertera relationship with NuVasive
Sakamoto, Takuya (MD)	No Relevant Financial Relationships
Santaguida, Carlo (MD, FRCSC)	Instructor relationship with Stryker; Chief Medical Officer relationship with Careaxis
Sasso, Rick (MD)	Patent Holder relationship with Medtronic; Consultant relationship with NuVasive
Satin, Alexander (MD)	Scientific/Medical Advisory Board Member relationship with Agada Medical; Consultant relationship with Degen Medical; Research Grant Site Principal Investigator relationship with Spineart
Savage, Jason (MD)	Consultant relationship with Stryker Spine

Alphabetical Participant Disclosure List

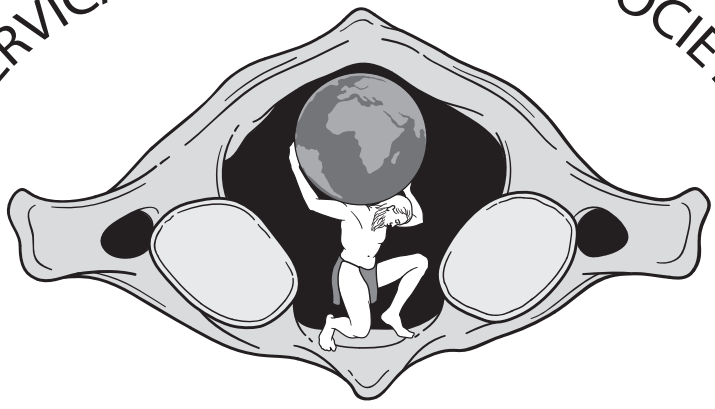
Name	Disclosure
Schroeder, Gregory (MD)	Consultant relationship with Medtronic, NuVasive, Zimmer, Stryker, Teledoc, Astura, ISD,; Consultant relationship with Bioventus, Wolters Klewer, AO Spine
Schuermans, Valérie (MD)	No Relevant Financial Relationships
Sciubba, Daniel (MD)	Consultant relationship with Depuy-Synthes; Consultant relationship with Medtronic; Consultant relationship with Stryker; Consultant relationship with Baxter
Sebastian, Arjun (MD, MSc)	No Relevant Financial Relationships
Shaffrey, Chris (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
Shah, Akash (MD)	No Relevant Financial Relationships
Shah, Shalin (DO)	No Relevant Financial Relationships
Shankar, Dhruv (BS)	No Relevant Financial Relationships
Shimer, Adam (MD)	Consultant relationship with Medtronic; Consultant relationship with Nuvasive
Song, Seong Hun (MD)	No Relevant Financial Relationships
Spiker, W. (MD)	Instructor relationship with Stryker; Fellowship Site relationship with AO
Spiker, W. Ryan (MD)	No Relevant Financial Relationships
Stauff, Michael (MD)	Research Grant Site Principal Investigator relationship with Empirical Spine; Consultant relationship with Depuy Synthes; Consultant relationship with Spineart
Steinmetz, Michael (MD)	royalties relationship with Zimmer Biomet; royalties relationship with Elsvier; Consultant relationship with Globus; honorarium relationship with Medtronic
Su, Brian (MD)	No Relevant Financial Relationships
Suk, Kyung-Soo (MD)	No Relevant Financial Relationships
Sun, Yu (MD)	No Relevant Financial Relationships
Suzuki, Akinobu (MD)	No Relevant Financial Relationships
Swiatek, Peter (MD)	No Relevant Financial Relationships
Takahashi, Masahito (MD, PhD)	No Relevant Financial Relationships

Name	Disclosure
Tamai, Koji (MD)	No Relevant Financial Relationships
Tan, Lee (MD)	Consultant relationship with Medtronic; Consultant relationship with Stryker; Consultant relationship with Globus; Consultant relationship with Integrity Implants
Tay, Bobby (MD)	Consultant relationship with Stryker; Consultant relationship with Synthes; Consultant relationship with Lumetra; Consultant relationship with Biomet/Zimmer; Fellowship Grant Support for Institution relationship with NuVasive; Fellowship Grant Support for the Institution relationship with Omega
Toci, Gregory (BS)	No Relevant Financial Relationships
Tortolani, P. Justin (MD)	Consultant relationship with Globus Medical; Scientific/Medical Advisory Board Member relationship with Innovasis; Research Grant Site Principal Investigator relationship with Innovasis; Consultant relationship with Innovasis
Traynelis, Vincent (MD)	Patent Holder relationship with Medtronic; Consultant relationship with NuVasive; Fellowship support relationship with AO; Fellowship Support relationship with NREF
Truumees, Eeric (MD)	No Relevant Financial Relationships
Vaccaro, Alexander (MD, PhD, MBA)	Stock Shareholder relationship with Advanced Spinal Intellectual Properties; 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 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; Stock Shareholder relationship with Atlas Spine; Stock Shareholder relationship with Avaz Surgical; Stock Shareholder relationship with Jushi; Stock Shareholder relationship with ViewFi Health; Royalties relationship with Aesculap; Royalties relationship with Atlas Spine; Royalties relationship with Globus; Royalties relationship with Medtronic; Royalties relationship with SpineWave; Royalties relationship with Stryker Spine

Alphabetical Participant Disclosure List

Name	Disclosure
Vachata, Petr (MD)	Employee relationship with KZ Krajska zdravotni; Consultant relationship with Medtronic, Johnson Johnson; Patent Holder relationship with Syntropiq; Corporate Board Member relationship with NSC; Research Grant Overall Principal Investigator relationship with KZ Krajska zdravotni
Vira, Shaleen (MD)	No Relevant Financial Relationships
Wang, Jeffrey (MD)	royalties relationship with Zimmer-Biomet; royalties relationship with Seaspine; royalties relationship with depuy-Synthes; Stock Shareholder relationship with bone biologics; Stock Shareholder relationship with pearldiver; Stock Shareholder relationship with electrocore; Stock Shareholder relationship with surgitech; 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
Wilent, W. Bryan (PhD)	VP of Quality relationship with Specialtycare; Board Member relationship with American Board of Neurophysiologic Monitoring; President-Elect relationship with American Society of Neurophysiological Monitoring
Wilson, Jefferson (MD)	Consultant relationship with Stryker Canada; Scientific/Medical Advisory Board Member relationship with Bioventus
Witiw, Christopher (MD, MS)	No Relevant Financial Relationships
Wolinsky, Jean-Paul (MD)	Educational Course Faculty relationship with AO North America
Woods, Barrett (MD)	Consultant relationship with Altus; Consultant relationship with stryker; Consultant relationship with medtronic
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
Yee, Timothy (MD)	No Relevant Financial Relationships
Yokota, Kazuya (MD, PhD)	No Relevant Financial Relationships
Yoon, S. Tim (MD, PhD)	Interbody Device relationship with Meditech Spine; Stock Shareholder relationship with Medyssey
Yu, Elizabeth (MD)	Research Grant Site Principal Investigator relationship with empirical spine; AOspine speaker relationship with AO north america
Zapolsky, Ivan (MD)	No Relevant Financial Relationships
Zavras, Athan (BA)	No Relevant Financial Relationships
Zhang, Andrew (MD)	No Relevant Financial Relationships
Zhou, Feifei (MD)	No Relevant Financial Relationships
Zuckerman, Scott (MD)	No Relevant Financial Relationships

CERVICAL SPINE RESEARCH SOCIETY



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Podium and E-Poster Presentations

PRESENTATION #1

Impact of Depression Severity on Patient Reported Outcomes Following Multilevel Anterior Cervical Discectomy and Fusion

Cara Geoghegan, BS, Conor Lynch, MS, Elliot Cha, MS, Caroline Jadczak, BS, Shruthi Mohan, BS, Kern Singh, MD[1]
Rush University Medical Center[1]

Introduction: Few studies have investigated the effects of preoperative depression and multilevel procedures on patient reported outcomes (PRO) following ACDF.[1-3] Our study aims to determine the impact of preoperative depression on PROs in single vs. multilevel ACDF procedures.

Materials and Methods: Eligible ACDF procedures were retrospectively reviewed from March 2015 to January 2020 using a prospectively maintained surgical database. Included patients underwent a primary single or multilevel ACDF and were excluded if surgery was indicated for infectious, malignant, or traumatic etiologies or missing preoperative PHQ-9 questionnaires. Demographic and perioperative characteristics were collected for all patients. The primary outcomes of interest were the following PROs: Visual Analogue Scale (VAS), Neck Disability Index (NDI), 12-Item Short Form Physical Composite Summary and Mental Composite Summary (SF-12 PCS & MCS), and Patient-Reported Outcomes Measurement Information System physical function (PROMIS PF). Primary outcomes were collected preoperatively and at 6-weeks, 12-weeks, 6-months, and 1-year postoperatively. Patients were stratified into 3 groups based on PHQ-9 score to reflect depressive symptom severity. Differences in demographic and perioperative variables were assessed using either Chi-square or Student's t-test. PHQ subgroups were further assessed, by multiple linear regression, for differences in PROs due to preoperative depression severity or both preoperative depression severity and number of levels fused. An α=0.05 was required to reject the null hypothesis.

Results: A total of 101 patients were included in this study with 42 categorized as having minimal depressive symptoms, 32 having mild, and 27 having moderate to severe. Average age was 48.1 years with 60% being male and 59% non-obese. The patient cohort demonstrated no significant differences in demographics between depressive groups outside of ethnicity (p=0.028) (Table 1). Mean operative time was 54.3 minutes with an estimated blood loss of 29.8mL. No significant perioperative differences were observed between groups (Table 2). Preoperative baseline values were significantly different between groups for all PROs (all p<0.01; Table 3) Improvement significantly differed between groups at 6-weeks for VAS arm, NDI, and SF-12 MCS (all p<0.05). At 12-weeks, VAS neck, NDI, SF-12 PCS and MCS, and PROMIS PF were significantly different between depression subgroups. Only SF-12 PCS and MCS demonstrated significant differences between groups at 6-months (both p<0.05), and VAS arm and SF-12 MCS were significantly different between groups at 1-year (both p<0.05). Multiple regression analysis revealed VAS arm at 1-year (p=0.029), NDI at 12-weeks (p=0.034), PROMIS PF at 6-weeks (p=0.038), and all postoperative timepoints for SF- MCS differed by preoperative depression severity and number of levels fused (Table 3).

Conclusion: Depression severity significantly impacted recovery of pain, disability, and physical function at preoperative and intermittent postoperative timepoints. Both preoperative depression severity and multilevel procedures significantly impacted arm pain, neck

PRESENTATION #1 continued

disability, and physical function at intermittent postoperative timepoints. While past studies have established a potential role of depression in postoperative outcome improvement, an additional factor must be considered in expected improvement of PROs following multilevel ACDF.

Table 1. Patient Demographics

	Minimal (n=42)	Mild (n=32)	Moderate to Severe (n=27)	*p-value
Age (mean ± SD)	50.6 ± 11.0	48.6 ± 7.7	46.9 ± 9.9	0.297
Gender				0.897
Female	42.9% (18)	37.5% (12)	40.7% (11)	
Male	57.1% (24)	62.5% (20)	59.3% (16)	
Body mass index (BMI)				0.567
<30 kg/m^2	64.3% (27)	56.3% (18)	51.9% (14)	
≥30 kg/m^2	35.7% (15)	43.7% (14)	48.1% (13)	
Smoking Status				0.895
Non-Smoker	85.7% (36)	84.4% (27)	81.5% (22)	
Smoker	14.3% (6)	15.6% (5)	18.5% (5)	
Ethnicity				**0.028**
White	80.9% (34)	81.2% (26)	63.0% (17)	
African-American	11.9% (5)	6.3% (2)	0.0% (0)	
Hispanic	2.4% (1)	6.3% (2)	25.9% (7)	
Asian	4.8% (2)	3.1% (1)	3.7% (1)	
Other	0.0% (0)	3.1% (1)	7.4% (2)	
Diabetic Status				0.987
Diabetic	88.1% (37)	87.5% (28)	88.9% (24)	
Non-Diabetic	11.9% (5)	12.5% (4)	11.1% (3)	
ASA Classification				0.159
≤2	80.4% (21)	90.6% (20)	95.8% (23)	
>2	19.5% (8)	9.4% (3)	4.2% (1)	
CCI				0.159
≤1	52.5% (33)	69.0% (20)	74.1% (20)	
>1	47.5% (19)	31.0% (9)	25.9% (7)	

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD = standard deviation

*p-value calculated using Pearson's Chi-square analysis or Student's t-test

Boldface indicates statistical significance

PRESENTATION #1 continued

Table 2. Operative Characteristics

	Minimal (n=42)	Mild (n=32)	Moderate to Severe (n=27)	*p-value
Spinal Pathology				
Herniated Nucleus Pulposus	85.7% (36)	90.6% (29)	85.2% (23)	0.510
Spinal Stenosis	57.1% (24)	65.6% (21)	66.7% (18)	0.655
Myeloradiculopathy	92.8% (39)	81.2% (26)	88.9% (24)	0.578
Operative Time (min)				
Mean ± SD	47.2 ± 87.1	63.5 ± 19.3	54.4 ± 18.2	0.489
Estimated Blood Loss (mL)				
Mean ± SD	31.7 ± 14.8	26.3 ± 9.4	30.8 ± 12.9	0.202
Length of Stay (hours)				
Mean ± SD	13.0 ± 9.9	13.1 ± 14.2	12.5 ± 15.4	0.981
Day of Discharge				0.138
POD0	71.4% (30)	81.3% (26)	80.0% (20)	
POD1	26.1% (11)	9.4% (3)	16.0% (4)	
POD2	2.3% (1)	9.4% (3)	0.0% (0)	
POD3	0.0% (0)	0.0% (0)	4.0% (1)	

POD = Postoperative day; SD = standard deviation
*p-value calculated using Pearson's Chi-square analysis or Student's t-test

PRESENTATION #1 continued

Table 3: Postoperative Improvement by Depression Severity and Number levels Fused

	Minimal Mean ± SD (n)	Mild Mean ± SD (n)	Moderate to Severe Mean ± SD (n)	*p-value	†p-value
VAS Neck					
Preoperative	4.7 ± 2.4 (40)	6.5 ± 2.1 (30)	7.4 ± 2.3 (27)	**<0.001**	-
6-weeks	3.0 ± 2.6 (38)	3.4 ± 2.4 (30)	3.6 ± 2.7 (24)	0.292	0.789
12-weeks	1.9 ± 2.3 (32)	3.3 ± 2.2 (24)	3.6 ± 2.5 (21)	**0.012**	0.172
6-months	2.1 ± 2.5 (28)	3.1 ± 2.2 (22)	2.9 ± 2.8 (19)	0.251	0.629
1-year	2.4 ± 2.3 (15)	3.0 ± 2.9 (9)	4.4 ± 3.5 (7)	0.143	0.554
VAS Arm					
Preoperative	5.0 ± 2.6 (40)	6.6 ± 2.2 (30)	6.9 ± 2.6 (27)	**0.002**	-
6-weeks	2.0 ± 2.3 (38)	3.2 ± 2.8 (30)	3.8 ± 5.2 (24)	**0.031**	0.326
12-weeks	3.3 ± 3.7 (32)	2.3 ± 2.4 (24)	3.5 ± 3.4 (21)	0.824	0.231
6-months	2.9 ± 3.7 (28)	3.1 ± 2.4 (22)	3.3 ± 3.4 (17)	0.693	0.991
1-year	3.0 ± 3.0 (15)	3.0 ± 3.3 (9)	7.0 ± 3.8 (7)	**0.031**	**0.029**
NDI					
Preoperative	25.7 ± 16.5 (40)	41.4 ± 17.0 (30)	50.5 ± 15.8 (27)	**<0.001**	-
6-weeks	23.5 ± 18.8 (38)	35.1 ± 17.7 (30)	35.4 ± 20.1 (24)	**0.009**	0.074
12-weeks	17.7 ± 17.2 (32)	29.9 ± 18.1 (24)	35.5 ± 24.5 (21)	**0.001**	**0.034**
6-months	17.7 ± 20.4 (28)	24.0 ± 14.5 (22)	22.2 ± 23.3 (17)	0.388	0.755
1-year	16.5 ± 16.3 (15)	20.8 ± 22.8 (9)	20.2 ± 20.7 (7)	0.621	0.969
SF-12 PCS					
Preoperative	39.0 ± 9.1 (41)	34.7 ± 7.4 (32)	31.8 ± 6.7 (27)	**<0.001**	-
6-weeks	36.9 ± 9.3 (34)	33.1 ± 5.3 (28)	33.3 ± 6.8 (23)	0.062	0.172
12-weeks	41.2 ± 10.1 (26)	39.1 ± 7.3 (21)	35.0 ± 8.4 (17)	**0.019**	0.216
6-months	43.6 ± 10.8 (24)	40.6 ± 9.1 (20)	36.6 ± 10.3 (12)	**0.038**	0.417
1-year	46.4 ± 8.0 (17)	47.6 ± 7.7 (9)	41.2 ± 15.7 (8)	0.254	0.524
SF-12 MCS					
Preoperative	55.2 ± 10.4 (41)	45.6 ± 8.6 (32)	33.4 ± 11.5 (27)	**<0.001**	-
6-weeks	55.3 ± 9.5 (34)	49.0 ± 11.3 (28)	43.4 ± 12.4 (23)	**<0.001**	**0.003**
12-weeks	57.4 ± 8.5 (26)	50.6 ± 9.1 (21)	39.6 ± 13.7 (17)	**<0.001**	**<0.001**
6-months	57.8 ± 7.8 (24)	45.1 ± 10.5 (20)	42.7 ± 14.1 (12)	**<0.001**	**0.001**
1-year	57.0 ± 8.9 (17)	53.8 ± 5.9 (9)	43.9 ± 16.3 (8)	**0.006**	**0.025**
PROMIS PF					
Preoperative	42.9 ± 7.6 (42)	37.4 ± 6.2 (32)	35.4 ± 4.9 (27)	**<0.001**	-
6-weeks	43.2 ± 7.1 (33)	38.0 ± 7.6 (23)	41.0 ± 6.1 (17)	0.147	**0.038**
12-weeks	47.8 ± 12.1 (20)	44.6 ± 4.7 (20)	40.9 ± 9.5 (12)	**0.046**	0.372
6-months	49.3 ± 8.0 (23)	42.5 ± 9.4 (14)	44.5 ± 8.4 (10)	0.070	0.145
1-year	49.3 ± 6.1 (16)	48.0 ± 8.3 (13)	45.3 ± 6.1 (9)	0.180	0.347

*p-values calculated using linear regression to assess outcomes between PHQ-9 severity groups
†p-values calculated using multiple linear regression to assess the interaction of preoperative PHQ-9 severity and multilevel procedures in predicting outcome improvement
Boldface indicates significance; SD = standard deviation

PRESENTATION #2

No Difference in Clinical Outcomes When Instrumenting Across the Cervicothoracic Junction in Multilevel Posterior Cervical Fusion

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Introduction: In the setting of multilevel posterior cervical fusion (PCF), instrumenting across the cervicothoracic junction (CTJ) remains a topic of debate. The proposed benefits of crossing the CTJ include decreased rates of adjacent-segment disease, increased fusion rates, and superior radiographic outcomes. However, constructs crossing the CTJ have also been associated with increased complication rates, prolonged operative duration, and increased blood loss. Despite studies evaluating surgical outcomes of PCF constructs crossing and not crossing the CTJ, there is a dearth of literature comparing clinical outcomes for patients. Accordingly, the purpose of this study was to determine if patient-reported outcome measures (PROMs) differed for patients undergoing multilevel PCF with constructs that crossed versus did not cross the CTJ.

Materials and Methods: Electronic medical records (EMR) were reviewed for all patients ≥18 years who underwent PCF between 2013 and January 2020 at a single institution. Exclusion criteria included incomplete preoperative and postoperative PROM data at a minimum of 11-months, revision procedures, or a preoperative diagnosis of tumor or infection. 3-month postoperative PROM data were also collected when available. Patient characteristics and demographic data were obtained from EMR. Patients were separated into groups based on construct: those who had constructs that crossed (crossed) the CTJ and those whose constructs did not (non-crossed). Additionally, subgroup analysis was performed for patients with constructs spanning C3-C7 and C3-T1. A delta score (Δ) was calculated for all PROMs. Independent two-sample t-tests were utilized for comparing continuous data between groups. Categorical data were compared using Pearson's chi-square tests. Alpha was set at 0.05.

Results: Of the 145 patients in the cohort, 75 patients (51.7%) had constructs which crossed the CTJ and 70 (48.2%) did not. Those in the crossed group had significantly more levels fused (5.16 vs. 3.74, $p<0.001$). There was a significantly greater proportion of non-smokers in the crossed group (70.4% vs. 48.6%, $p=0.030$) (Table 1). Crossing the CTJ resulted in significantly lower postoperative neck disability index (NDI) scores (27.3 vs. 35.6, $p=0.022$) (Table 2). Subsequent grouping resulted in 40 (44.9%) patients in the C3-C7 group and 49 (55.1%) patients in the C3-T1 group with no significant differences in patient demographics or characteristics between groups. There were no significant differences between preoperative, postoperative, or Δ PROM scores between groups (Table 3).

Conclusion: Patients undergoing multilevel PCF whose constructs crossed the CTJ demonstrated significantly lower postoperative NDI scores compared to patients who constructs ended in the cervical spine, with no significant differences in Δ score. Additionally, when comparing constructs spanning C3-C7 versus C3-T1, no significant differences in clinical

PRESENTATION #2 continued

outcomes were found. The results suggest that crossing the CTJ for multilevel PCF does not cause a clinically significant difference in patient reported outcomes.

Table 1. Patient demographics based on crossing the cervicothoracic junction

	Non-crossed (N=70)	Crossed (N=75)	P-value
Age (years)	59.8 (10.2)	62.1 (10.6)	0.182
Sex			0.740
Female	27 (38.6%)	32 (42.7%)	
Male	43 (61.4%)	43 (57.3%)	
Body mass index	30.6 (5.19)	30.6 (6.52)	0.798
Diabetes	12 (17.1%)	19 (25.3%)	0.318
Smoking Status			**0.030***
Current Smoker	13 (18.6%)	8 (11.3%)	
Former Smoker	23 (32.9%)	13 (18.3%)	
Non-Smoker	34 (48.6%)	50 (70.4%)	
PMH of Depression	22 (31.4%)	19 (25.3%)	0.529
PMH of Anxiety Disorder	15 (21.4%)	18 (24.0%)	0.864
Estimated blood loss (cc)	188 (64.4)	316 (385)	0.310
Number of levels fused	3.74 (0.56)	5.16 (0.64)	**<0.001***
Symptom duration			0.360
< 6 months	28 (41.2%)	38 (52.8%)	
6 months – 2 years	23 (33.8%)	18 (25.0%)	
> 2 years	17 (25.0%)	16 (22.2%)	

*Indicates statistical significance ($p<0.05$).

Abbreviations: Past Medical History (PMH), Selective Serotonin Reuptake Inhibitor (SSRI)

PRESENTATION #2 continued

Table 2. Patient reported outcome measures based on crossing the cervicothoracic junction

		Non-crossed (N=70)	*Crossed (N=75)*	*P-value*
MCS-12	Preoperative	46.2 (11.5)	46.9 (11.8)	0.626
	1-year postop	52.0 (11.3)	52.5 (11.0)	0.649
	Delta	5.73 (12.7)	5.61 (12.0)	0.953
	MCID	37 (52.9%)	37 (49.3%)	0.796
	3-month postop[1]	48.7 (10.9)	49.5 (13.9)	0.796
	Follow-up (days)	683 (325)	698 (358)	0.822
PCS-12	Preoperative	31.7 (8.52)	32.2 (9.27)	0.862
	1-year postop	37.5 (10.2)	40.2 (11.6)	0.145
	Delta	5.81 (11.7)	7.99 (12.6)	0.231
	MCID	33 (47.1%)	39 (52.0%)	0.676
	3-month postop[1]	34.5 (9.9)	33.6 (10.2)	0.708
	Follow-up (days)	683 (325)	698 (358)	0.822
NDI	Preoperative	39.1 (20.1)	36.9 (21.3)	0.412
	1-year postop	35.6 (21.1)	27.3 (20.2)	**0.022***
	Delta	3.51 (21.2)	9.60 (21.6)	0.075
	MCID	15 (21.4%)	23 (30.7%)	0.282
	3-month postop[2]	30.5 (17.7)	29.7 (16.6)	0.856
	Follow-up (days)	689 (422)	794 (541)	0.498
VAS Neck	Preoperative	5.60 (2.91)	4.78 (3.50)	0.172
	1-year postop	3.13 (2.65)	2.43 (2.68)	0.055
	Delta	2.47 (3.36)	2.34 (3.63)	0.833
	MCID	35 (50.0%)	33 (44.0%)	0.578
	3-month postop[3]	4.15 (2.45)	3.21 (3.07)	0.385
	Follow-up (days)	650 (366)	683 (381)	0.666
VAS Arm	Preoperative	5.21 (2.86)	4.71 (3.20)	0.332
	1-year postop	2.71 (2.64)	2.00 (2.51)	0.062
	Delta	2.50 (3.25)	2.70 (2.89)	0.684
	MCID	19 (27.1%)	20 (26.7%)	1.000
	3-month postop[3]	3.64 (3.11)	2.86 (2.94)	0.519
	Follow-up (days)	650 (366)	683 (381)	0.666
MJOA[4]	Preoperative	13.4 (3.02)	13.1 (3.18)	0.633
	1-year postop	14.1 (3.00)	14.8 (2.64)	0.231
	Delta	0.77 (3.10)	0.88 (3.38)	0.401
	MCID	11 (21.2%)	14 (33.3%)	0.274
	3-month postop[5]	14.9 (2.75)	14.7 (3.01)	0.680
	Follow-up (days)	489 (195)	522 (251)	0.752

*Indicates statistical significance ($p<0.05$).
[1]Non-crossed N=32, Crossed N=38
[2]Non-crossed N=29, Crossed N=32
[3]Non-crossed N=19, Crossed N=11
[4]Non-crossed N=52, Crossed N=42
[5]Non-crossed N=33, Crossed N=37

Abbreviations: Mental Health Component Score (MCS), Minimum Clinically Important Difference (MCID), Modified Japanese Orthopaedic Association (MJOA), Neck Disability Index (NDI), Physical Health Component Score (PCS), Visual Analog Scale (VAS)

PRESENTATION #2 continued

Table 3. Patient reported outcome measures comparisons when stopping at C7 versus T1

		C3-C7 (N=40)	*C3-T1 (N=49)*	*P-value*
MCS-12	Preoperative	49.0 (11.6)	47.1 (12.5)	0.494
	1-year postop	52.0 (11.8)	52.2 (10.8)	0.938
	Delta	2.98 (12.2)	5.03 (11.9)	0.429
	MCID	15 (37.5%)	24 (49.0%)	0.384
	3-month postop[1]	50.0 (11.0)	46.9 (15.2)	0.472
	Follow-up (days)	697 (328)	632 (289)	0.233
PCS-12	Preoperative	31.6 (8.45)	32.5 (9.21)	0.741
	1-year postop	37.5 (9.61)	39.2 (11.2)	0.501
	Delta	5.89 (10.4)	6.71 (11.6)	0.725
	MCID	18 (45.0%)	23 (46.9%)	1.000
	3-month postop[1]	34.7 (11.1)	33.1 (10.5)	0.636
	Follow-up (days)	697 (328)	632 (289)	0.233
NDI	Preoperative	37.0 (18.9)	35.9 (20.5)	0.668
	1-year postop	34.6 (19.8)	27.9 (19.7)	0.106
	Delta	2.39 (22.0)	7.96 (21.2)	0.231
	MCID	7 (17.5%)	16 (32.7%)	0.167
	3-month postop[2]	30.1 (20.9)	29.4 (17.1)	0.917
	Follow-up (days)	700 (422)	712 (474)	0.732
VAS Neck	Preoperative	5.37 (2.71)	4.66 (3.49)	0.409
	1-year postop	2.70 (2.42)	2.53 (2.74)	0.485
	Delta	2.67 (3.04)	2.13 (3.41)	0.436
	MCID	22 (55.0%)	22 (44.9%)	0.462
	3-month postop[3]	3.59 (2.00)	3.38 (3.72)	0.898
	Follow-up (days)	647 (408)	674 (359)	0.621
VAS Arm	Preoperative	4.64 (2.85)	4.74 (3.31)	0.915
	1-year postop	2.46 (2.56)	2.22 (2.74)	0.377
	Delta	2.19 (3.20)	2.52 (2.78)	0.609
	MCID	10 (25.0%)	13 (26.5%)	1.000
	3-month postop[3]	2.84 (3.14)	2.63 (3.50)	0.921
	Follow-up (days)	647 (408)	674 (359)	0.621
MJOA[4]	Preoperative	13.5 (3.24)	12.7 (3.43)	0.245
	1-year postop	14.7 (2.75)	14.8 (2.33)	0.961
	Delta	0.94 (3.11)	1.11 (3.06)	0.476
	MCID	7 (21.9%)	9 (33.3%)	0.489
	3-month postop[5]	15.8 (2.54)	14.3 (2.46)	0.065
	Follow-up (days)	505 (217)	536 (284)	0.967

[1]C3-C7 N=19, C3-T1 N=23
[2]C3-C7 N=17, C3-T1 N=18
[3]C3-C7 N=11, C3-T1 N=4
[4]C3-C7 N=32, C3-T1 N=27
[5]C3-C7 N=19, C3-T1 N=22

Abbreviations: Mental Health Component Score (MCS), Minimum Clinically Important Difference (MCID), Modified Japanese Orthopaedic Association (MJOA), Neck Disability Index (NDI), Physical Health Component Score (PCS), Posterior Cervical Fusion (PCF), Visual Analog Scale (VAS)

PRESENTATION #3

Trends in 2 Year Outcomes of a Prospective Consecutively Enrolled Single-Center Adult Cervical Deformity Series: Optimal Realignment Correlates with Superior Outcomes

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Introduction: Adult cervical deformity(CD) is a debilitating disorder of the spine characterized by radiographic malalignment of the cervical vertebral segments in the sagittal and/or coronal planes. CD significantly compromises patient's health-related quality of life. While advances in spinal realignment have shown promising short-term clinical results, the durability of CD-corrective surgery remains a clinical challenge. The aim of this retrospective cohort study of a prospectively collected CD database was to describe the 2-year outcomes for patients undergoing surgical correction of cervical deformity.

Materials and Methods: Operative CD patients >18yrs with up to 2-year(2Y) HRQL/ radiographic data were included. Cervical deformity was defined as meeting at least one of the following radiographic parameters: C2-C7 lordosis < -15°, TS-CL>35°, segmental cervical kyphosis >15° across any 3 vertebra between C2-T1, C2-C7 SVA>4cm, McGregor's slope>20°, or CBVA>25°. Univariate analyses assessed demographics, surgical descriptors, radiographic parameters, HRQL scores, and complication rates from baseline(BL) to 2Y postop.

Results: 141 patients with cervical deformity met inclusion criteria (59.6yrs, 54% F, BMI 28.2±8.3, CCI: 0.93), and underwent surgical correction (levels fused 6.1±4.9, EBL: 1056 mL, operative time: 347 min). By surgical approach, 14.9% anterior-only, 67.4% posterior-only, and 16.3% combined. 68 patients(48.2%) underwent osteotomy. 58 underwent facet osteotomy or Ponte, 13 had partial or complete corpectomy, 4 underwent opening wedge, and 8 underwent closing wedge or VCR. The most common UIV was C3 and most common LIV was C7. Radiographic parameters are reported in Table 1. By 2Y postop, 13 patients improved in Ames cSVA modifier, 19 in TS-CL, 8 in Horiz modifier, 1 in SVA modifier, and 6 in mJOA. Overall, 36(25.5%) patients improved in at least 1 Ames modifier. Mean HRQLs at BL were as follows: NRS Back: 6.3, NRS Neck: 6.1, NDI: 52.2, mJOA: 13.3, EQ5D: 4.3. By 2Y, 26 patients met MCID for EQ5D, 34 for NDI, and 21 for mJOA. Patients who improved in the Ames mJOA modifier were also more likely to meet MCID for NDI and EQ5D by 2Y(both $p<0.01$). In terms of neurologic outcomes, the following number of patients presented with a deficit at BL: bladder incontinence: 4, bowel incontinence: 3, gait abnormality: 7, hand clumsiness: 21, hand numbness: 23, Lhermitte sign: 1, paresthesia: 23, weakness: 27, corticospinal motor deficit: 6, hand muscle atrophy: 11, hyperreflexia: 3, and Hoffman's sign: 5 patients. By 2Y, 10 of the 37 patients who had a BL neuro deficit no longer reported that deficit. By 2Y postop, 22 patients(15.6%) required reoperation. Overall, 70 patients(49.6%) were reported to have had experienced a complication. 2 patients developed dysphagia, 11 had a neurologic complication, 6 cardiopulmonary, 13, had an operative complication like wound dehiscence or hematoma, and 6 developed a surgical site infection. There were 2 mortalities. 34 patients(24.1%) had a radiographic complication. There were 28 cases of DJK (?DJKA>10° between LIV and LIV-2), of which 9 were DJF (DJK requiring reoperation).

Conclusion: Correction of cervical deformity results in notable clinical and radiographic

PRESENTATION #3 continued

improvement. Most patients achieve favorable outcomes, though complications most notably distal junctional kyphosis or failure still occur and need to be minimized.

Table 1. Mean baseline and 2Y postoperative radiographic parameters in a cohort of 141 cervical deformity patients.

Parameter	Baseline (°)	2Y postop (°)
S1SS	32.6	31.7
PT	21.9	24.8
PI	54.6	57.4
PI-LL	7.1	5.9
L1-S1	-2.5	13.4
T4-T12 thoracic kyphosis (TK)	6.9	-21.1
C7-S1 SVA	-35.2 mm	9.7 mm
T1PA	19.2	18.5
TS-CL	24.8	25.5
C2-C7 cervical lordosis (CL)	-12.1	4.1
C2-C7 SVA (cSVA)	6.0	19.1
C2-T3	-15.1	-1.0
T1SS	33.4	36.4
McGregor slope	2.9	-4.9
CVBA	7.2	2.9

PRESENTATION #4

Is it better to stop at C2 or C3/4 in elective posterior cervical decompression and fusion?

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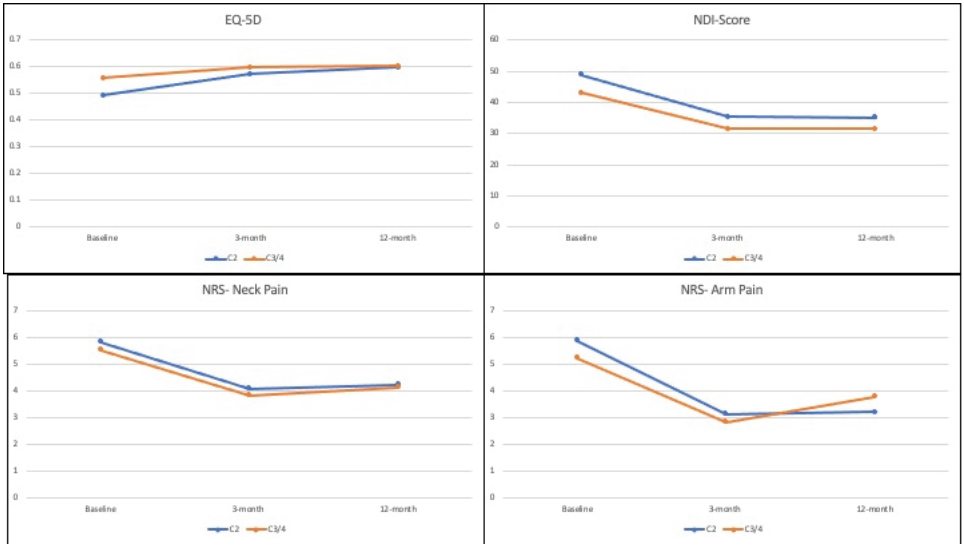
Introduction: When performing posterior cervical laminectomy and fusion (PCLF), spine surgeons must select the upper instrumented vertebrae (UIV), frequently choosing to stop at C2 or the subaxial cervical spine (C3/C4). While C2 offers superior fixation, vertebral artery proximity adds technical difficulty and additional risk, in addition to more segments fused. Conversely, although C3/4 preserves motion segments, lateral mass fixation offers inferior fixation. Differences in long-term complication rates and patient-reported outcomes (PROs) for these techniques remain unknown. In patients undergoing PCLF, we compared operative data, complication rates, and PROs between those with a UIV of C2 vs. C3/C4.

Materials and Methods: A single-institution, prospective, longitudinal registry was queried for patients undergoing elective PCLF for degenerative conditions from 12/2010-06/2018. Patients with a UIV of C1 or above and C5 and below, and those with non-degenerative etiologies were excluded. Included patients were divided into those with a UIV of C2 or C3/C4. Cohorts were 2:1 propensity matched for the variable of fusion extension to the thoracic spine. Demographic, operative, complication, and 1-year PRO data were collected. Student's t-tests and chi-squared tests were performed.

Results: A total of 117 patients were successfully propensity matched (44 C2 vs. 88 C3/C4). Demographics were similar between groups, notably including fusion extension to the thoracic spine (p=0.588). As expected, the C2 group featured more levels fused (5.63±1.89 vs. 4.50±0.91, p=0.001) and longer operative times (225±63 vs. 181±45, p<0.001). No differences in estimated blood loss (EBL) (365±307 vs 422±465, p=0.494) or length of stay (LOS) (4.38±4.10 vs. 3.85±3.04, p=0.424) were detected. Twenty-one total adverse events were recorded. Identical surgical complication rates (7.7%, p=1.000) were seen including pseudoarthrosis and implant failure requiring revision (5.1%, p=1.000). Both groups achieved significant improvement in PROs at 1-year including EQ-5D, numeric rating scale-neck/arm pain, and neck disability index. A sub-analysis of the C2 group comparing screw type (pedicle, pars, laminar) revealed no significant differences in operative data, complications, or PROs.

Conclusion: In a cohort of patients undergoing PCLF, those with a UIV of C2 had only longer operative times compared to those with an UIV of C3/C4, with no differences in EBL, LOS, complication rates, or 1-year PROs. Screw type at C2 did not impact outcomes. These results suggest, with the exception of increased operative time, extension to C2 has no appreciable difference on surgical outcomes.

PRESENTATION #4 continued



Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #4 continued

Table 1. Comparison of Adverse events between the propensity matched groups of cervical fusion extension to C2 vs C3/4.

	Total (N=117)	C2 (39)	C3 or C4 (78)	p-value
Any Adverse Event*	21 (17.9%)	5 (12.8%)	16 (20.5%)	0.444
Medical Adverse Event (within 1-year)	12 (10.3%)	2 (5.1%)	10 (12.8%)	0.332
Urinary Tract Infection	*3*	-	*3*	
Respiratory Tract Related	*2*	*1*	*1*	
Dysphagia/ GI Related	*1*	-	*1*	
Pain	*1*	-	*1*	
Others (Dehydration, Seizures)	*5*	*1*	*4*	
Surgical Adverse Event (at any time till date)	9 (7.7%)	3 (7.7%)	6 (7.7%)	1.00
Pseudoarthrosis or Failure of Instrumentation	*6*	*2*	*4*	
Adjacent segment disease	*2*	*0*	*2*	
Wound Infection	*1*	*1*	-	

**Adverse Event: Major Complication, Readmissions, Return to Operating Room for Revision or Wound Drainage*

PRESENTATION #5

Preoperative Diagnosis of a Mental Health Disorder is Associated with Increased Postoperative Rates of Dysphagia after Anterior Cervical Spine Surgery

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Introduction: Mental health disorders (MHDs) have been implicated with worse postoperative outcomes after various surgical procedures including higher rates of surgical site infection, postoperative pain, opioid usage, and revision procedures. Past studies have also demonstrated a higher prevalence of dysphagia in both acute and community mental health settings. Dysphagia is among the most common complications after anterior cervical spine surgery (ACSS) including anterior cervical discectomy and fusion (ACDF), total disc replacement (TDR), and corpectomy as a result of manipulation of the soft tissue and neurovascular structures of the anterior neck. Currently, there is sparse literature describing the association between an established diagnosis of an MHD and the rate of dysphagia after ACSS.

Materials and Methods: We retrospectively evaluated all patients who underwent ACSS with a single surgeon between the years of 2014 and 2020. Patients with a minimum follow-up of 6 months were stratified into two cohorts: the first consisting of patients without an established diagnosis of an MHD (Non-MHD), and the second including patients with a diagnosed MHD and history of pharmacotherapy. Patients with diagnoses of depression, anxiety, bipolar disorder, schizophrenia, post-traumatic stress disorder (PTSD), and substance abuse disorder were included in the MHD cohort. Pre- and postoperative patient-reported outcome (PROs) scores were evaluated, including the SWAL-QOL survey for dysphagia, Neck Disability Index (NDI), Visual Analog Scale (VAS) Arm, VAS neck, Short Form 12-Item Health Survey (SF12), Veteran's Rand 12-Item Health Survey (VR12), and Patient-Reported Outcomes Measurement Information System (PROMIS) depression scores. T-test and chi-square was performed for continuous and categorical variables. Multivariate regression controlled for baseline differences across cohorts.

Results: A total of 123 (54 female, 69 male) and 68 (34 female, 34 male) Non-MHD and MHD patients were assessed with a mean follow-up of 9.45±8.07 and 8.91±8.47 months ($p=0.67$), respectively. MHD patients had a higher prevalence of concomitant neurological disorders (9.9% vs 22.2%, $p=0.023$) and osteoporosis (0.8% vs 6.3%, $p=0.030$). The MHD group reported significantly worse baseline PROMIS depression (48.2±9.84 vs 56.1±8.56, $p<0.001$), SF12 (50.5±10.7 vs 43.5±11.0, $p<0.001$), and VR12 (52.1±11.1 vs 45.9±10.8, $p<0.001$) mental health components compared to Non-MHD patients, in addition to worse NDI (36.0±20.0 vs 54.3±20.0, $p=0.002$) and VAS Neck (5.14±3.19 vs 6.49±3.22, $p=0.044$) (Table 1). Postoperative evaluation demonstrated worse mental health status outcomes among MHD patients on PROMIS depression (47.0±10.0 vs 52.5±11.3, $p=0.019$), worse swallow function on SWAL-QOL (86.0±12.1 vs 80.1±12.2, $p<0.001$), and worse arm pain on VAS Arm (2.40±2.68 vs 3.18±3.03, $p=0.010$).

Conclusion: ACSS is associated with significantly higher postoperative dysphagia in patients diagnosed with an MHD when compared to patients without an established diagnosis, although the absolute difference was small. Furthermore, MHD patients were more likely to

PRESENTATION #5 continued

continue to experience worse mental health status and greater postoperative arm pain than their counterparts without a mental health diagnosis. Given the high prevalence of MHDs in patients with spinal pathology, it is important for spine surgeons to take note of the increased incidence of dysphagia faced by this patient population.

Table 1. Patient reported outcomes.

	Non-MHD	MHD	*Univariate*	*Multivariate*	
	n=124	n=68	p-value	β	p-value
Preoperative					
PROMIS Depression	48.2±9.84	56.1±8.56	**< 0.001**	**8.90**	**< 0.001**
SF12 Mental Health	50.5±10.7	43.5±11.0	**< 0.001**	**-7.94**	**< 0.001**
VR12 Mental Health	52.1±11.1	45.9±10.8	**0.001**	**-7.40**	**< 0.001**
NDI	36.0±20.0	54.3±20.0	**< 0.001**	**16.9**	**0.002**
VAS Arm	5.08±2.94	5.55±3.41	0.493	0.42	0.634
VAS Neck	5.14±3.19	6.49±3.22	**0.050**	**1.85**	**0.044**
SWAL-QOL	92.6±5.89	92.3±4.53	0.928	-4.41	0.180
SF12 Physical Health	33.1±10.1	30.7±7.71	0.106	-2.32	0.214
VR12 Physical Health	34.8±10.8	31.3±9.06	**0.039**	-3.51	0.086
Postoperative					
PROMIS Depression	47.0±10.0	52.4±11.3	**0.024**	**6.53**	**0.019**
SF12 Mental Health	49.1±10.3	47.3±10.7	**0.019**	-3.89	0.152
VR12 Mental Health	51.7±10.8	49.9±10.6	**0.027**	-4.88	0.071
NDI	24.3±17.6	27.6±17.8	0.437	6.36	0.280
VAS Arm	2.40±2.68	3.18±3.03	0.242	**2.04**	**0.010**
VAS Neck	3.01±3.15	3.63±3.07	0.403	1.45	0.070
SWAL-QOL	86.0±12.1	80.1±12.2	**0.001**	**-11.1**	**0.033**
SF12 Physical Health	33.8±9.83	35.0±11.9	0.565	-1.46	0.580
VR12 Physical Health	35.4±10.7	36.2±12.1	0.718	-2.94	0.280

PROMIS = Patient-Reported Outcomes Measurement Information System; NDI = Neck Disability Index; VAS = Visual Analog Scale; SWAL-QOL = Swallowing Quality of Life; SF12 = 12-Item Short Form Survey; VR12 = Veterans Rand 12-Item Health Survey; Bolding indicates statistical significance ($p < 0.05$)

PRESENTATION #6

Which traditional functional outcome measures and their specific components are most affected by proper re-alignment and clinical improvement in Adult Cervical Deformity Surgery?

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Introduction: With patient reported outcomes measures becoming more prevalent as a tool to assess improvement after corrective ACD surgery there remains limited data if a correlation exists with radiographic improvement. This retrospective cohort study of a prospective adult cervical deformity database aimed to identify the quality of life metrics most impacted by postoperative radiographic alignment.

Materials and Methods: Operative CD patients (cervical kyphosis >10°, coronal scoliosis >10°, cSVA >4cm, TS-CL >10°, or CBVA >25°) ≥18 years old with complete baseline (BL), 2Y HRQoL and radiographic data were included. Descriptive analysis identified cohort demographics, radiographic parameters, and surgical details. Bivariate analysis and multivariate analysis determined which components of the Ames cervical deformity criteria most affected HRQL component scores. Conditional inference tree (CIT) random forest modeling was used to rank which HRQL components were most impacted by radiographic alignment.

Results: 106 cervical deformity patients met inclusion criteria(61.6yrs, 67%F, BMI: 28.4kg/m2, CCI: 0.96±1.3). Surgical details: 7.6± 3.8 levels fused; mean EBL of 808mL, operative time of 391±230.8 min. By surgical approach, 46.61% had a posterior approach, 34.75% combined approach, and 18.64% anterior approach. Radiographically at baseline, patients presented with: PT: 18.8± 11.3; PI: 53.0±11.1; PI-LL: -.45±17.7; SVA:-4.34±66.8, TS-CL: 38.1 ±21.4; cSVA: 45.2±25.6, T1S: 38.4. TSCL was positively correlated with NDI (r=.28), and negatively correlated with EQ5D (r=-.247). SVA was negatively correlated with mJOA (r=-.36), and EQ5D (r=-.238). T1S was positively correlated with EQ5D VAS (r=.31), all $p<0.05$). cSVA showed no correlation with overall scores. In a component analysis, CIT determined the HRQL outcomes that were most impacted by radiographic alignment where a significant relationship exists as follows. For TSCL: EQ5D-Pain, NDI-Work, SWAL-Communication, cSVA: NDI-Work, SWAL-Communication, and EQ5D-Pain, SVA: EQ5D- Mobility, EQ5D-Activity and SWAL-Communication, T1S: EQ5D-Activity, NDI-Recreation and EQ5D-Pain.

Conclusion: TSCL, SVA, and T1S all show significant relationships with overall clinical outcomes by two-years. When looking at individual component scores, pain, return to work, and communication were the most impacted when looking across all four parameters corrected.

PRESENTATION #7

Long Term Associations Between Current Smoking Status and Outcome After Elective Cervical Spine Surgery

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Introduction: Smoking is one of the most influential modifiable risk factors negatively impacting both pathogenesis of degenerative spine disease as well as postoperative outcomes following elective spine surgery. While the relationship between smoking and pseudoarthrosis has been well established, there are limited studies assessing its influence on overall clinical outcome.

Materials and Methods: Patients who had elective cervical spine surgery from January 2017 to March 2021 in the Michigan Spine Surgery Improvement Collaborative (MSSIC) were included in this study. Primary outcomes included: patient satisfaction; 0-10 pain scale for arm and neck pain; PROMIS Physical Function (PROMIS PF); EQ-5D and return to work. Improvements in PROs were measured using the minimally clinical important difference for each instrument. Follow-up was up to 2-years after surgery. Generalized estimating equations were used for multivariate analysis to adjust for covariates.

Results: A total of 7,936 patients were included in the analysis. 1,732 patients (21.8%) were included in the smoking cohort. Compared to baseline, patients in the smoking cohort were less likely to be satisfied with surgery at 1-year (aOR 0.90; p=0.006). They were also less likely to achieve MCID at 90-days (aOR 0.92, p=0.039), 1-year (aOR 0.86; p=0.004), and 2-years (aO 0.68; p=0.012) using PROMIS. In addition, smokers were less likely to achieve MCID at 1-year (aOR 0.87; p=0.009) with neck pain scale. Smokers were also less likely to achieve MCID at 90-days (aOR 0.91; p=0.009) with arm pain scale. Lastly, smoking patients were less likely to achieve MCID with EQ-5D at 90-days (aOR 0.84; p=0.002), and at 1-year (aOR 0.80; p=0.001).

Conclusion: Smoking is associated with poor postoperative patient reported outcomes after elective cervical spine surgery. In addition to medical and surgical complications of surgery, this result can be used to provide evidence-based smoking cessation counseling prior to surgery.

PRESENTATION #8

Prediction of complications after anterior cervical spinal fusion: a machine learning-driven approach

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Introduction: Anterior cervical fusion procedures have grown in prevalence due to excellent outcomes and low complication risk, and reduced hospitalization length. The average age and comorbidity burden of patients undergoing anterior cervical fusion have increased. These patients are at elevated risk of suffering complications with significant associated cost and morbidity.[1–3] Accurate risk stratification of patients undergoing this procedure is of great utility. Advanced machine learning (ML) methods have become increasingly employed due to their ability to recognize complex non-linear relationships between variables. ML models for pre-operative risk stratification of patients undergoing anterior cervical fusion remain limited. We aim to develop a ML algorithm for prediction of major complications after anterior cervical fusion and identify characteristics important to model performance.

Materials and Methods: Consecutive adult patients who underwent anterior cervical fusion at our institution between 2013-2020 were included. The primary outcome was major perioperative complication within the index admission (e.g. pneumonia, respiratory failure, renal failure, venous thromboembolism, wound complications, neurologic complications) (Table 1). Number of fused levels, surgical approach and indication, pre-operative symptoms, and medical/psychiatric comorbidities were included as explanatory features. We build an LR model and four ML benchmark models that represent different classes of modeling approaches: AdaBoost, gradient boosting, XGBoost, random forest. Five-fold stratified cross-validation was used to avoid model overfitting. Discrimination and calibration were assessed using area under the receiver operating characteristic curve (AUROC) and Brier score, respectively. We also report area under the precision-recall curve (AUPRC). We rank the contribution of the included variables to model performance.

Results: A total of 524 patients were included in this study. There were 48 cases of major complication (9.2%). The random forest model demonstrated the highest discrimination (AUROC: 0.777 + 0.06) compared to LR (0.741 + 0.06), outperforming the three other ML models (Table 1). This model was the best-calibrated with a Brier score of 0.072 + 0.006. the random forest model also had the highest AUPRC of 0.417 + 0.115. Combined anterior-posterior approach, corpectomy, and posterior instrumentation are important to both the random forest and LR models. Seven of the ten most important features to ML model performance are much less important for LR: pre-operative bowel dysfunction, pre-operative bladder dysfunction, HIV infection, spinal fracture, staged approach, malignancy, infection (Table 2).

Conclusion: Most risk prediction tools for complications after anterior cervical fusion have historically been developed with LR. We report an ML algorithm for prediction of major complications after anterior cervical fusion. This algorithm is well-calibrated and demonstrates excellent risk prediction, superior to LR. Furthermore, this ML model built from our institutional cohort is more accurate than models built with administrative databases for adverse outcomes after anterior cervical fusion. Notably, the predictors most important for the ML model are

PRESENTATION #8 continued

different from those for LR. This suggests that the superior discriminative capability of ML methods stems from their ability to capture complex factor-factor interactions that LR is unable to detect. By providing accurate prognostic information, this algorithm may improve understanding of surgical risks and benefits, facilitating the pre-operative shared decision-making process and aiding with patient selection.

Table 1. Model performance for logistic regression and advanced ML models

Model	AUROC	Brier score	AUPRC
Random Forest	**0.777 ± 0.063**	**0.072 ± 0.006**	**0.417 ± 0.115**
Logistic Regression	0.741 ± 0.058	0.082 ± 0.01	0.331 ± 0.093
Gradient Boosting	0.740 ± 0.061	0.082 ± 0.009	0.326 ± 0.058
AdaBoost	0.754 ± 0.070	0.078 ± 0.005	0.359 ± 0.064
XGBoost	0.731 ± 0.054	0.079 ± 0.007	0.346 ± 0.040

PRESENTATION #8 continued

Table 2. Relative feature importance for complications after anterior cervical fusion

Feature	Rank in random forest (Rank in logistic regression)
Binary features	
Pre-operative bowel dysfunction	1 (12)
HIV positive	2 (33)
Spinal fracture	3 (24)
Malignancy	4 (41)
Spinal infection	5 (20)
Combined approach	6 (4)
Pre-operative bladder dysfunction	7 (22)
Corpectomy	8 (1)
Staged approach	9 (26)
Posterior instrumentation	10 (5)
Continuous features	
Pre-operative white blood cell count	1 (6)
Number of fused levels	2 (3)
Charlson comorbidity index	3 (2)
Pre-operative hemoglobin	4 (1)
Age	5 (5)
Body mass index	6 (4)

PRESENTATION #9

Social Media Posts pertaining to Anterior Cervical Discectomy and Fusion (ACDF) Surgery: A Cross-Sectional Analysis of Patient and Surgeon Perceptions

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Introduction: Social media offers a powerful and expanding platform for sharing the patient experience with a large audience through an unsolicited and unfiltered perspective. The source and content of social media postings around anterior cervical discectomy and fusion (ACDF) has not been previously reported. The purpose of this study was to analyze publicly available content on a major social media outlet related to ACDF surgery based on perspective, location, timing, content, tone, and patient satisfaction.

Materials and Methods: A query of content from a major social media outlet, Instagram, was performed for the study period January 1, 2018 to January 1, 2020. Content was identified by the hashtags "#acdf" or "#acdfsurgery." The most popular content was ranked by number of "likes" and the 1,500 most popular posts were included. Content was characterized and classified.

Results: An initial search revealed 6,500 publicly available posts tagged with "#acdf" or "#acdfsurgery." Of the 1,500 most "liked" posts, 1,136 posts related specifically to ACDF surgery. Overall, patients (85.0%) and surgeons (11.8%) shared the greatest number of posts (Table 1). Most posts originated from the Unite States (77%). Regarding timing and content, 70.5% of posts were postoperative. Most posts depicted patients performing daily activities, participating in sports, and completing daily work activities (54.4%) or displayed images related to surgical site, including pictures of the incision, dressing, or cervical collar (18.6%). The overall tone was positive in 79.2% of posts.

Regarding satisfaction rates, 59.8% of patient posts expressed satisfaction with their ACDF clinical course while patients expressed dissatisfaction in 14.1% of posts. (Fig 1). With regard to type of content posted stratified by user, patients were primarily referencing return to sport, work, or daily activity (61.2%) or the surgical site, including images of the incision, dressing or cervical collar (20.9%) (Table 2). Medical professionals, on the other hand, shared medical imaging in their posts (31.9%) and depictions of the operating room (21.5%). Univariate and multivariate subgroup analyses were conducted to assess the determinants of patients expressing dissatisfaction in their posts. After controlling for confounders, posts by female patients were more than four times as likely to express dissatisfaction (OR=4.16, CI=2.5 to 6.92, p=<0.0001).

Conclusion: This study identified three key trends in social media and ACDF surgery. First, patients and non-medical professionals posting about ACDF on a major social media outlet outnumber spine surgeons and medical professionals nearly nine to one. Second, patients focused heavily on return to work, play, and activities of daily living followed by the appearance of the surgical site whereas spine surgeons focused on medical imaging. Third, ACDF patients are generally positive about their surgical care. However, more than 1 in 10 patients expressed some degree of dissatisfaction with their overall surgical experience. Overall, social media offers a unique window into our understanding of patients undergoing ACDF and the key aspects of

PRESENTATION #9 continued

their care that matter most to them. Analysis of social media outlets offers surgeons and health care professionals a distinctive opportunity to address patient concerns, manage expectations, and generally enhance health care delivery.

PRESENTATION #9 continued

Table 1: Summary of ACDF Social Media Content

Shared Content Characteristics	All Posts N= 1,136 n (%)
Type of Media	
Text	9 (0.8)
Video + Photo + Text	21 (1.9)
Video + Text	157 (13.8)
Photo + Text	949 (83.5)
Hashtag	
#acdf	633 (55.7)
#acdfsurgery	335 (29.5)
Both #acdf and #acdfsurgery	168 (14.8)
Original Poster	
Patient	965 (85.0)
Friend/Family of Patient	16 (1.4)
Spine Surgeon or Group	134 (11.8)
Non-Spine Surgeon Physician	3 (0.3)
Therapist	6 (0.5)
Nurse	1 (0.1)
Physician Assistant	1 (0.1)
Hospital	1 (0.1)
Law Group	2 (0.2)
Implant Device Manufacturer	7 (0.6)
Sex	
Male	359 (31.6)
Female	763 (67.2)
N/A	14 (1.2)
Region	
Northeast	246 (21.7)
Midwest	79 (7.0)
South	316 (27.8)
West	234 (20.6)
Non-US	261 (23.0)
Phase of Care	
Preoperative	20 (1.8)
Postoperative	801 (70.5)
Perioperative (within 1 week of OR)	223 (19.4)
Non-operative	92 (8.1)
Depiction of Post	
Article, poster, or advertisement	3 (0.3)
Clinic Scene	34 (3.0)
Imaging	118 (10.4)
Surgical site	207 (18.2)
OR scene	32 (2.8)
Other	86 (7.6)
Daily activity, sport, or work	618 (54.4)
Surgical device	18 (1.6)
Surgical technique	20 (1.8)
Tone	
Positive	900 (79.2)
Negative	134 (11.8)
Neutral	102 (9.0)
Patient Satisfaction	
Expressing patient satisfaction	679 (59.8)
Expressing patient dissatisfaction	160 (14.1)
Expressing neither patient satisfaction/dissatisfaction	154 (13.6)
Unrelated to specific patient interaction	143 (12.6)

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.

PRESENTATION #9 continued

Table 2: Analysis of Post Content by User

User	Article, poster, advertisement n (%)	Clinic Scene n (%)	Imaging n (%)	Surgical site n (%)	OR Scene n (%)	Other n (%)	Daily activity, work, sport n (%)	Surgical Device n (%)	Surgical Technique n (%)	p-value
Patients	0 (0)	17 (1.7)	69 (7)	205 (20.9)	1 (0.1)	81 (8.3)	600 (61.2)	7 (0.7)	1 (0.1)	**<0.0001**
Medical Professionals	2 (1.4)	17 (11.8)	46 (31.9)	2 (1.4)	31 (21.5)	5 (3.5)	17 (11.8)	5 (3.5)	19 (13.2)	
Other	1 (10)	0 (0)	2 (20)	0 (0)	0 (0)	0 (0)	1 (10)	6 (60)	0 (0)	

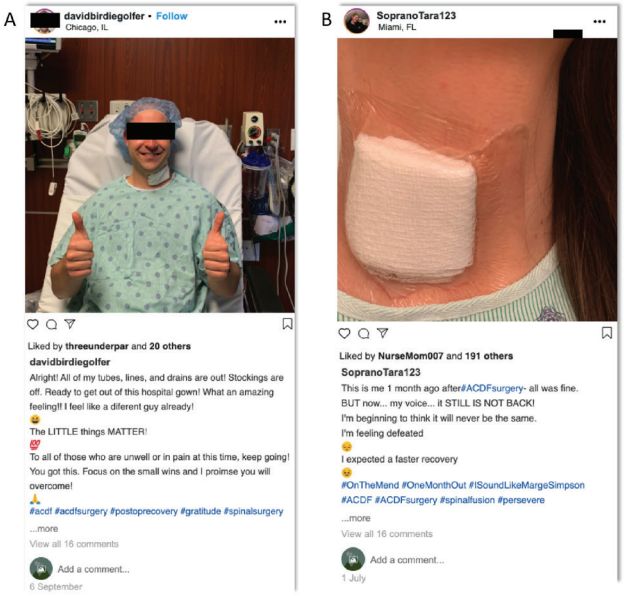

Figure 1. Example Social Media Content Posted by Patients. A. Patient expressing satisfaction with his ACDF surgery. **B.** Patient expressing dissatisfaction with her post-operative course. *Source: These are representations based on real patient social media content.*

PRESENTATION #10

Comparison of Clinical and Radiographic Outcomes After C3 Laminoplasty versus C3 Laminectomy

Joshua Rivera, BA, Jeremy Guinn, BS, BA, Andrew Chan, MD, Alexa Semonche, MD, Xiao Tan, BA, Justin Lee,, Burooj Mahmood, BA, Alysha Jamieson, BS, Kamal Kolluri,, Parishkrita Srivastava,, Yasmine Mahmoudieh,, Rafael Guizar, BA, Jeremy Huang,, Vivian Le, MPH, Praveen Mummaneni, MD, Dean Chou, MD, Lee Tan, MD

Introduction: Several studies suggested that a C3 laminectomy rather than C3 laminoplasty reduces post-operative neck pain in patients undergoing multi-level laminoplasty. We seek to determine the if this hypothesis holds true in at a high-volume academic spine center.

Materials and Methods: Patients undergoing multi-level laminoplasty with either C3 laminectomy or C3 laminoplasty by three surgeons from 2009-2020 were retrospectively studied. All patients had 36" films. Demographic variables, surgical factors, radiographic measurements, and clinical outcomes were collected. Univariate analysis was used to determine baseline different. Multivariate regression was performed to correct for confounding variables.

Results: There were 310 patients (214 male) identified for the study, with 120 patients in the C3 laminectomy group and 190 patients in the laminoplasty group. The mean age was 63.6 years, and mean follow-up was 1.61 ± 1.70 years. There was no statistically significant difference in baseline patient characteristics.

Multivariate regression showed no differences between two groups in post-operative neck pain (p=0.91), post-operative arm pain (p=0.86), post-operative mJOA (p=0.20), post-operative neck disability index (NDI) (p=0.53), post-operative sagittal vertical axis (SVA) (p=0.17), post-operative thoracic kyphosis (TK) (p=0.96), post-operative cervical lordosis (CL) (p=0.37), post-operative T1 slope (p=0.43), post-operative cervical sagittal vertical axis (cSVA) (p=0.51), and post-operative k-line tilt (p=0.60).

However, patients undergoing C3 laminectomy had increased EQ-5D (p=0.04, ß=0.15) and larger range of motion when measured from the superior endplate of C2 to the inferior endplate of C4 (p=0.02, ß=3.84) and from the superior endplate of C2 to the lowest instrumented vertebrae (LIV) (p=0.02, ß=3.79).

Conclusion: As with previously reported advantages of performing a C3 laminectomy over a C3 laminoplasty, we observed better clinical outcomes and increased cervical range of motion. Further prospective studies with larger sample size are warranted.

PRESENTATION #10 continued

Table 1. Summary of demographic and preoperative radiographic variables using univariate analysis

	Overall	C3 Laminoplasty	C3 Laminectomy	P-value	Coefficient
All patients	N = 310	N = 190	N = 120		
Age (years)	63.6 ± 12.6	64.8 ± 11.5	61.6 ± 14.0	0.36	2.11
Male Sex	214	131	83		
Female Sex	96	59	37	0.97	
BMI	28.5 ± 8.3	28.7 ± 9.8	28.2 ± 5.2	0.53	0.63
SVA (mm)	42.4 ± 43.5	35.8 ± 41.8	49.2 ± 44.5	0.09	-1.67
TK (°)	32.2 ± 13.8	32.8 ± 13.2	31.7 ± 14.4	0.67	0.43
CL (°)	11.5 ± 8.4	11.8 ± 8.6	11.1 ± 8.1	0.54	0.60
T1 (°)	31.3 ± 10.3	31.6 ± 10.1	31.0 ± 10.5	0.63	0.49
CSVA (°)	32.5 ± 15.9	32.9 ± 17.1	31.9 ± 14.3	0.64	0.47
K-line Tilt (°)	16.9 ± 9.6	17.0 ± 9.9	16.7 ± 9.2	0.86	0.17
C2-C4 Range of Motion (°)	14.7 ± 8.6	15.7 ± 7.7	13.0 ± 9.6	0.41	-1.67
C2-LIV Range of Motion (°)	23.6 ± 11.7	24.5 ± 11.6	22.1 ± 11.8	0.16	2.07

PRESENTATION #10 continued

Table 2. Summary of postoperative outcomes and radiographic variables using multivariate analysis

	Beta coefficient (95% CI)	P-value
Neck Pain	-0.07 (-1.31, 1.17)	0.91
Arm Pain	-0.03 (-1.04, 1.04)	0.86
mJOA	2.01 (-1.11, 5.12)	0.20
NDI	2.84 (-4.12, 7.31)	0.53
EQ-5D	0.15 (-0.002, 0.30)	0.04
SVA (mm)	-11.81 (-28.6, 4.94)	0.17
TK (°)	-0.14 (-5.57, 5.30)	0.96
CL (°)	1.03 (-1.23, 3.28)	0.37
T1 (°)	-1.05 (-3.64, 1.55)	0.43
CSVA (°)	1.33 (-2.61, 5.28)	0.51
K-line Tilt (°)	0.73 (-2.00, 3.46)	0.60
C2-C4 Range of Motion (°)	3.84 (0.51, 5.18)	0.02
C2-LIV Range of Motion (°)	3.79 (0.57, 7.00)	0.02

PRESENTATION #11

Cervical Disc Replacement for Radiculopathy versus Myeloradiculopathy. An MCID Analysis.

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Hospital for Special Surgery[1] Hospital flr Special Surgery[2]

Introduction: Several previous randomized controlled trials have documented the success of cervical disc replacement (CDR) in treating radiculopathy and/or myelopathy, but many did not systematically compare outcomes of patients with radiculopathy versus those with myelopathy. Currently, there is still controversy about whether CDR utilization in patients with components of myelopathy can result in equivalent outcomes when compared to its use in patients with only radiculopathy. The purpose of the present study was to compare the minimally clinically important difference (MCID) across multiple patient reported outcomes (PROs) in patients undergoing CDR for cervical spondylotic radiculopathy versus myeloradiculopathy.

Materials and Methods: Patients who underwent one or two-level CDR with radiculopathy versus myeloradiculopathy were identified, and prospectively collected data was retrospectively reviewed. Demographic variables, preoperative diagnosis, and operative variables were collected for each patient. The following preoperative and postoperative PROs were prospectively collected: Neck Disability Index (NDI), VAS-Neck, VAS-Arm, Short Form-12 Health Survey (SF-12) Physical Component Score (PCS), SF-12 Mental Component Score (MCS), PROMIS Physical Function (PF). Postoperatively, PROs were collected at 6 weeks, 12 weeks, and final follow-up (minimum 6 months). Demographic variables and operative characteristics were analyzed for differences between patients with radiculopathy versus myeloradiculopathy. PROs were assessed for differences between the two diagnosis groups as well as improvements within each group following surgery. An MCID analysis of PROs for each diagnosis group was performed and the percentage of patients achieving the MCID was compared between the two diagnosis groups.

Results: A total of 85 patients were included, of which 48 (56%) had radiculopathy and 37 (44%) had myeloradiculopathy. Average follow-up was 13.4 months. There were no significant differences in preoperative demographic variables, or the number and distribution of cervical levels treated between the two diagnosis groups. There were no significant differences in preoperative NDI, Neck-VAS, Arm-VAS, SF-12 PCS, SF-12 MCS, and PROMIS PF scores between the two groups.

At the final postoperative visit, there was no significant difference in each PRO assessed between the radiculopathy and myeloradiculopathy groups and both groups demonstrated statistically significant improvement in each PRO compared to preoperative values ($P<0.02$).

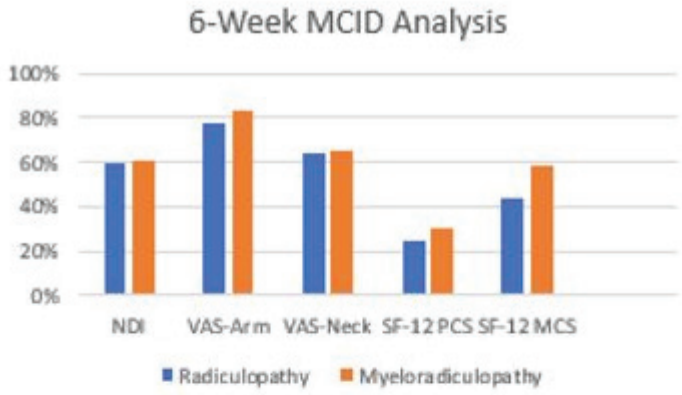
MCID analysis demonstrated that at 6-week, 12-week, and final postoperative follow-up there was no significant difference in the percentage of patients with radiculopathy or myeloradiculopathy achieving the MCID for each PRO assessed (Figure 1). In both diagnosis groups the percentage of patients achieving the MCID for each PRO continued to increase from the 6-week to final postoperative follow-up except for the SF-12 MCS in patients with

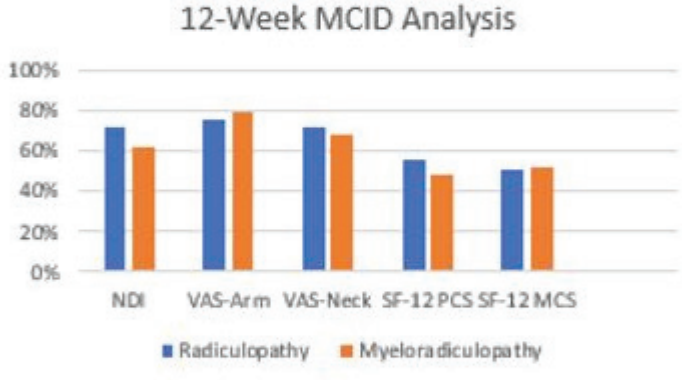
PRESENTATION #11 continued

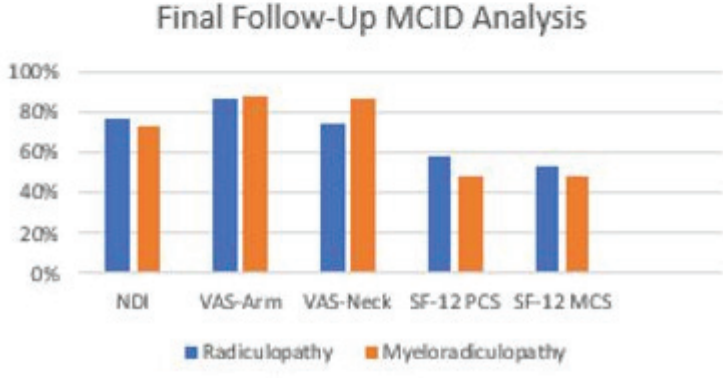
myeloradiculopathy (Figure 2).

Conclusion: This is the first study to compare the MCID across various PROs in patients with radiculopathy versus myelopathy undergoing CDR. The percentage of patients achieving the MCID was not significantly different at each postoperative period assessed in the radiculopathy and myeloradiculopathy groups. In addition, the percentage of patients achieving the MCID continued to increase from 6-weeks to final follow-up in both groups for almost all PROs assessed.

PRESENTATION #11 continued







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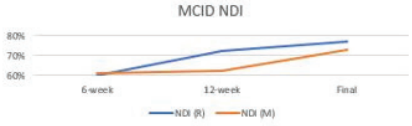

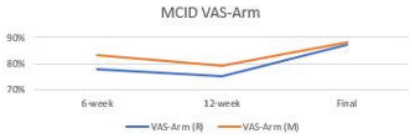

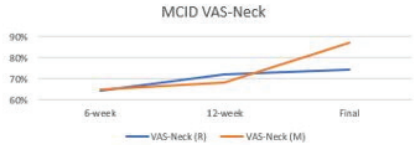

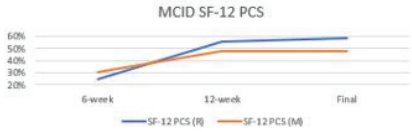

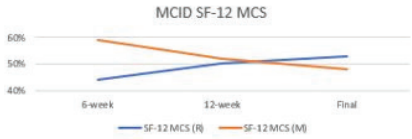

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

PRESENTATION #12

The influence of timing of surgical decompression for acute spinal cord injury: a pooled analysis of individual patient data in 1,548 cases

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University of Toronto[1]

Introduction: While there is a strong biological rationale for early decompression of the injured spinal cord, the influence of the timing of surgical decompression for acute spinal cord injury (SCI) remains debated with substantial variability in clinical practice. This study sought to objectively evaluate the effect of timing of decompressive surgery for acute SCI on long-term neurological outcomes.

Materials and Methods: This was a pooled analysis of individual patient data (IPD) derived from four independent prospective, multi-center data sources, which cumulatively spanned from December 1991 to March 2017. Three of these studies have been published; of these, only one specifically analyzed the effect of the timing of surgical decompression previously. IPD was obtained by request from study authors. All patients who underwent decompressive surgery for acute SCI within these datasets were identified. Patients were stratified into early (< 24 hrs) and late (= 24 hrs) decompression groups. Neurological outcomes were assessed by American Spinal Injury Association (ASIA) examination. The primary endpoint was change in total motor score at 1 year. Secondary endpoints included ASIA Impairment Scale (AIS) grade and change in upper extremity motor, lower extremity motor, light touch, and pin prick scores at 1 year. One-stage meta-analyses were performed by hierarchical mixed-effects regression adjusting for baseline score, age, injury mechanism, AIS grade, level of injury, and steroids. Effect sizes were summarized by mean difference (MD) for sensorimotor scores and common odds ratio (cOR) for AIS grade, along with corresponding 95% confidence intervals (CIs). As a secondary analysis, ?total motor score was regressed against time to surgical decompression (hours) as a continuous variable using a restricted cubic spline with adjustment for the same covariates.

Results: The study cohort consisted of 1,548 patients. Patients who underwent early surgical decompression (N=528) experienced greater recovery than the late surgery group (N=1,020) at 1 year for total motor score (MD 4.0, 95% CI 1.7-6.3, P=0.001), light touch score (MD 4.3, 95% CI 1.6-7.0, P=0.002), and pin prick score (MD 4.0, 95% CI 1.5-6.6, P=0.002) (Table A). There was a shift toward better AIS grades, indicating less severe impairment, at 1 year in favor of early decompression (cOR 1.48, 95% CI 1.16-1.89, P=0.002) (Fig 1). In patients with cervical SCI, early decompressive surgery resulted in disproportionate motor score improvement in the upper (MD 2.2, 95% CI 1.0-3.3, P<0.001) over lower limbs (MD 1.3, 95% CI -0.3-3.0, P=0.115). In patients with thoracic SCI, early surgery yielded superior motor score improvement in the lower limbs (MD 4.4, P=0.034). When time to surgical decompression was modeled as a continuous variable, there was a steep decline in ?total motor score with increasing time over the first 24 to 36 hours after injury (P<0.001); thereafter, recovery plateaued (Fig 2).

Conclusion: Surgical decompression within 24 hours of acute SCI improves sensorimotor recovery. The first 24 to 36 hours after injury appears to represent a critical window to achieve optimal neurological recovery with surgery following acute SCI.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #12 continued

Table A. Outcomes at 1 year by time to surgical decompression (one-stage meta-analyses)*

Outcome	Late Surgery, *N* = 1,020	Early Surgery, *N* = 528	Effect Size† (MD or cOR)	P Value
ΔTotal motor score	19.7 (15.3, 24.0)	23.7 (19.2, 28.2)	4.0 (1.7, 6.3)	0.001
ΔLight touch score	14.8 (11.2, 18.4)	19.0 (15.1, 23.0)	4.3 (1.6, 7.0)	0.002
ΔPin prick score	14.2 (9.8, 18.6)	18.3 (13.7, 22.9)	4.0 (1.5, 6.6)	0.002
AIS grade			1.48 (1.16, 1.89)	0.002
A	37.9 (34.3, 41.5)	32.4 (28.3, 36.4)		
B	11.4 (9.7, 13.0)	12.1 (10.3, 13.8)		
C	9.7 (8.0, 11.3)	10.4 (8.6, 12.1)		
D	33.2 (30.9, 35.6)	35.0 (32.4, 37.5)		
E	7.8 (6.2, 9.5)	10.2 (8.1, 12.3)		

*Adjusted for baseline score, age, mechanism of injury, AIS grade, level of injury, and administration of steroids

†MD for Δtotal motor score, Δlight touch score, and Δpin prick score; cOR for AIS grade

Values in parentheses are 95% CIs

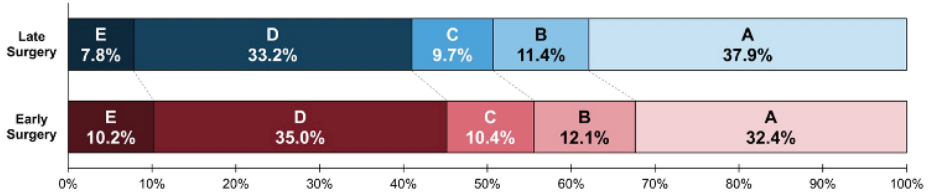

Fig 1. Distribution of AIS grades at 1 year among patients who underwent early (< 24 hrs; *N* = 528; bottom panel) versus late (≥ 24 hrs; *N* = 1,020; top panel) decompressive surgery for acute spinal cord injury. Early surgical decompression was associated with a shift toward more favorable AIS grades at 1 year, indicating less severe neurological impairment, compared to late surgery (cOR 1.48, 95% CI 1.16-1.89, P=0.002).

Abbreviations. AIS, American Spinal Injury Association (ASIA) Impairment Scale; CI, confidence interval; cOR, common odds ratio

PRESENTATION #12 continued

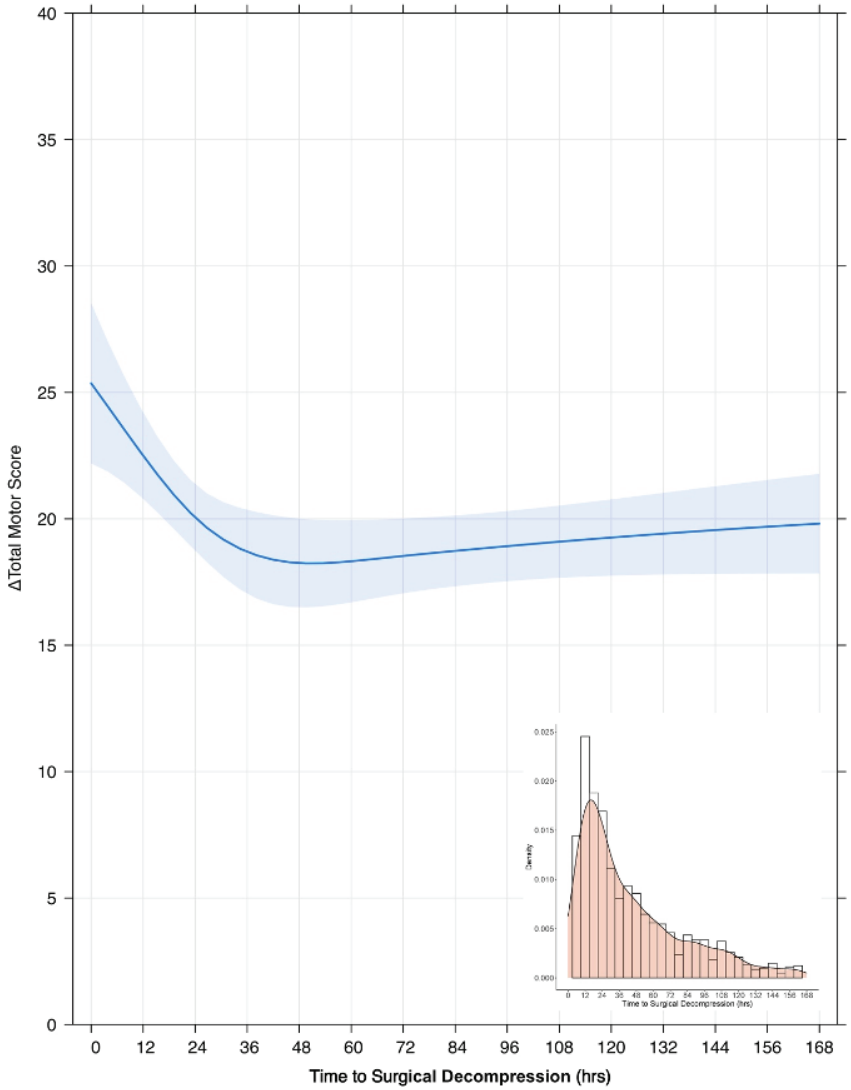

Fig 2. Risk-adjusted* relationship of time to surgical decompression in hours (X-axis) with change in total motor score from baseline to 1 year (Y-axis) in patients with acute spinal cord injury (*N* = 1,548). Shaded area indicates 95% confidence interval. Inset (bottom right) is a density plot of the frequency distribution of time to surgical decompression within the study cohort.
*Adjusted for baseline total motor score, age, mechanism of injury, AIS grade, level of injury, and administration of steroids.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #13

Comparison of Clinical Guidelines for Reimbursement for Intra-Operative Neuromonitoring During Spine Surgery in the United States

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Jacobi Medical Center[1]

Introduction: Intraoperative neuromonitoring (IOM) is a term used to describe a variety of electrodiagnostic tests used to monitor the integrity of neural pathways during surgical procedures involving the spine. The purpose of IOM is to reduce the risk of damage to the patient's spinal cord and nerve roots by providing real time information to the surgeon and anesthesiologist. The specificity, sensitivity and accuracy of IOM has been evaluated elsewhere. Insurance providers use guidelines to determine which specific spinal procedures warrant reimbursement for IOM. The purpose of this study was to compare the guidelines of the top commercial health insurance carriers in the United states for IOM in spinal surgery.

Materials and Methods: The largest commercial health insurance carriers in the United States were selected by market share. An online search was then conducted to identify insurance carrier's published reimbursement guidelines for IOM in spine surgery. Surgeries were categorized by anatomic location and type of procedure (microdiscectomy, decompression, posterolateral fusion, interbody fusion and insertion of pedicle screws). Guidelines were evaluated for criteria used for reimbursement and evidence-based literature provided by the carrier and professional society consensus statements.

Results: Of the top twenty health insurance carriers in United States by market share, ten had guidelines for IOM reimbursement publicly available. These carriers were variable in the frequency with which they updated guidelines, spanning from 2012 to 2019. There is also a significant heterogeneity in the specificity of language used in regards to categories of procedures, with some guidelines including "lumbar procedures below L1-L2", "discectomy", and "decompression" versus others broadly providing guidelines for "spinal, intracranial, plexus, or vascular procedures". Two of the top major insurance carriers recently adopted a guideline to no longer deem IOM medically necessary for lumbar procedures below L1-L2 and have terminated their reimbursement. The remaining eight insurance carriers still give relatively wide discretion to the operating surgeon for determining what is deemed medically necessary. The majority of the evidence for either approving or denying reimbursement is based on the consensus statements by neurosurgical or neurophysiologic professional societies and a number of individual studies with Level 3 and 4 evidence. 50% of the top twenty insurance carriers do not have publicly available published guidelines regarding reimbursement for IOM.

Conclusion: This study demonstrates that United States insurance carrier guidelines for reimbursement of IOM during spinal surgery are heterogenous, non-specific, and not based on level I evidence. Most notably, there is a recent development among at least two of the largest insurers to unilaterally deny reimbursement for lumbar procedures below L1-L2. Many spine surgeons use IOM and rely on the IOM information, in part, to facilitate the identification of nerve root or spinal cord injury or irritation and make intra-operative decisions based on this information. The lack of a clear industry-wide consensus and the alarming discrepancy evidenced by two outlier insurance companies warrant further scrutiny and investigation about insurance IOM guidelines.

PRESENTATION #14

Posterior Cervical Spinal Fusion Assemblies Intended to Cross the Cervicothoracic Junction: A Mechanical Analysis

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University of Arkansas for Medical Scien[1]

Introduction: When posterior cervical fusions are extended into the thoracic spine, an instrumentation transition is often utilized.1-4 The cervical rod (3.5 mm) can continue using thoracic screws designed to accept the cervical rods (fig 1.A). Alternatively, traditional thoracic screws may be used to accept thoracic rods (5.5 mm). This requires the use of a 3.5-5.5 mm transition rod (fig 1.B) or a separate 5.5 mm rod and a connector to fix the 3.5 mm and 5.5 mm rod together (fig 1.C). Fusion success depends on immobilization of vertebrae, yet the mechanics provided by these different assemblies are unknown.1,2 The objective of this study is to evaluate the mechanical properties of three posterior spinal fusion assemblies commonly used to cross the cervicothoracic junction. The results will better inform surgical decision making and may improve patient outcomes.

Materials and Methods: Three titanium alloy posterior fusion assemblies intended to cross the cervicothoracic junction (described in fig 1) underwent static compressive bending, tensile bending, and torsion as described in ASTM F1717 (fig 2) to a torque of 2.5 Nm.5 Five samples of each assembly were attached to ultrahigh molecular weight polyethylene blocks via multiaxial screws for testing. The distance from the axis of rotation to the point of attachment of the rod and cervical screw was used as the lever arm to calculate the force required to create the desired torque for each test: lever arm of 37 mm, requiring 67.6 N of force to generate 2.5 Nm of torque. Force and displacement were recorded, and stiffness of each construct calculated.

Results: An ANOVA was performed and resulted in p-values all $p<0.05$, indicating the test groups were significantly different. Therefore, pairwise t-tests with Bonferroni corrections ($p<0.017$) were used to determine pairs that were significantly different. Assembly A (3.5 mm rods only) was found to be significantly less stiff than Assembly B (transition rods) and Assembly C (3.5 mm-connector- 5.5 mm rods) in each mode of bending: compression bending, tension bending, and torsion. Assembly A had a significantly larger range of motion in compression bending and torsion, but not tension bending. The only significant difference between Assembly B and Assembly C was found in the stiffness of compression bending.

Conclusion: The results of this study indicate that incorporating a 5.5 mm rod in a fusion assembly adds significant stiffness to the construct. When stability of a fusion is of heightened concern, as demonstrated by the ASTM F1717 vertebrectomy (worst case scenario) model, including 5.5 mm rods may increase fusion success rates.

PRESENTATION #14 continued

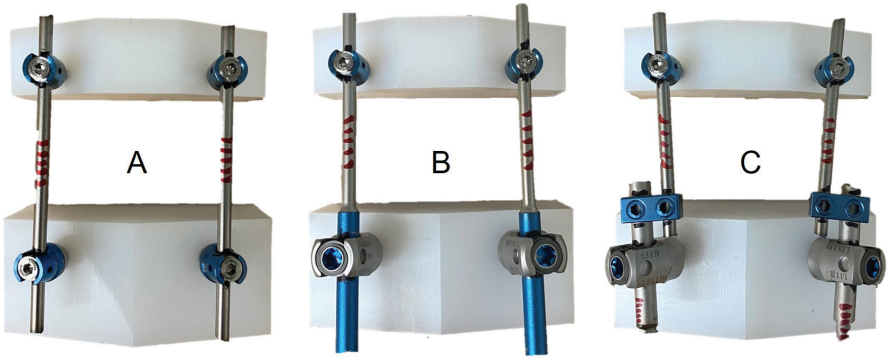

Figure 1: Posterior spinal fusion assemblies intended to cross the cervicothoracic junction. *Assembly A*: 3.5 mm cervical rods. *Assembly B*: 3.5 to 5.5 mm dilating rods. *Assembly C*: 3.5 mm-Connector-5.5 mm rods.

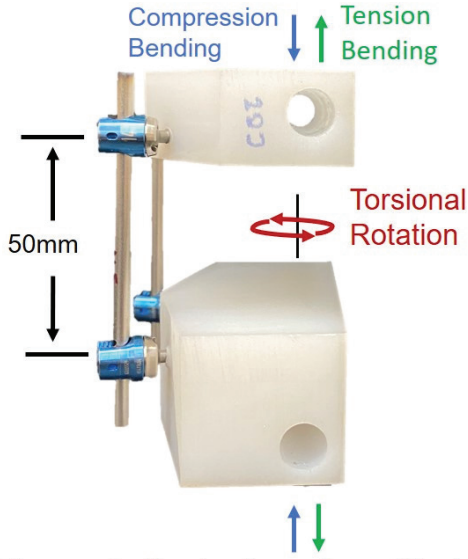

Figure 2: Illustration of modified ASTM F1717 testing setup. Screws are placed in UHMWPE blocks and fixed to fusion rods.

PRESENTATION #14 continued

Table 1: Mean ROM and stiffness values for each assembly in each test. Pairwise significant differences are indicated.

Test	Measure	Assembly A	Assembly B	Assembly C
Compression Bending	ROM (SD) (mm)	6.8 (0.6)*‡	5.2 (0.9)*	5.3 (0.5)‡
	Stiffness (SD) (N/mm)	10.1 (0.2)*‡	12.7 (0.2)*†	12.0 (0.2)†‡
Tension Bending	ROM (SD) (mm)	5.0 (0.3)	4.4 (0.7)	4.8 (0.4)
	Stiffness (SD) (N/mm)	10.6 (0.7)*‡	12.7 (0.4)*	11.9 (0.5)‡
Torsion	ROM (SD) (°)	10.4 (0.4)*‡	5.3 (0.4)*	5.4 (0.5)‡
	Stiffness (SD) (Nm/°)	0.4 (<0.1)*‡	0.9 (0.1)*	0.9 (0.1)‡

Significant Differences: * = A vs B $p<0.017$, † = B vs C $p<0.017$, ‡ = A vs C $p<0.017$

PRESENTATION #15

Comparative effectiveness of surgical approaches for cervical myelopathy: quality of life assessments from the CSM-S trial

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University of Utah[1]

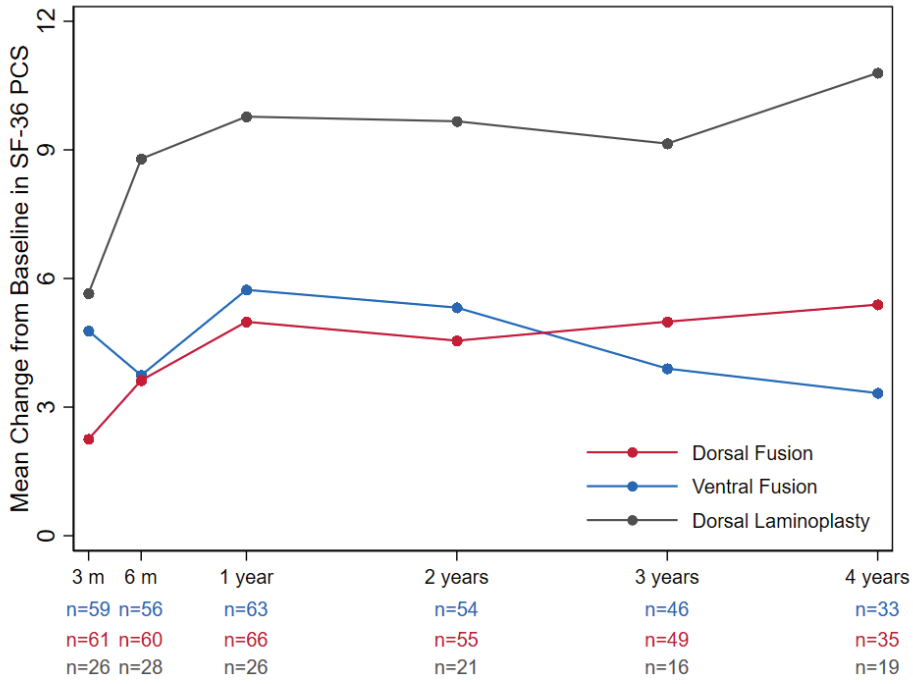
Introduction: The Cervical Spondylotic Myelopathy-Surgical study is a randomized prospective study conducted to compare the effectiveness of ventral versus dorsal (fusion or laminoplasty) surgery for patients with multi-level CSM. We have previously reported 2 year results (1). Outcomes were compared up to 4 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. 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) were obtained pre-operatively, 3 months, 6 months, and at 1, 2, 3, and 4 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 fusion, dorsal fusion, and laminoplasty groups. 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. Follow-up from patients was obtained from 80% (2 years), 68% (3 years), and 64% (4 years). Patients, regardless of strategy, demonstrated significant improvements in NDI and mJOA over a four year period post-operatively. DL was associated with the lowest complication rate 10.7% vs. 29.0% (DF) vs. 47.0% (VF) (P=0.002). As randomized, there were no significant differences in SF36-PCS at 2 years between ventral and dorsal surgery. At three years (similar to what was reported previously from 2 year data), DL has superior improvement in primary outcome SF-36 PCS (9.1) when compared with VF (3.9; P<0.001) and DF (5.0; P=0.004). Moreover at 4 years, DL had superior improvement in primary outcome SF-36 PCS (10.8) when compared with VF (3.3; P=0.001) and DF (5.4; P=0.001). At both 3 and 4 years, DL also had superior improvement in EQ-5D scores [0.21 (3 years), 0.22 (4 years)] when compared with VF [0.10; P=0.001 (3 years), 0.10; P=0.01 (4 years)] and DL had superior EQ-5D improvement compared with DF [0.12; P=0.001 (3 years), 0.12; P=0.001 (4 years)].

Conclusion: Patients undergoing surgery for CSM demonstrate improved overall quality of life. In this trial where equipoise was verified, the superior improvement observed at 1 and 2 years in health-related quality of life following dorsal laminoplasty (as selected by surgeon) for CSM was maintained over 4 years.

PRESENTATION #15 continued



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PRESENTATION #16

Cervical Total Disc Replacement: Available Implant Size Matters

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Introduction: Multiple cervical total disc replacement (TDR) studies have found this procedure to produce outcomes noninferior or superior to anterior cervical discectomy and fusion (ACDF). While restoration of disc height of a collapsed, degenerated segment is a goal of TDR surgery, there are potential problems with over-distracting the segment with an implant. Several biomechanical studies investigating the potential impact of prosthesis height, particularly with respect to implant sizes larger than the natural disc space height, found that increased implant height was associated with decreased range-of-motion and reduced facet overlap, possibly altering the loading of the adjacent facet joints. These changes have also been found to be possible contributing factors to the development of heterotopic ossification. With respect to implant height, one study found that in 36% of a study population, the height of the cervical disc space was less than the minimal height of available TDRs, which is generally 5 mm. The purposes of this study were to: 1) analyze the heights of cervical disc spaces to be replaced with a TDR; 2) measure the heights of the disc spaces adjacent to the treated level (providing insight to normal disc height), and 3) investigate the frequency of use of a smaller height TDR implant when available.

Materials and Methods: Radiographs from a Food and Drug Administration (FDA) Investigational Device Exemption (IDE) trial evaluating a TDR were measured. This produced 261 disc height measurements from C3-4 to C6-7. This provided the heights of 164 treated levels and 261 adjacent heights. To investigate the TDR implant size selected by surgeons, data from the Simplify® Cervical Artificial Disc FDA IDE trial were analyzed. The device is available in 4, 5, and 6 mm heights. The device height selected was recorded and used in the current study. Of note, the 4 mm height became available only after trial enrollment was 13% complete.

Results: Measurements made of the 261 levels adjacent to a degenerated level to be treated by TDR found that 55% of disc spaces had a height of 4 mm or less. Among the levels to be replaced with a TDR, 82% were less than 4 mm in height. In the FDA trial in which a 4 mm device was available, it was selected for use in 38% of patients, a 5 mm device was used in 53% and a 6 mm implant was used in 9% of patients.

Conclusion: This study found that many disc levels to be implanted with TDR had a height of <4mm prior to surgery. Even among the adjacent segments not being operated, 55% were of height <4 mm, suggesting that motion preserving implants of greater heights may have the potential to overdistract the disc space. In a recent FDA IDE trial, which offered a 4mm TDR implant height, this was selected by the surgeon in 39% of patients, suggesting a need for smaller disc implant heights. Further investigation is warranted to determine if the lower height implants are related to more favorable clinical and/or radiographic results.

PRESENTATION #17

Simulated Bundled Payments for Four Common Surgical Approaches to Treat Cervical Spondylotic Myelopathy: A Consideration to Break the Clinical Equipoise

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Introduction: A recently published randomized controlled trial (RCT) found that a ventral approach did not significantly improve patient-reported outcomes over dorsal approaches for cervical spondylotic myelopathy (CSM).1 While some pathologies determine suitability of one approach over another, the decision is commonly based on surgeon preference.1–4 In the era of value and bundled payments initiatives, cost profile of various approaches will form an important determinant to break this clinical equipoise. Comparison of inflation adjusted reimbursements for four of the commonest surgical treatments of CSM using a single nationally representative database is the key strength of presented analysis over existing cost studies.

Our objective was to compare retrospective 90-day and 2-year bundled payments for ≥2-level anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), posterior laminectomy and fusion (CF) and laminoplasty (LP) done for CSM.

Materials and Methods: IBM® MarketScan® Research Database (2005-2018) was used to study beneficiaries (30-75 years old) covered by Commercial payors who underwent surgery for CSM. Index admission (surgeon, hospital services, operating room/implants) and post-discharge inpatient (readmission, revision surgery, inpatient rehabilitation), outpatient (imaging, emergency department, office visits, physical therapy) and medication related payments have been described. Ninety-day and 2-year bundled payment amounts have been reported for each procedure. All payments are reported as median and interquartile range (Q1-Q3), and adjusted to 2018 US dollars.

Results: A total of 14,462 patients with median age of 53 years were included. Index hospital stay was 60.3% (surgery and implants: 43.7%) and surgeon payments were 15.9% of the average 90-day bundle. Post-discharge payments comprised 10.7% of 90-day costs. A brief summary of 90-day payments has been given in Table 1. Breakdown of payments over 2-years have been described.

Conclusion: LP for CSM had the lowest 90-day and 2-year payments, including lowest surgeon reimbursement among all procedures. LF was the most expensive and an average 90-day bundle was 62% more expensive than LP. Operating room and implant costs constitute over 40% of the 90-day bundle, with LF costs averaging $9,000-$13,000 (48-85%) more than other procedures. 90-day cost savings upwards of $18,000 (>40%) with lower risk of complications and readmission over 90-days can be achieved with LP or anterior approaches as compared to LF. For CSM pathologies where both ventral and dorsal approaches are suitable, this data can benefit surgeons in decision making. While ventral and dorsal fusion techniques are widely known among surgeons, improvement in access and training opportunities for young surgeons to learn LP techniques can improve its utilization. Additionally, our results intend to trigger discussion of revenue sharing of savings with the aim to align incentives among surgeons, hospitals and payors to maximize value of surgical management of CSM.

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PRESENTATION #17 continued

Payments, Median (Q1-Q3)	Commercial				P-value
	ACDF (n=11,217)	ACCF (n=2,342)	LF (n=352)	LP (n=551)	
Index Surgery					
Complications, n (%)	709 (6.3)	200 (8.5)	45 (12.8)	29 (5.3)	<0.01
Length of Stay, Median (Q1-Q3)	1 (1-2)	1 (1-2)	4 (3-5)	2 (2-3)	<0.01
Discharge to Nursing Care/Rehabilitation, n (%)	134 (1.1)	47 (2.0)	42 (11.9)	20 (3.6)	<0.01
Hospital	$25,997 (18,056, 38,004)	$26,684 (18,237, 40,134)	$40,522 (27,132, 60,039)	$22,643 (12,490, 36,229)	<0.01
Surgery/Operating Room	$18,949 (12,465, 28136)	$19,199 (12,881, 28.952)	$28,429 (17,495, 41.563)	$15,332 (8,047, 26.823)	<0.01
Surgeon	$6,736 (4,884, 9,222)	$8,088 (6,102, 10,927)	$7,893 (5,680, 11,000)	$4,172 (2,845, 6,808)	<0.01
Total Index Surgery	$38,325 (28,782, 53,348)	$41,106 (30,405, 59,964)	$58,858 (40,662, 86,747)	$33,393 (21,136, 53,134)	<0.01
90-day Post-discharge					
Readmission, n (%)	617 (5.5)	171 (7.3)	46 (13.1)	52 (9.4)	<0.01
Revision Surgery, n (%)	43 (0.4)	22 (0.9)	2 (0.6)	2 (0.4)	<0.01
Inpatient	$20,789 (10,284, 44,724)	$29,268 (10,482, 58,324)	$26,996 (14,397, 52,677)	$26,793 (12,550, 62,525)	0.03
Outpatient	$1,600 (497, 4,459)	$2,021 (631, 4,863)	$2,848 (1,149, 5,652)	$1,716 (503, 3,949)	<0.01
Prescription medications	$199 (0, 847)	$202 (0, 973)	$455 (53, 1,224)	$263 (23, 948)	<0.01
Post-discharge, Total	$2,483 (852, 5,706)	$3,015 (1,101, 6,344)	$4,211 (1,781, 9,253)	$2,436 (885, 6,107)	<0.01
90-day bundle	$42,731 (31,937, 59,914)	$45,931 (34,307, 68,768)	$64,542 (46,600, 100,855)	$37,867 (26,217, 59,932)	<0.01

PRESENTATION #18

Do Inflammatory Cytokines Affect Patient Outcomes after ACDF?

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Introduction: In spinal spondylotic disease, inflammatory cells and degenerating intervertebral discs release TNFα, IL-1, IL-6, IL-8, and IL-17 at elevated levels promoting cellular changes and matrix degradation resulting in disc space collapse, herniation, nerve/cord compression, pain generation, and ultimately functional disability. For reasons not understood, certain patients experience worse symptomatic and functional improvement after anterior cervical discectomy and fusion (ACDF). Given the role of the inflammatory cascade in spinal degenerative disease, it has been hypothesized that inflammatory markers may serve as a predictor of patient outcomes after surgery. The purpose of this study is to determine if a relationship exists between known mediators of inflammation (IL-6, IL-8, TNF-alpha, HMGB1, and WBCs), preoperative cervical spine disease severity, and clinical outcomes after ACDF.

Materials and Methods: All patients over age 18 who underwent ACDF for cervical spondylosis with associated radiculopathy and/or myelopathy between 2015-2017 from a single institution were prospectively recruited. Patients were excluded if their surgery was performed for traumatic injury, malignancy, or infection, or if they were diagnosed with systemic inflammatory or autoimmune diseases. Peripheral blood samples were collected preoperatively at the time of intravenous line placement. Serum cytokine concentrations, IL-6, IL-8, and TNF-α, were measured using V-PLEX Human Proinflammatory Panel II (4-Plex) (meso scale discovery, Rockville, MS, USA) and concentrations of HMGB1 were measured with a commercially available enzyme-linked immunosorbent assay (ELISA). Patient demographics (age, sex, race, smoking status), surgical characteristics (preoperative diagnosis, number of fusion levels), duration of symptoms, previous opioid use, and preoperative and one-year postoperative patient reported outcomes measures (PROMs) including the Neck Disability Index (NDI), VAS Neck pain, VAS Arm pain, and Short Form-12 (SF-12: with MCS and PCS components) were collected. Preoperative and postoperative PROMs were compared with a paired t-test. Correlation between preoperative cytokines and both demographic parameters and PROMs was assessed with spearman's rho coefficient.

Results: A total of 77 patients were enrolled. Patient demographic and surgical characteristics are summarized in Table 1. Follow-up PROMs were available from 62% (n=48) of patients at a minimum of one-year after ACDF. The overall the preoperative cytokine levels were: IL-6—0.72pg/ml, IL-8—11.4pg/ml, TNF-α— 2.68, HMGB1—1.37pg/ml, WBC—6.91/ high powered field (HPF). Preoperative symptoms lasting less than one year were weakly correlated with elevations in HMGB1 (ρ=0.328) and WBC (ρ=0.302) (Table 2). Statistically significant preoperative to postoperative improvement was demonstrated for NDI (p= 0.002), VAS Arm (p <0.001), VAS Neck (p <0.001), and PCS (p <0.001). Lower preoperative PCS was weakly correlated with elevated HMGB1 (ρ= 0.303). Likewise, decreased MCS was weakly correlated with elevated WBCs (ρ= 0.337) (Table 2). Delta MCS (ρ= 0.306) and MCS RR (ρ= 0.321) exhibited a weakly positive correlation with IL-6 (Table 3).

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PRESENTATION #18 continued

Conclusion: Preoperative cytokine levels demonstrated minimal correlation with preoperative symptoms or clinical improvement after ACDF for cervical spondylotic disease, suggesting that profiling of patient cytokines has limited utility in predicting the effects of surgical intervention or guiding management in patients with cervical spondylotic disease.

Table 1: Full Cohort Patient Demographic and Surgical Factors

Patient Parameter	N=77
Age	52.7
Sex:	
Female	59.7%
Male	40.3%
Race Code:	
Caucasian	90.9%
African American	5.19%
Hispanic	2.60%
Asian	1.30%
Diagnosis:	
Radiculopathy	53.2%
Myelopathy	16.9%
Myeloradiculopathy	29.9%
Smoker Status:	
Never	48.1%
Former	35.1%
Current	16.9%
Levels Fused:	
Single- level	33.8%
Multi- level	66.2%
Duration of Preop Symptoms	
< 1 Year	52.5%
≥ 1 Year	47.5%
Preop Opioid Use	
Yes	23.7%
No	76.3%

PRESENTATION #18 continued

Table 2: Correlation Between Patient Cytokines and Preoperative Demographics and PROMs

Patient Parameter	IL-6 N=68	IL-8 N=77	TNF-α N=77	HMGB1 N=34	WBC N=34
Age	0.096	0.207	0.042	0.075	-0.127
Sex	-0.046	-0.070	-0.046	0.086	-0.099
Race	0.029	-0.234	-0.210	-0.115	-0.038
Preop Diagnosis	0.030	-0.033	0.019	-0.072	-0.227
Smoking Status	0.035	0.002	0.065	-0.232	0.051
Number of Levels Fused	0.116	-0.248	-0.167	-0.207	-0.176
Duration of Preop Symptoms	-0.155	0.103	0.089	-0.328*	-0.302*
Preop Opioid Use	0.251	-0.039	-0.013	-0.142	-0.271
NDI	0.143	-0.142	-0.057	0.257	0.165
VAS Arm	0.118	-0.014	0.061	-0.131	0.174
VAS Neck	0.207	-0.040	0.021	-0.050	0.170
PCS	0.070	0.019	-0.036	-0.303*	-0.116
MCS	-0.273	0.044	-0.051	-0.219	-0.337*

* Indicates weak relationship

PRESENTATION #18 continued

Table 3: Correlation Between Preoperative Cytokines and Change in PROMs After ACDF

Change in PROM		IL-6	IL-8	TNF-α
NDI N=43	Δ	0.072	0.039	-0.066
	RR	-0.141	-0.078	0.075
	MCID	0.032	-0.069	0.108
VAS Arm N=44	Δ	0.119	-0.163	-0.034
	RR	-0.216	0.124	-0.016
	MCID	0.046	0.096	0.000
VAS Neck N=44	Δ	0.051	-0.146	-0.069
	RR	-0.229	0.014	-0.018
	MCID	-0.065	0.043	0.054
PCS N=47	Δ	-0.199	0.059	-0.095
	RR	-0.199	0.036	-0.086
	MCID	-0.232	0.154	-0.117
MCS N=47	Δ	0.306*	0.091	0.098
	RR	0.321*	0.125	0.104
	MCID	0.298	0.219	0.240
* Indicates weak relationship				

PRESENTATION #19

Discharge to Rehabilitation Predicts Greater Morbidity in Patients Undergoing Posterior Cervical Decompression and Fusion

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Introduction: There has been an emphasis on limiting overall health costs by reducing 30-day readmission and morbidity. More recently, studies have evaluated discharge disposition as a potential way to improve short-term outcomes. Snyder et al. (2019) previously evaluated the impact of discharge disposition on 30-day outcomes for posterior cervical decompression and fusion (PCDF), but did not distinguish between pre- and post-discharge morbidity. This is the first large-scale database study to compare 30-day readmission and post-discharge morbidity between home and rehabilitation discharge dispositions for patients undergoing PCDF.

Materials and Methods: Adults who underwent PCDF, who were identified using the 2005-2018 NSQIP datasets using CPT code 22600 with a decompression code. Patients were excluded if they had anterior, thoracic, lumbar, deformity, revision, nonelective/emergency, infection-related, or tumor surgery. Primary outcomes were 30-day readmission and post-discharge morbidity. Secondary outcomes were baseline differences, pre-discharge morbidity, and predictors of primary outcomes. Univariate and multivariate regression was utilized to compare readmission and morbidity between discharge dispositions and to evaluate and control for predictors and baseline differences.

Results: 8,912 PCDF patients (2,187 rehab) were included (Table a). Rehab patients were more likely ($p<0.001$) to be older (66.9 vs 59.4 years), female (46.1 vs 42.6%, $p=0.004$), African American (21.4 vs 13.8%), and functionally dependent (11.0 vs 2.2%) and more likely ($p<0.001$) to have diabetes (27.1 vs 17.5%), hypertension (68.4 vs 55.2%), ASA-class ≥3 (80.2 vs 57.7%), pre-discharge reoperation (3.4 vs 1.1%), pre-discharge morbidity (13.1 vs 4.4%), greater OR time (198 vs 170 min), and length of stay (5.9 vs 3.3 days).

Patients discharged to rehab had greater readmission (10.4 vs 8.0%, $p=0.002$) and post-discharge morbidity (7.1 vs 4.0%, $p<0.001$) rates. After adjusting for baseline differences and predictors of primary outcomes, multivariate analysis revealed that readmission ($p=0.071$, OR=1.311) no longer statistically differed, but rehab independently predicted post-discharge morbidity ($p<0.001$, OR=2.232) (Tables b-c).

Age (OR=1.020), elevated creatinine (OR=2.891), pre-discharge reoperation (OR=27.557), and post-discharge morbidity (OR=28.920) predicted readmission. ASA-class ≥3 (OR=1.462) and length of stay (OR=1.107) predicted post-discharge morbidity.

Conclusion: Despite controlling for baseline differences and predictors of outcomes, discharge to rehab independently predicted morbidity, but no longer predicted readmission rates. This could be the result of patients receiving limited therapy or less time out of bed due to limited independence while in rehab. There may also be a surveillance phenomenon whereby patients in rehab who develop subtle symptoms of a minor complication are under closer observation and are therefore more likely to be diagnosed and treated for that complication than if they were at home. In conclusion, appropriate rehab discharge can potentially reduce readmission rates to those of healthier patients discharged to home who underwent PCDF, however

PRESENTATION #19 continued

increased rates of morbidity in rehab discharge warrant further investigation.

Table 1. Baseline differences in patient demographic, comorbidity, laboratory, and procedural factors, and primary outcomes, compared by discharge disposition

	Home, *n* (%)	Rehab, *n* (%)	*P*	Cases available
	N = 6,725	N = 2,187		8,912
Demographics				
Mean age (years; SD)	59.4 (11.6)	66.9 (11.0)	**<0.001**	8,912
African American race	838 (13.8%)	425 (21.4%)	**<0.001**	8,080
Hispanic Ethnicity	326 (5.3%)	126 (6.2%)	0.145	8,147
Male gender	3,859 (57.4%)	1,178 (53.9%)	**0.004**	8,912
Comorbidities				
Functionally dependent	149 (2.2%)	239 (11.0%)	**<0.001**	8,864
Obese	3,061 (45.7%)	1,022 (46.9%)	0.309	8,876
Smoker	1,789 (26.6%)	443 (20.3%)	**<0.001**	8,912
Dyspnea	357 (5.3%)	218 (10.0%)	**<0.001**	8,912
Diabetes mellitus	1,177 (17.5%)	593 (27.1%)	**<0.001**	8,912
COPD	392 (5.8%)	198 (9.1%)	**<0.001**	8,912
Heart failure	16 (0.2%)	18 (0.8%)	**<0.001**	8,912
Hypertension	3,710 (55.2%)	1,496 (68.4%)	**<0.001**	8,912
Open wound	20 (0.3%)	37 (1.7%)	**<0.001**	8,912
Chronic steroid use	317 (4.7%)	139 (6.4%)	**0.002**	8,912
Unexpected weight loss	27 (0.4%)	13 (0.6%)	0.241	8,912
Bleeding disorder	103 (1.5%)	71 (3.2%)	**<0.001**	8,912
ASA-class ≥3	3,875 (57.7%)	1,753 (80.2%)	**<0.001**	8,904
Lab Values				
Elevated creatinine	188 (3.1%)	141 (6.9%)	**<0.001**	8,043
Elevated white cell count	396 (6.5%)	149 (7.2%)	0.242	8,186
Decreased hematocrit	926 (14.9%)	577 (27.7%)	**<0.001**	8,282
Abnormal platelet count	376 (6.1%)	207 (10.0%)	**<0.001**	8,196
Procedural Factors				
Operative time (min)	170 (85)	198 (95)	**<0.001**	8,908
Wound class ≥2	45 (0.7%)	16 (0.7%)	0.758	8,912
Levels fused	2.1 (1.1)	2.2 (1.2)	**<0.001**	8,912
Length of stay	3.3 (2.5)	5.9 (4.6)	**<0.001**	8,905
Primary Outcomes				
Readmission	437 (8.0%)	183 (10.4%)	**0.002**	7,186
Reoperation	211 (3.1%)	124 (5.7%)	**<0.001**	8,912
Pre-discharge reoperation	76 (1.1%)	75 (3.4%)	**<0.001**	8,912
Post-discharge reoperation	135 (2.0%)	49 (2.2%)	0.506	8,912
Overall morbidity	549 (8.2%)	423 (19.3%)	**<0.001**	8,912
Pre-discharge morbidity	297 (4.4%)	286 (13.1%)	**<0.001**	8,911
Post-discharge morbidity	266 (4.0%)	156 (7.1%)	**<0.001**	8,911

[#]Fisher's Exact Test. Bold values indicate significance ($P<0.05$). ASA, American Society of Anesthesiologists. COPD, chronic obstructive pulmonary disease. SD, standard deviation.

PRESENTATION #19 continued

Table 2. Univariate and multivariate analysis of predictors of readmission

	Univariate			Multivariate	
	Readmission (N = 620)	No readmission (N = 6,566)	*P*	OR (95% CI)	*P*
Demographics					
Mean age (years; SD)	63.6 (11.7)	60.8 (11.9)	**<0.001**	1.020 (1.008, 1.032)	**<0.001**
African American race	99 (17.1%)	935 (15.6%)	0.348	1.063 (0.778, 1.452)	0.702
Hispanic ethnicity	24 (4.1%)	331 (5.5%)	0.160		
Male gender	375 (60.5%)	3,674 (56.0%)	**0.030**	1.103 (0.865, 1.405)	0.430
Comorbidities					
Functionally dependent	43 (7.0%)	272 (4.2%)	**0.001**	1.310 (0.792, 2.168)	0.293
Obese	301 (48.6%)	2,985 (45.6%)	0.154		
Smoker	146 (23.5%)	1,688 (25.7%)	0.238	1.197 (0.893, 1.603)	0.228
Dyspnea	51 (8.2%)	419 (6.4%)	0.076	1.034 (0.662, 1.614)	0.885
Diabetes mellitus	154 (24.8%)	1,263 (19.2%)	**0.001**	1.012 (0.756, 1.354)	0.937
COPD	51 (8.2%)	417 (6.4%)	0.071	0.835 (0.520, 1.342)	0.457
Heart failure	4 (0.6%)	23 (0.4%)	0.287#	0.690 (0.153, 3.114)	0.630
Hypertension	411 (66.3%)	3,789 (57.7%)	**<0.001**	1.240 (0.943, 1.630)	0.124
Open wound	4 (0.6%)	42 (0.6%)	1.000#	0.219 (0.039, 1.232)	0.085
Chronic steroid use	47 (7.6%)	325 (4.9%)	**0.005**	1.443 (0.916, 2.273)	0.114
Unexpected weight loss	7 (1.1%)	27 (0.4%)	**0.024#**	4.605 (1.764, 12.025)	**0.002**
Bleeding disorder	19 (3.1%)	125 (1.9%)	**0.049**	1.683 (0.891, 3.177)	0.108
ASA-class ≥3	451 (73.0%)	4,076 (62.1%)	**<0.001**	1.038 (0.784, 1.375)	0.795
Lab values (mean; SD)					
Elevated creatinine	55 (9.6%)	225 (3.8%)	**<0.001**	2.891 (1.905, 4.386)	**<0.001**
Elevated white cell count	33 (5.7%)	416 (6.9%)	0.297		
Decreased hematocrit	134 (23.1%)	1,111 (18.2%)	**0.003**	1.019 (0.756, 1.373)	0.903
Abnormal platelet count	52 (9.1%)	423 (7.0%)	0.068	1.013 (0.659, 1.558)	0.952
Procedural factors					
Operative time (min)	188 (95)	177 (89)	**0.002**	1.001 (0.999, 1.002)	0.429
Wound-class ≥2	5 (0.8%)	45 (0.7%)	0.617#		
Levels fused	2.2 (1.1)	2.1 (1.1)	**0.023**	1.041 (0.943, 1.150)	0.423
Length of stay	4.1 (2.9)	3.9 (3.4)	0.213	0.998 (0.960, 1.037)	0.909
Primary outcomes					
Reoperation	205 (33.1%)	108 (1.6%)	**<0.001**	27.557 (19.194, 39.562)	**<0.001**
Pre-discharge reoperation	31 (5.0%)	101 (1.5%)	**<0.001**	3.731 (1.992, 6.989)	**<0.001**
Post-discharge reoperation	174 (28.1%)	7 (0.1%)	**<0.001**	232.686 (91.056, 594.609)	**<0.001**
Morbidity	301 (48.5%)	564 (8.6%)	**<0.001**	8.666 (6.712, 11.188)	**<0.001**
Pre-discharge morbidity	62 (10.0%)	451 (6.9%)	**0.004**	1.197 (0.773, 1.856)	0.420
Post-discharge morbidity	264 (42.6%)	120 (1.8%)	**<0.001**	28.920 (21.042, 39.747)	**<0.001**
Discharge destination[1]					
Rehabilitation	183 (10.4%)	1,569	**0.002**	1.311 (0.977, 1.760)	0.071
Home	437 (8.0%)	4,997			

[1]Percent of patients with morbidity within discharge destination. #Fischer's exact test. Bold values indicate significance ($P<0.05$). ASA, American Society of Anesthesiologists.

PRESENTATION #19 continued

Table 3. Univariate and multivariate analysis of predictors of post-discharge morbidity

	Univariate			Multivariate	
	Morbidity (N = 422)	No morbidity (N = 8,489)	*P*	OR (95% CI)	*P*
Demographics					
Mean age (years; SD)	63.1 (11.9)	61.1 (11.9)	**0.001**	1.001 (0.987, 1.015)	0.872
African American race	67 (17.2%)	1,196 (15.6%)	0.376	1.126 (0.774, 1.638)	0.534
Hispanic ethnicity	21 (5.4%)	431 (5.6%)	0.875		
Male gender	256 (60.7%)	4,780 (56.3%)	0.078	1.159 (0.865, 1.554)	0.323
Comorbidities					
Functionally dependent	29 (6.9%)	359 (4.3%)	**0.010**	1.151 (0.640, 2.072)	0.638
Obese	210 (49.9%)	3,872 (45.8%)	0.101		
Smoker	105 (24.9%)	2,127 (25.1%)	0.936	0.876 (0.613, 1.252)	0.467
Dyspnea	43 (10.2%)	532 (6.3%)	**0.003**	1.489 (0.905, 2.451)	0.117
Diabetes mellitus	107 (25.4%)	1,663 (19.6%)	**0.004**	1.225 (0.869, 1.725)	0.246
COPD	44 (10.4%)	546 (6.4%)	**0.001**	1.631 (0.976, 2.725)	0.062
Heart failure	5 (1.2%)	29 (0.3%)	**0.021**[#]	6.458 (1.859, 22.435)	**0.003**
Hypertension	262 (62.1%)	4,943 (58.2%)	0.117	1.408 (1.946, 1.021)	**0.037**
Open wound	7 (1.7%)	50 (0.6%)	**0.017**[#]	2.740 (0.774, 9.705)	0.118
Chronic steroid use	26 (6.2%)	430 (5.1%)	0.319	0.640 (0.344, 1.191)	0.159
Unexpected weight loss	1 (0.2%)	39 (0.5%)	1.000[#]		
Bleeding disorder	8 (1.9%)	166 (2.0%)	0.931	0.412 (0.138, 1.228)	0.112
ASA-class ≥3	318 (75.4%)	5,310 (62.6%)	**<0.001**	1.462 (1.025, 2.086)	**0.036**
Lab values (mean; SD)					
Elevated creatinine	24 (6.2%)	305 (4.0%)	**0.032**	0.607 (0.334, 1.104)	0.102
Elevated white cell count	26 (6.7%)	519 (6.7%)	0.973		
Decreased hematocrit	87 (22.2%)	1,415 (17.9%)	**0.033**	1.114 (0.779, 1.592)	0.554
Abnormal platelet count	32 (8.3%)	551 (7.1%)	0.365	1.089 (0.646, 1.838)	0.749
Procedural factors					
Operative time (min)	190 (99)	176 (88)	**0.002**	1.002 (1.000, 1.003)	0.063
Wound-class ≥2	3 (0.7%)	58 (0.7%)	0.765[#]		
Levels fused	2.2 (1.2)	2.1 (1.1)	0.055	1.050 (0.927, 1.189)	0.444
Length of stay	4.1 (2.7)	3.9 (3.4)	0.470	1.107 (1.037, 1.181)	**0.002**
Primary outcomes					
Readmission	264 (68.8%)	356 (5.2%)	**<0.001**	28.574 (20.799, 39.256)	**<0.001**
Reoperation	141 (33.4%)	194 (2.3%)	**<0.001**	4.797 (3.273, 7.031)	**<0.001**
Pre-discharge reoperation	21 (5.0%)	130 (1.5%)	**<0.001**	3.333 (1.611, 6.896)	**0.001**
Post-discharge reoperation	120 (28.4%)	64 (0.8%)	**<0.001**	5.388 (3.491, 8.317)	**<0.001**
Pre-discharge morbidity	36 (8.5%)	547 (6.4%)	0.091	0.996 (0.572, 1.733)	0.988
Discharge destination[1]					
Rehabilitation	156 (7.1%)	2,030	**<0.001**	2.232 (1.580, 3.155)	**<0.001**
Home	266 (4.0%)	6,459			

[1]Percent of patients with post-morbidity within discharge destination. [#]Fischer's exact test. Bold values indicate significance ($P<0.05$). ASA, American Society of Anesthesiologists.

PRESENTATION #20

Cervical Laminectomy with Instrumented Fusion is Associated with a Higher Incidence of Postoperative C5 Palsy Compared to Cervical Laminoplasty with Reconstruction: Single Surgeon and National Inpatient Sample Analyses

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Introduction: Cervical laminectomy with instrumented fusion (LF) and cervical laminoplasty with reconstruction (LP) are common procedures used to treat degenerative cervical myelopathy. Like other spine surgeries, LF and LP carry a risk of nerve root injury that most commonly presents as postoperative C5 palsy. While nerve palsies often resolve over time, they reduce patient satisfaction and may impede recovery after surgery. Prior studies disagree about which procedure is associated with a higher risk of C5 palsy. In this study, we investigated whether LF and LP are associated with different rates of C5 palsy at 1 month follow-up in a single-surgeon cohort and nationally representative cohort.

Materials and Methods: We identified patients undergoing non-revision LF or LP procedures for treatment of cervical myelopathy in both a single-surgeon series cohort (2004-2018; Mount Sinai Hospital, New York, NY) and a nationally representative cohort drawn from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database (2006-2017). For the single-surgeon cohort, C5 palsy within 1 month of surgery was recorded. For the NSQIP cohort, peripheral nerve injury (PNI) within 1 month of surgery was recorded. Unadjusted differences in nerve palsy rates between LF and LP patients were evaluated using z-test. Multivariable logistic regression was used to evaluate the association between procedure type and postoperative C5 palsy or PNI while adjusting for covariates. Adjusted odds ratios (aOR) with 95% confidence intervals (CI) were obtained. P-values less than 0.05 were considered significant.

Results: The single-surgeon cohort comprised 185 LF and 79 LP patients. Without adjusting for covariates, LF patients had a higher rate of 1-month C5 palsy (LF 8%, LP 0%, $p = 0.01$). An aOR could not be obtained due to the absence of C5 palsy in the LP group. The national cohort comprised 3,542 LF and 1,943 LP patients. Without adjusting for covariates, LP patients had a significantly higher rate of 1-month PNI (LF 11%, LP 16%, $p < 0.001$). After adjusting for age, sex, BMI, ASA physical status, procedure time, length of stay, and history of diabetes, COPD, hypertension, steroid use, and/or bleeding disorder, we found no significant difference in odds of 1-month PNI between LF and LP (aOR = 0.84, 95% CI 0.70 - 1.01, $p = 0.07$).

Conclusion: Our findings from the single-surgeon series suggest that cervical LF is associated with significantly higher rates of postoperative C5 palsy as compared to LP. However, these findings are not corroborated by our analysis of a nationally representative patient sample, which showed no difference in PNI rates between LF and LP. This discrepancy may be attributable to the broader definition of PNI used in the NSQIP database versus the more specific definition of C5 palsy used in the single-surgeon cohort analysis. Nonetheless, LF patients should be more closely monitored for new-onset C5 or other root palsies during follow-up visits and referred for electrodiagnostic testing as appropriate.

PRESENTATION #20 continued

Table 1. Comparison of demographics, perioperative characteristics, comorbidities, and C5 palsy rates between cervical laminoplasty and cervical laminectomy with fusion patients in the Mount Sinai Hospital single-surgeon cohort (n = 264).

	Laminoplasty	**Laminectomy with fusion**	**Univariable Analysis**	
	Mean (SD) or Count (%)	Mean (SD) or Count (%)	Statistical test	P-value
Number of patients	79	185	-	-
Demographic and Perioperative Variables				
Age (years)	62 (11)	62 (12)	t-test	0.97
Male sex (%)	62 (78.5%)	122 (65.9%)	z-test	**0.04**
BMI	30.0 (7.2)	28.8 (11.3)	t-test	0.59
Had previous spine surgery (%)	26 (32.9%)	47 (25.4%)	z-test	0.21
Anesthesia time (min)	247 (39)	299 (63)	t-test	**0.02**
Procedure time (min)	127 (24)	175 (53)	t-test	**<0.001**
ASA physical status (%)				
1	3 (3.8%)	4 (2.2%)		
2	46 (58.2%)	73 (39.5%)	chi-squared	0.18
3	28 (35.4%)	80 (43.2%)		
4	1 (1.3%)	4 (2.2%)		
Estimated blood loss (mL)	251 (120)	495 (314)	t-test	**<0.001**
Length of stay (days)	3.4 (2.5)	4.3 (2.4)	t-test	**0.03**
Number of spine levels operated on	6.1 (0.8)	5.3 (0.9)	t-test	**0.05**
Comorbidities				
Asthma (%)	4 (5.1%)	16 (8.6%)		0.31
Diabetes mellitus (%)	14 (17.7%)	22 (11.9%)		0.21
Hypertension (%)	37 (46.8%)	89 (48.1%)		0.85
Hyperlipidemia (%)	36 (45.6%)	60 (32.4%)	z-test	**0.04**
Coronary artery disease (%)	11 (13.9%)	21 (11.4%)		0.56
COPD (%)	2 (2.5%)	4 (2.2%)		0.85
Arthritis (%)	4 (5.1%)	11 (5.9%)		0.78
GERD (%)	13 (16.5%)	20 (10.8%)		0.20
Outcomes				
C5 Palsy within 1 Month after Surgery (%)	0 (0.0%)	14 (7.6%)	z-test	**0.01**

PRESENTATION #20 continued

Table 2. Comparison of demographics, perioperative characteristics, comorbidities, and peripheral nerve injury (PNI) rates between cervical laminoplasty and cervical laminectomy with fusion patients in the NSQIP database national cohort (n = 5,485).

	Laminoplasty	Laminectomy with fusion	Univariable Analysis	
	Mean (SD) or Count (%)	Mean (SD) or Count (%)	Statistical test	P-value
Number of patients	1943	3542	-	-
Demographic and Perioperative Variables				
Age (years)	61 (12)	63 (11)	t-test	**<0.001**
Male sex (%)	1262 (65.0%)	2128 (60.1%)	z-test	**<0.001**
BMI	29.7 (6.4)	29.5 (6.4)	t-test	0.35
Anesthesia time (min)	260 (81)	281 (86)	t-test	**<0.001**
Procedure time (min)	164 (73)	184 (82)	t-test	**<0.001**
ASA physical status (%)				
1	38 (2.0%)	32 (0.9%)		
2	804 (41.4%)	1034 (29.2%)	chi-squared	**<0.001**
3	1042 (53.6%)	2200 (62.1%)		
4	58 (3.0%)	272 (7.7%)		
Length of stay (days)	4.0 (5.5)	5.3 (8.4)	t-test	**<0.001**
Comorbidities				
Diabetes mellitus (%)	426 (21.9%)	786 (22.2%)		0.82
Smoker (%)	422 (21.7%)	868 (24.5%)		0.02
Dyspnea (%)	68 (3.5%)	209 (5.9%)		**<0.001**
COPD (%)	82 (4.2%)	244 (6.9%)	z-test	**<0.001**
Hypertension requiring medication (%)	1102 (56.7%)	2201 (62.1%)		**<0.001**
Steroid use (%)	76 (3.9%)	190 (5.4%)		0.02
Bleeding disorder (%)	40 (2.1%)	91 (2.6%)		0.24
Outcomes				
PNI within 1 Month after Surgery (%)	306 (15.7%)	394 (11.1%)	z-test	**<0.001**

PRESENTATION #21

Understanding the Effects of Three-Column Osteotomies on Regional and Global Alignment in patients with Moderate to Severe Cervical Deformity

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Introduction: Rigid inflexible sagittal cervicothoracic deformities often necessitate high-grade osteotomies in order to achieve adequate radiographic correction. This study assesses the impact on both regional and global alignment parameters following use of three-column osteotomies in the cervicothoracic spine for correction of moderate to severe cervical deformity through 1-year follow up.

Materials and Methods: A retrospective review of consecutive cohort of patients that underwent cervical and cervicothoracic deformity correction from 2010 to 2018 was performed. Inclusion criteria was cervical kyphosis > 20 degrees and/or cervical sagittal vertical axis (cSVA) > 4cm, and use of three-column osteotomies for surgical correction. All spinopelvic radiographic parameters were measured at 6 week, 3 month, 6 month, and 1 year follow up visits. Percent change in parameters from the postoperative scoliosis x-ray films were then calculated to assess changes over time.

Results: A total of 33 patients had at least 1-year follow-up and comprehensive scoliosis x-rays to assess global spinopelvic parameters. Mean age was 60.0 years, and 57.6% of patients were female. Patients were grouped into distinct cohorts (all patients, patients requiring future revision surgery, and patients without future revision surgery) to observe how regional and global parameters were influenced by use of 3CO in the cervicothoracic spine. Overall, preoperative measures significantly improved postoperatively in all cervicothoracic parameters: cervical lordosis (CL) (-3.7 vs. -10.2 degrees, p=0.044), cSVA (6.7 vs. 4.0 cm, p<0.001), T1 slope (48.3 vs. 30.4 degrees, p<0.001) and thoracic kyphosis (TK) (64.8 vs. 43.3 degrees, p<0.001). Serial radiographic measurements demonstrated a decompensation in cervical lordosis at 1-year follow up (6wk: +37.04%, 3mo: +41.02%, 6mo: +75.15%, 1yr: -49.15%) and SVA (6wk: -10.83%, 3mo: -119.96%, 6mo: -150.10%, 1yr: -95.65%) when compared to postoperative measurements. Conversely, cSVA, T1 slope, TK, LL, PI and sacral slope (SS) remained stable over the 1-year postoperative course, while pelvic tilt (PT) demonstrated a slight increase (6wk: +51.10%, 3mo: +41.86%, 6mo: +41.91%, 1yr: +40.76%). When examining only patients who required future revision surgery, similar trends were observed with decompensation in CL (6wk: +14.40%, 3mo: +11.28%, 6mo: +67.28%, 1yr: -68.69%) and SVA (6wk: +135.53%, 3mo: -88.09%, 6mo: -139.55%, 1yr: -119.84%). Measurements of cSVA, T1 slope, TK, LL, PI, and SS remained stable, while PT was significantly elevated from postoperative measurements up until 1-year follow up (6wk: +145.79%, 3mo: +87.13%, 6mo: +146.82%, 1yr: +14.72%). In patients who did not undergo any revision surgery, these trends persisted although with lesser magnitude than the revision surgery cohort: decompensation was observed in CL (6wk: +50.63%, 3mo: +65.34%, 6mo: +80.67%, 1yr: -35.48%) and SVA (6wk: -98.64%, 3mo: -146.03%, 6mo: -158.31%, 1yr: -76.84%), while cSVA, T1 slope, TK, LL, PI, and SS remained stable.

Conclusion: Notably, CL improved significantly in patients with severe kyphotic deformity in the cervical spine, before decompensating by the 1-year mark in reference to direct

PRESENTATION #21 continued

postoperative measurements. Interestingly, we also observed decompensation in global alignment parameters of SVA across all three patient cohorts, as patients exhibited reciprocal changes following use of 3CO in the cervical spine. Additional studies with longitudinal follow-up remain essential for understanding the impact of cervical 3CO.

Table 1: Serial radiographic measurements across all patients following 3CO for cervical deformity correction. Measurements from 6 week, 3 month, 6 month, and 1-year follow up images were compared to postoperative measurements to assess longitudinal changes.

	Preop (mean)	Postop (mean)	Change	p-value	6wk-postop (%)	3mo-postop (%)	6mo-postop (%)	1yr-postop (%)
CL	-3.7	-10.2	-6.4	0.044	37.04	41.02	75.15	-49.15
cSVA	6.7	4.0	-2.7	0.000	8.37	-13.44	-7.86	-4.95
T1-slope	48.3	30.4	-17.9	0.000	-1.57	-12.53	-7.46	-5.70
SVA	2.4	3.6	1.3	0.196	-10.83	-119.96	-150.10	-95.65
TK	64.8	43.3	-21.5	0.000	6.15	7.86	3.03	2.79
LL	52.5	45.3	-7.2	0.006	11.62	7.55	7.12	10.58
PI	53.9	57.8	3.9	0.034	6.91	7.40	5.25	6.14
PT	20.5	20.6	0.1	0.967	51.10	41.86	41.91	40.76
SS	33.3	35.7	2.5	0.321	3.09	-0.54	-0.18	-3.29

PRESENTATION #21 continued

Table 2: Serial radiographic measurements in patients who underwent eventual revision surgery vs. no revision surgery following 3CO for cervical deformity correction. Measurements from 6 week, 3 month, 6 month, and 1-year follow up images were compared to postoperative measurements to assess longitudinal changes.

Revision	Preop (mean)	Postop (mean)	Change	p-value	6wk-postop (%)	3mo-postop (%)	6mo-postop (%)	1yr-postop (%)
CL	-7.1	-10.6	-3.5	0.638	14.40	11.28	67.28	-68.69
cSVA	6.0	3.0	-3.0	0.000	46.04	-9.61	-3.10	-5.97
T1-slope	49.1	31.7	-17.4	0.001	9.91	-12.09	5.05	-0.94
SVA	3.1	4.1	1.0	0.536	135.53	-88.09	-139.55	-119.84
TK	61.3	42.5	-18.8	0.002	11.17	11.65	13.20	13.89
LL	46.7	43.5	-3.2	0.368	9.12	11.98	-2.47	16.14
PI	56.8	60.0	3.2	0.597	20.55	11.34	18.06	3.69
PT	25.2	24.1	-1.1	0.738	145.79	87.13	146.82	14.72
SS	31.0	36.1	5.1	0.272	-3.23	-4.32	1.52	-5.99

No Revision	Preop (mean)	Postop (mean)	Change	p-value	6wk-postop (%)	3mo-postop (%)	6mo-postop (%)	1yr-postop (%)
CL	-2.0	-9.9	-7.9	0.013	50.63	65.34	80.67	-35.48
cSVA	7.0	4.5	-2.6	0.000	-14.23	-16.57	-11.19	-4.24
T1-slope	47.9	29.7	-18.2	0.000	-8.45	-12.89	-16.22	-9.03
SVA	2.0	3.4	1.4	0.269	-98.64	-146.03	-158.31	-76.84
TK	66.5	43.7	-22.8	0.000	2.92	4.76	-4.08	-4.99
LL	55.1	46.3	-8.9	0.009	13.11	3.93	13.82	6.69
PI	52.6	56.7	4.0	0.031	-0.88	4.17	-3.71	7.78
PT	18.3	18.7	0.4	0.911	-3.01	4.82	-31.53	58.12
SS	33.3	35.7	2.5	0.321	3.09	-0.54	-0.18	-3.29

PRESENTATION #22

Proximal and Distal Reciprocal Changes Following Cervical Deformity Malalignment Correction

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Introduction: Hyperextension of C0-C2 is a painful compensatory mechanism used to maintain horizontal gaze that is analogous to high pelvic tilt to maintain upright posture. The magnitude and impact of relaxation of this hyperextension following CD correction are not well understood. The purpose of this study was to investigate whether correction of cervical sagittal malalignment allows for relaxation of C0–C2 hyperextension and improved clinical outcome.

Materials and Methods: This study is a retrospective review of CD patient with minimum 1-year follow-up. CD patients undergoing surgery short of the occiput and the pelvis were included. In addition to the classic alignment parameters, ROM and reserve of extension were calculated across the C2-C7 and C0-C2 segments. After describing the cohort in terms of pre-operative information, correlations and hierarchical stepwise regressions investigated the association between C2-C7 correction and change in C0-C2 reserve of extension while controlling for maintenance of horizontal gaze. Stratification by ΔC2-C7 percentile was conducted followed by paired t-tests to investigate changes in TK, C0-C2 and reserve of extension within each percentile.

Results: 65 patients were included (61.8yo±9.6, 68%F). At baseline, they presented with a cervical kyphotic alignment (C2-C7: -11.7°±18.2; TS-CL: 38.6°±18.6), a negative global alignment (SVA: -12mm±71), and hyperlordosis at C0-C2 (33.2°±11.8). The ROM was 25.7°±17.7 and 21.3°±9.9 at C2-C7 and C0-C2, respectively, with an associated reserve of extension of ~9° for each segment. Limited C0-C2 ROM and reserve of extension significantly correlated with the Neck Disability Index (r=-0.371 & -0.394) and with decreased general health (r=0.455 & 0.512) (all p<0.005).

The mean number of levels treated was 7.0±3.1 (24.6% ACDF, 43.1% posterior), with 49.2% of the patients receiving an osteotomy, and 16.9% a 3CO. At 1 year, C2-C7 increased to 5.5°±13.4, SVA became neutral (12mm±54), C0-C2 decreased to 27.7°±11.7, and TK increased to -49.4±18.1 (all p <0.001). At C2-C7 ROM decreased significantly to 9.5°±14.1, and increased to 27.6°±8.1 at C0-C2 without change in reserve of extension. The horizontal gaze significantly improved (4.5±13.3 vs -0.5±9.3 p=0.003).

Controlling for horizontal gaze, change in C2-C7 lordosis significantly correlated with increased TK (r=-0.615, p<0.01), decreased C0-C2 (r=-0.686, p<0.001), and increased C0-C2 reserve of extension (r=0.414, p<0.015). Larger C0-C2 ROM and reserve of extension correlated with decrease in Neck Disability Index (r=-0.571 & -0.470 p<0.05).

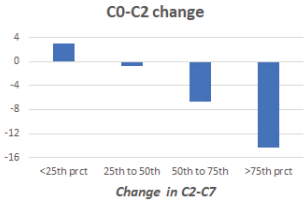
Stratification by ΔC2-C7 percentile highlighted the reciprocal change above and below the fusion (Figure 1). Within the lowest percentile (ΔC2-C7: 2°±9.6), no significant difference was

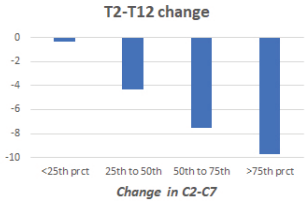
PRESENTATION #22 continued

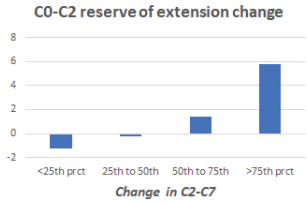
noticed between pre and 1 year, while within the highest percentile (ΔC2-C7: -42.8±14.1), C0-C2 decreased (-9.7°±10.5, p=0.001) and TK kyphosis increased (14.3°±7.5, p<0.001) and C0-C2 reserve of extension increased (5.8°±6.4, p=0.026).

Sub analysis on patients with available 2-year data (N=42) demonstrated similar trends.

Conclusion: Correction of cervical malalignment can significantly impact proximal (C0-C2) and distal (T2-T12) compensation. Restoration of a more natural alignment resulted in an increase of the reserve of extension between C0-C2 and was associated with improved clinical outcomes.







PRESENTATION #23

When Does the Construct Need to Extend to the Thoracic Spine in Patients Undergoing Correction for Cervical Deformity?

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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 when the thoracic spine should be included in the construct. This purpose of this retrospective cohort study was to investigate the CD patients in whom fusion to the thoracic spine was warranted.

Materials and Methods: Included: operative CD pts (C2-C7 lordosis < -15°, TS-CL >35°, segmental cervical kyphosis >15° across any 3 vertebra between C2-T1, C2-C7 SVA >4cm, McGregor's slope >20°, or CBVA > 25°) with baseline (BL) and up to 2-year(2Y) data. Patients with UIV at or above C4 and LIV extending beyond C7 into the thoracic spine were isolated (CT fusions). CT fusion patients were further stratified to upper and lower thoracic LIVs: T1-T4 [Short Fusion], beyond T4 [Long Fusion]. CT fusion patients were identified as having an optimal outcome at 2Y postop if they 1) did not have DJF and 2) had Virk et al. good clinical outcome [≥2 of the following: NDI <20 or meeting MCID, mild myelopathy (mJOA ≥14), NRS-Neck ≤5 or improved by ≥2 points from baseline]. Univariate analysis compared pts with long fusion and optimal outcome (L/Success) vs. pts with short fusion and treatment failure (S/Fail). Multivariate analysis and ROC curve assessed demographic, surgical, and radiographic predictors of S/Fail and L/S Success status. Conditional inference tree (CIT) determined cut-off values for the continuous predictors.

Results: 72 cervical deformity patients with CT fusion included (60.3±9.0yrs, 60% F, 29.4±7.6 kg/m2, levels fused: 7.8±3.2). By approach, 61% posterior-only and 39% combined. 59 patients(82%) had CT fusions with LIV of T4 or above, while 13 patients (18%) had fusions extending below T4. 32 patients (44.4%) met the optimal outcome criteria, with no difference by fusion length (p=0.171). 8 patients qualified as long fusions with treatment success, while 35 patients were classified as short fusions with treatment failure. Regression analysis identified the predictors of treatment success in patients with fusion construct extending beyond T4: baseline sacral slope ≤33.5° (OR: 15.0), not undergoing high grade (PSO or VCR) osteotomy (OR: 15.0) and being Ames descriptor type C (OR: 13.5); all $p<0.05$). ROC curve accounting for these factors resulted in an AUC of 82.0%. Regression analysis identified predictors of treatment failure in patients with short fusion construct: levels fused >6 (OR: 4.3), Ames descriptor type CT (OR: 11.5), Ames cSVA modifier grade 1 or 2 at BL (OR: 4.56), and Flatneck Kim et al. sagittal morphotype (OR: 4.5); all $p<0.05$. Multivariate regression and ROC curve accounting for these factors resulted in an AUC of 84.3%.

Conclusion: Treatment success in patients with fusion constructs extending into the thoracic spine vs. treatment failure in patients with short fusions may be reliably predicted by the location of the deformity apex, measures of surgical invasiveness, and preoperative deformity severity. Specifically, treatment success in longer fusions is related to deformity apex in the cervical spine and having deformity where adequate correction does not necessitate high grade osteotomy.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #24

Durability and Failure Mechanisms of Cervical Deformity Correction Surgery

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Introduction: Cervical Deformity (CD) surgery can markedly improve patient quality of life. Postoperative cervical malalignment has been correlated with poor health outcomes (HRQL). The longevity of CD correction and the mechanism of alignment deterioration are not well understood. This study aims to investigate preoperative risk factors and failure mechanisms that erode CD corrections and the impact on functional outcomes.

Materials and Methods: A retrospective review of a prospective database of operative CD patients was analyzed. Patients with baseline, 3 months, 6 months and 1year cervical radiographs were included. Cervical Sagittal Vertical Axis (cSVA) <4cm was used to categorize patients as well-aligned vs mal-aligned. Additionally, three subsets were compared: group A. patients who were mal-aligned preoperative (cSVA=4) and remained well aligned at 1year postop; group B. patients who were well-aligned but experienced alignment deterioration (cSVA=4cm) up to 1year postop; group C. Patients who never attained cSVA<4cm. These groups were compared in terms of demographic factors, surgical factors, baseline radiographic parameters and radiographic and surgical outcomes at baseline and 1 year, using t-tests and X2 tests for continuous and categorical variables, respectively.

Results: 155 patients included (mean age 61.41, 60.9% F). The entire cohort was analyzed at all time points for alignment using cSVA (Figure 1A). Among 89 patients with x-rays at every time point, 30 (34%) were group A, 17 (19%) group B and 41 (46%) group C. Among group B patients, 4 patients lost their correction by 3 months, 6 more by 6 months and 8 more by 1year (Figure 1B). The never aligned cohort (group C) was significantly older compared to group A and B (65.9 vs. 61.8 vs. 58.8, p=0.038). Group B and C, neither of which were well aligned at 1year, had a significantly higher rates of DJK (47.1% vs 42.9% vs. 3.3%, p=0.001). Other failure mechanisms in the deterioration group included loss of subjacent spinopelvic compensation and PJK. At baseline, patients with alignment deterioration (group B) had a smaller cSVA compared to group A and C (40.5 vs. 52.0 and 60.1mm, p=0.001), and less TK (-43.4 vs. -55.9 vs. -61.4, p=0.049). Patients with deterioration (group B) had worsening of their mJOA score at 6 months compared to group A and C (2.50 vs. 0.04 vs. 1.20, p=0.032). There were no significant differences in smokers, BMI, frailty, osteoporosis, levels fused, UIV, LIV, EBL, operative time, rod diameter, rod material, utilization 3 Column Osteotomy, mean osteotomy grade, in construct (fused) loss of alignment or revision rate between the groups (all p>.05)

Conclusion: Cervical Deformity correction surgery failed to achieve acceptable sagittal alignment in 46% of patients. In those with successful correction, 36% suffered alignment deterioration within 1 year. Distal junctional kyphosis was the most common failure mechanism leading to loss of correction or failure to reach good alignment.

PRESENTATION #24 continued

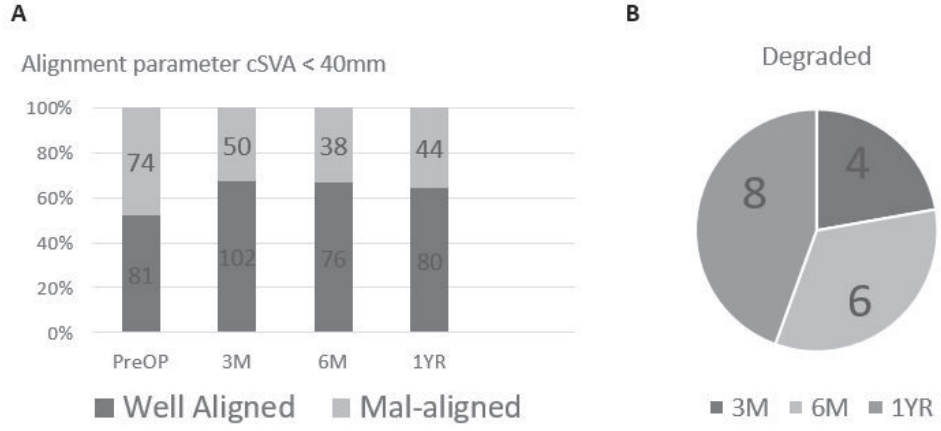

Figure 1: (A) Cervical Deformity patients were grouped based on cSVA into Well Aligned (cSVA <40) and Mal-aligned (cSVA ≥40) at baseline (PreOP) and 3 time points postoperatively. (B) Number of patients whose alignment degraded from Well Aligned to Mal-aligned at each different time point postoperatively.

PRESENTATION #25

Identifying T1 Slope Thresholds for Optimal Functional and Clinical Outcomes in Cervical Deformity Correction

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Introduction: Surgical correction of cervical deformity (CD) has been associated with superior alignment and functional outcomes. It has not yet been determined whether pre- and postoperative T1 slope correlate with health-related quality of life (HRQL) metrics and radiographic complications. The objective of this retrospective cohort study was to determine the impact of T1S on functional outcomes and DJK/DJF development in operative cervical deformity patients.

Materials and Methods: Included: operative CD patients with UIV above C7, and with pre- (BL) and up to 2-year(2Y) postop radiographic/HRQL data. Cervical deformity was defined as meeting ≥1 of the following radiographic parameters: C2-C7 lordosis < -15°, TS-CL>35°, segmental cervical kyphosis >15° across any 3 vertebra between C2-T1, C2-C7 SVA>40mm, McGregor's slope>20°, or CBVA>25°. Spearman's rank-order correlation assessed the impact of preoperative T1S on baseline HRQLs. Independent samples t-tests determined differences in preoperative T1S by meeting Virk et al. good clinical outcome criteria [≥2 of the following: NDI <20 or meeting MCID, mild myelopathy (mJOA ≥14), NRS-Neck ≤5 or improved by ≥2 points from BL], and developing complications. The impact of 3-month postoperative T1S on follow-up HRQLs, meeting Virk criteria, and complication rates was assessed in the same manner. Logistic regression and machine learning conditional inference tree (CIT) were used to determine postoperative radiographic thresholds for 1) achieving a Virk good clinical outcome, and 2) for developing DJK or DJF by 2Y postop.

Results: 162 CD patients met inclusion criteria (60.0±10.6years, 59%F, BMI 28.7±7.2kg/m2, CCI: 0.90±1.26) and underwent surgery (levels fused 6.7±3.9, EBL 842mL, op time 338min). By approach, 22.8% underwent anterior-only, 48.1% posterior-only, and 29.0% combined. Mean BL HRQLs and radiographic parameters are reported in Table 1. Postoperatively, the mean T1 slope was 34.8° at 3-months, 36.3° at 1 year, and 36.3° at 2 years. 88 patients (54.3%) met the Virk good clinical outcome criteria. There were 58 cases of DJK, of which 14 qualified as DJF.

Baseline T1 slope was not correlated with baseline disability for any HRQL (all p>0.05). T-tests revealed no significant differences in preoperative T1S between patients with DJK or DJF by 2Y postop. Spearman correlation identified a significant association between higher 2Y T1S and lower 2Y mJOA (p=0.035), indicating higher degree of disability. T-tests showed that patients who developed DJK had a higher 3-month postoperative T1S (39.0° vs. 32.1°, p=0.022); as did patients who developed DJF (48.9° vs. 33.2°, p<0.001). Patients who met the Virk criteria did not differ in postop T1S from those with a less favorable clinical outcome (p>0.05). Logistic regression with CIT determined that a 3-month postoperative T1S >36.7° was predictive of developing DJK (OR: 2.99, p=0.004) and a T1S >44.5° was predictive of developing DJF by 2Y postop (OR: 5.48, p=0.005). No threshold was identified for meeting the Virk good clinical outcome criteria.

Conclusion: In our cohort of cervical deformity patients, postoperative T1 slope was significantly associated with occurrence of radiographic complications. Spine surgeons should

PRESENTATION #25 continued

take T1 slope into account during their surgical planning to minimize risk of DJK or DJF.

Table 1. Mean baseline HRQLs and radiographic parameters in a cohort of 162 operative cervical deformity patients.

HRQLs	
	Mean
NRS back	5.2
NRS neck	6.8
NDI	49.5
mJOA	13.5
Radiographic parameters	
	Mean
Pelvic Tilt	19.4°
PI-LL Mismatch	0.68°
C7-S1 SVA	3.0mm
T2-T12 kyphosis	-45.5°
C2-C7 lordosis	-7.7°
T1 slope	30.4°
TS-CL	35.7°
C2 slope	37.2°
C2-C7 SVA	43.4mm

PRESENTATION #26

Comparison of MRI-based Vertebral Bone Quality (VBQ) Score with Bone Mineral Density Measured by Quantitative Computer Tomography (QCT) in Patients undergoing Cervical Spinal Surgery

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Introduction: The association between bone status and efficacy of surgical instrumentation is a well-known fact. Dual energy X-ray absorptiometry (DXA) has been used as the gold standard for bone status assessment. Recently, alternative radiographic methods for the evaluation of bone quality have been explored in spine surgery. The MRI-based vertebral bone quality (VBQ) score was introduced as a bone quality marker in the lumbar spine and studies showed VBQ could be utilized for the prediction of osteoporotic fracture or complications after spine surgery. However, it has not been investigated whether VBQ can be utilized in the cervical spine. The objective of this study was to assess the association between VBQ scores and bone mineral densities (BMDs) measured by QCT of the spinal levels C2-T1 in patients undergoing anterior cervical discectomy and fusion (ACDF).

Materials and Methods: We retrospectively reviewed the data of patients that underwent ACDF from 2015 to 2018 at a single, academic institution. Subjects with previous cervical instrumentation or missing/incomplete preoperative cervical spine CT or MRI imaging were excluded. Asynchronous quantitative computed tomography (QCT) measurements of the lateral masses of the C2-T1 vertebral bodies were performed. The VBQ score in each cervical level was calculated by dividing the signal intensity of the vertebral body by the signal intensity of the cerebrospinal fluid on midsagittal T1-weighted MRI images. Inter- and intra-observer reliability of the VBQ measurements was assessed. The regional differences and correlations of cervical VBQ were assessed using the Spearman's correlation test and Friedman test. VBQ scores were also compared with QCT vBMD. The statistical significance level was set at $p<.05$.

Results: A total of 102 patients (37.3 % female) were included. The patient population was 89.2% Caucasian with a mean age of 57 years and a mean BMI of 28.4 kg/m2. The ICCs of inter-/intra-observer reliability of the VBQ measurements were 0.85-0.99. VBQ values of C2-T1 vertebrae were strongly correlated with each other. C2 showed the highest VBQ value [Median (IQR) 2.33 (1.33,4.23)] and T1 showed the lowest VBQ value [Median (IQR) 1.64 (0.81,3.88)]. There was significant weak to moderate negative correlations between QCT BMDs and VBQ Scores for all levels [C2= -0.394 (-0.542- -0.223), $p<0.001$; C3= -0.400 (-0.549- -0.218), $p<0.001$; C4= -0.377 (-0.532- -0.190), $p<0.001$; C5= -0.282 (-0,459- -0.098), $p<0.005$; C6= -0.350 (-0.520- -0.187), $p<0.001$; C7= -0.223 (-0.379- -0.040), $p<0.025$; T1= -0.324 (-0.505- -0.132), $p<0.001$].

Conclusion: This is the first study to correlate MRI VBQ scores with QCT BMDs for cervical spinal levels. We found that VBQ scores have a significant negative correlation with BMDs based on the QCT values for every cervical level from C2 to C7 and for T1. This suggests that MRI-based VBQ measurements could be used as bone status markers in the cervical spine. Further studies are required to determine the utilities of both VBQ and vBMD for predicting osteoporosis-related complications in the cervical spine.

PRESENTATION #27

Paraspinal Sarcopenia Predicts Worse Patient Reported Outcomes Following Posterior Cervical Fusion

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Introduction: Studies in the lumbar spine suggest a correlation between sarcopenia and worse patient outcomes. The purpose of this study was to determine whether paraspinal fat degeneration as described by Goutalier grade is associated with radiographic and patient-reported outcomes in patients undergoing posterior cervical fusion (PCF).

Materials and Methods: We performed a retrospective cohort study of patients undergoing PCF at a single institution between the years 2015 and 2020. We utilized preoperative magnetic resonance images to classify patients into Goutalier grades. Radiographic parameters including bone mineral density (BMD), longus colli and multifidus size, and cervical deformity measurements including but not limited to C2 SVA, C2 slope, C2-C7 lordosis and thoracic kyphosis were obtained. Patient-reported outcomes, including Neck Disability Index (NDI), RAND score, and EQ-5D scores and surgical complications were recorded. These parameters were analyzed according to the patients' Goutalier grade.

Results: We identified 99 patients for inclusion. A total of 36 patients were classified as Goutalier 0-1 (group 1), 39 were Goutalier 2 (group 2), and 24 were Goutalier 3-4 (group 3). Goutalier groups 1 and 2 experienced significant improvement in all 3 outcome scores. Goutalier group 3 did not experience a significant improvement in NDI. Average postoperative NDI scores were 12.7 in group 1, 14.3 in group 2, and 21.6 in group 3. The percentage of patients in each group reporting worse disability after surgery was 0% in Group 1, 17.9% in Group 2, and 41.6% in Group 3 ($p<.01$).

Conclusion: The present study is the first to assess the association between cervical paraspinal muscle Goutalier grade and patient-reported outcomes following PCF. Based on our study, patients with worse cervical paraspinal degeneration preoperatively were less likely to experience improvement after surgery.

PRESENTATION #28

What are the Post-operative Consequences of Intraoperative Neuromonitoring Changes during Cervical Spine Surgery

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Introduction: To date there have been several studies with no consensus on the utility of intraoperative neurophysiological monitoring (IONM) for cervical spine surgery. Considering the purpose of these surgeries is to relieve compression on neural elements, any worsening of neurologic symptoms following surgery is considered an unexpected complication. IONM is widely utilized in spinal surgery to detect in real time and hopefully, to prevent intraoperative neurologic complications. The objective of this study is to identify risk factors and outcomes for patients undergoing cervical spine surgery and sustained IONM changes.

Materials and Methods: A retrospective study of patients undergoing cervical spine surgery at a level 1 trauma center from 2012 to 2016 was performed. Demographic and surgical variables were collected as well as the presence of IONM changes and post-operative neurological changes

Results: 663 patients undergoing cervical spine surgery were identified. There were 283 females (42.7%) and 380 males (57.3%) with an average age of 54.8 years; 108 Black, 539 White, 6 Hispanic, 6 Asian, 1 Native American, and 3 other/unknown. The overall rate of IONM changes was 7.69% (51/663). The rate was 5.61% (22/392) in patients undergoing an anterior approach versus 10.84% (27/249) in patients who had posterior approaches versus 10% (2/20) in patients who had combined approaches (p-value = 0.04045). Therefore, we found a statistically significant association between surgical approach and number of IONM changes. The overall rate of neuromonitoring changes that did not recover intraoperatively was 3.8% (25/663). 5/51 (9.8%) had permanent post-operative changes in their neurologic exam; 4 were posterior cervical procedures and 1 was anterior. 2 of the IONM changes led the surgeon to perform an intraoperative wakeup test, and 1 led the patient to remain intubated for a postoperative MRI. 4 of the 5 cases with resulting postoperative neurologic changes were considered permanent IONM changes where one was transient and returned to baseline prior to the conclusion of the procedure. 4 cases led to a change in the treatment plan intraoperatively; one laminoplasty was converted to a complete laminectomy, and another patient was taken directly to MRI postoperatively to evaluate for compressive causes for IONM changes.

Conclusion: Of the 51 patients with IONM changes, 5 patients had changes in their neurologic status postoperatively. Our study demonstrates positive IONM changes during cervical spine surgery does notify the surgeon of the increased possibility of worsened neurological status postoperatively. Additionally, our cohort demonstrates posterior cervical spine surgeries had a significantly higher rate of pertinent IONM changes compared to anterior procedures.

PRESENTATION #29

Impact of inhalational anesthetic agents on the baseline monitorability of upper extremity motor evoked potentials (MEPs) during cervical spine surgery: A review 16,559 procedures

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Introduction: During cervical spine surgery, motor evoked potentials (MEPs) are often utilized to monitor both spinal cord and spinal nerve root function. Previous studies have evaluated the impact of anesthetic regimen on MEP monitoring of spinal cord function, but less is known about the impact on establishing reliable MEPs from all at-risk myotomes for the monitoring of spinal nerve root function.

Materials and Methods: Baseline MEP data from a total of 16,559 extradural cervical spine procedures utilizing multimodality intraoperative neuromonitoring (IONM) including MEPs between January 2017 and March 2020 were obtained from a multi-institutional database. Patients younger than 18, and procedures involving tumor resection were excluded.

Two cohorts were delineated based on the anesthetic regimen: a total intravenous anesthesia (TIVA) regimen versus a regimen balanced with volatile inhalational and intravenous agents (Balanced). The objective was to compare the baseline monitorability and amplitude of MEPs between the two cohorts.

The baseline monitorability of each muscle MEP was evaluated by the IONM team at the start of every procedure, communicated to the surgeon, and recorded in the patient's electronic medical record. The relationship between the anesthetic regimen and baseline monitorability was estimated using mixed effects logistic regression. A random subset of the procedures was retrospectively reviewed and the amplitude of each baseline muscle MEP was measured. A mixed-effects linear regression model was used to estimate possible differences in average amplitude associated with anesthesia regimen

Results: Baseline MEPs were reported monitorable from all targeted muscles at the start of surgery in 87.1% of procedures in the TIVA cohort but in just 65.5% of procedures in the Balanced cohort, yielding a raw disparity of 21.6%. The model-adjusted monitorability disparity between cohorts for a given upper extremity muscle MEP ranged from 1.1% -13.0% but was smallest for distal intrinsic hand muscle MEPs (1.1%) and was largest for proximal upper extremity muscle MEPs (deltoid: 10.8%, biceps brachii: 8.8%, triceps: 13.0%) where the monitorability was significantly decreased in the Balanced cohort relative to the TIVA cohort ($P < 0.0001$) (Table 1).

For both anesthetic cohorts, median proximal muscle MEP amplitudes were smaller (deltoid, biceps, triceps) than the distal hand MEP amplitudes, and between cohorts, the median amplitudes of MEPs from all muscles were smaller in the Balanced cohort relative to the TIVA cohort (Figure 1). The effect of the anesthetic regimen was especially pronounced on the proximal upper extremity muscles as the model-adjusted disparity in amplitude between the two anesthetic cohorts was largest for MEPs recorded from those muscles (deltoid: 74.3%, biceps: 78.0%, triceps: 54.9.0%; $P <0.01$) (Table 2).

Conclusion: TIVA is the preferred anesthetic regimen for optimizing MEP monitoring of nerve

PRESENTATION #29 continued

root function during cervical spine surgery. Inhalational agents significantly decrease MEP monitorability and amplitudes for most muscles, and this effect is especially pronounced for proximal limb muscles such as the deltoid, biceps, and triceps, which have inherently smaller baselines regardless of anesthetic regimen. Anesthesia effects likely explain, in part, discordant published reports of the sensitivity of MEPs in diagnosing evolving nerve root dysfunction during cervical spine surgery.

Table1: Selected descriptive and inferential results for baseline MEP monitorability for each anesthesia cohort. Muscles by anesthesia cohort with a model-adjusted P-Value <0.0001 are highlighted in grey.

Muscle	Anesthesia Cohort (n)[a]	Percent Reported Monitorable (95% CI)	Model-Adjusted Percent Monitorable (95% CI)	Model Adjusted Disparity	P-Value
Deltoid	TIVA (12992)	96.3 (96.0-96.6)	**98.5 (98.1 - 98.8)**	**10.8%**	**<0.0001**
	Balanced (3086)	77.1 (75.6 - 78.6)	**87.7 (84.3 - 90.4)**		
Biceps Brachii	TIVA (5616)	94.3 (93.7 - 94.9)	**98.1 (97.6 - 98.5)**	**8.8%**	**<0.0001**
	Balanced (2847)	78.6 (77.1 - 80.1)	**89.3 (86.2 - 91.7)**		
Triceps	TIVA (9971)	92.9 (92.3 - 93.4)	**96.2 (95.2 - 97.0)**	**13.0%**	**<0.0001**
	Balanced (2229)	73.1 (71.2 - 74.9)	**83.2 (78.7 - 86.9)**		
Intrinsic Hand	TIVA (11707)	92.6 (92.1 - 93.0)	95.8 (94.8 - 96.7)	1.1%	0.0176
	Balanced (2826)	90.3 (89.1 - 91.3)	96.9 (95.9 - 97.7)		

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.

PRESENTATION #29 continued

FIGURE 1: Raw peak-to-trough amplitude data in μV for the upper extremity muscles from each anesthesia cohort (TIVA: blue; Balanced: yellow). Each measurement is plotted (circles) and the box plots show median amplitudes with interquartile ranges. MEPs greater than 8000 μV in amplitude were plotted at 8000 μV.

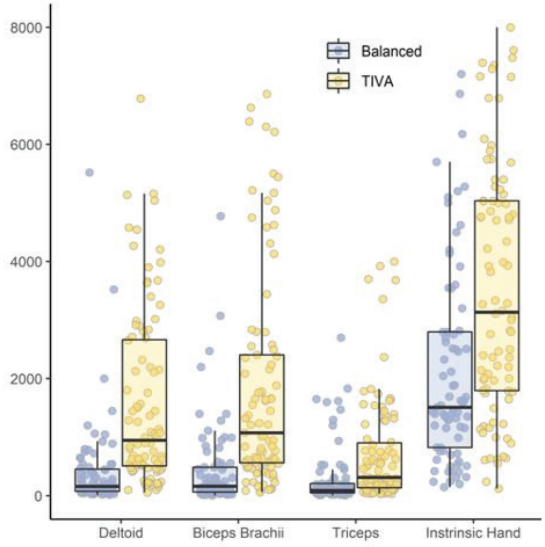


TABLE 2: Selected descriptive and inferential results for baseline MEP peak-to-trough amplitude for each muscle by anesthesia cohort. Muscles by anesthesia cohort with a disparity >50% are shown in grey.

Muscle	Anesthesia Cohort	Median Amplitude in μV [IQR]	Model-Adjusted Average Amplitude in μV (95% CI)	Model Adjusted Disparity in Amplitude	P-Value
Deltoid	TIVA	1002 [522 - 2711]	944 (667 - 1336)	**74.3%**	**<0.0001**
	Balanced	162 [76 - 456]	243 (157 - 377)		
Biceps Brachii	TIVA	1142 [564 - 2474]	1000 (707 - 1415)	**78.0%**	**<0.0001**
	Balanced	165 [62 - 488]	220 (142 - 341)		
Triceps	TIVA	314 [140 - 904]	326 (230 - 461)	**54.9%**	**0.0099**
	Balanced	92 [51 - 211]	147 (95 - 229)		
Intrinsic Hand	TIVA	3578 [1866 - 5618]	3578 [1866 - 5618]	42.1%	0.3174
	Balanced	1572 [824 - 2914]	2071 (1334 - 3214)		

PRESENTATION #30

Is the Use of rh-BMP associated with Increased Incidence of Cancer?

Nida Fatima, MD[1], John Shin, MD, Junseok Bae, MD, Peter Loughenbury, MB ChB, KJ Murphy, MD, Amit Jain, MD, Zorica Buser, PhD, Hans Joerg Meisel, MD, K. Daniel Riew, MD, AO Spine Knowledge Forum Degenerative, NA
Massachusets General Hospital[1]

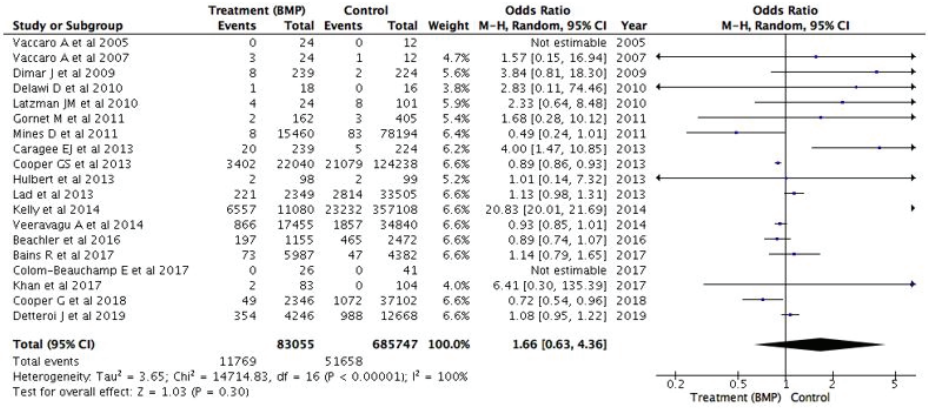
Introduction: Recombinant human bone morphogenetic protein (rhBMP) is frequently used in spinal arthrodesis to stimulate bone fusion. However, there is a potential concern for rhBMP in the promotion of tumor growth due to the presence of BMP receptors on a variety of cancer cells. The study was conducted to determine if there is an increased risk of developing cancer after exposure to rhBMP and if the risk is dose and/or exposure dependent.

Materials and Methods: We conducted a systematic review of electronic databases using different MeSH terms from 2000 to 2020. Pooled and subgroup analyses were performed using fixed and random effect models based upon heterogeneity (I2). The results were reported as odds ratio (OR) with 95% confidence interval (CI). Further scatter log plot was conducted to determine the dose-response relationship between rhBMP and incidence of cancer.

Results: A total of 467,916 patients from 25-studies (10 Randomized Controlled Trials, 14 Retrospective Cohort Studies and 1 Case-Control Study) were included. In our study, 110,808 patients (62.5% females) received rhBMP while the remaining 357,108 patients (58.4% females) were in the control group. There was no statistically significant difference in terms of age (p=0.37), body mass index (p=0.51) and mean follow-up (p=0.28) between the two groups. There did not exist any statistically significant difference in terms of cancer incidence between the treatment and control group (OR: 95% CI: 0.63-4.36, p=0.30). However, the patients receiving rhBMP 2 had significantly higher risk of cancer than those receiving rhBMP 7 (p=0.03) at a mean follow-up of 33.5±20.2 months. Furthermore, lower doses of rhBMP were associated with none to minimal incidence of cancer while those receiving higher doses were associated with increased risk of cancer. The steepest point of the dose-response curve corresponded with 8mg/ml rhBMP.

Conclusion: Our study did not demonstrate any risk of tumorigenesis or metastasis with rhBMP administration compared to the placebo group. However, there was a dose-dependent correlation of rhBMP with cancer. Further prospective studies are needed to validate our results.

PRESENTATION #30 continued

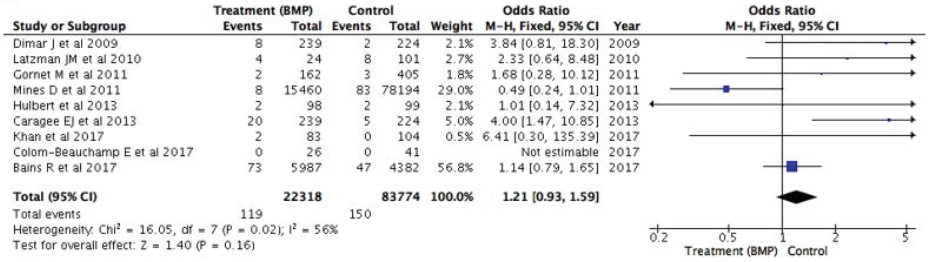


Study or Subgroup	Treatment (BMP) Events	Total	Control Events	Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Vaccaro A et al 2005	0	24	0	12		Not estimable	2005
Vaccaro A et al 2007	3	24	1	12	4.7%	1.57 [0.15, 16.94]	2007
Dimar J et al 2009	8	239	2	224	5.6%	3.84 [0.81, 18.30]	2009
Delawi D et al 2010	1	18	0	16	3.8%	2.83 [0.11, 74.46]	2010
Latzman JM et al 2010	4	24	8	101	5.9%	2.33 [0.64, 8.48]	2010
Gornet M et al 2011	2	162	3	405	5.4%	1.68 [0.28, 10.12]	2011
Mines D et al 2011	8	15460	83	78194	6.4%	0.49 [0.24, 1.01]	2011
Caragee EJ et al 2013	20	239	5	224	6.2%	4.00 [1.47, 10.85]	2013
Cooper GS et al 2013	3402	22040	21079	124238	6.6%	0.89 [0.86, 0.93]	2013
Hulbert et al 2013	2	98	2	99	5.2%	1.01 [0.14, 7.32]	2013
Lad et al 2013	221	2349	2814	33505	6.6%	1.13 [0.98, 1.31]	2013
Kelly et al 2014	6557	11080	23232	357108	6.6%	20.83 [20.01, 21.69]	2014
Veeravagu A et al 2014	866	17455	1857	34840	6.6%	0.93 [0.85, 1.01]	2014
Beachler et al 2016	197	1155	465	2472	6.6%	0.89 [0.74, 1.07]	2016
Bains R et al 2017	73	5987	47	4382	6.6%	1.14 [0.79, 1.65]	2017
Colom-Beauchamp E et al 2017	0	26	0	41		Not estimable	2017
Khan et al 2017	2	83	0	104	4.0%	6.41 [0.30, 135.39]	2017
Cooper G et al 2018	49	2346	1072	37102	6.6%	0.72 [0.54, 0.96]	2018
Detterol J et al 2019	354	4246	988	12668	6.6%	1.08 [0.95, 1.22]	2019
Total (95% CI)		**83055**		**685747**	**100.0%**	**1.66 [0.63, 4.36]**	
Total events	11769		51658				

Heterogeneity: Tau² = 3.65; Chi² = 14714.83, df = 16 (P < 0.00001); I² = 100%
Test for overall effect: Z = 1.03 (P = 0.30)

Odds Ratio M-H, Random, 95% CI
0.2 0.5 1 2 5
Treatment (BMP) Control

A

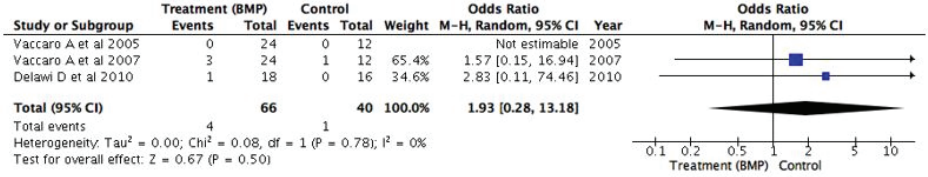


Study or Subgroup	Treatment (BMP) Events	Total	Control Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Dimar J et al 2009	8	239	2	224	2.1%	3.84 [0.81, 18.30]	2009
Latzman JM et al 2010	4	24	8	101	2.7%	2.33 [0.64, 8.48]	2010
Gornet M et al 2011	2	162	3	405	1.8%	1.68 [0.28, 10.12]	2011
Mines D et al 2011	8	15460	83	78194	29.0%	0.49 [0.24, 1.01]	2011
Hulbert et al 2013	2	98	2	99	2.1%	1.01 [0.14, 7.32]	2013
Caragee EJ et al 2013	20	239	5	224	5.0%	4.00 [1.47, 10.85]	2013
Khan et al 2017	2	83	0	104	0.5%	6.41 [0.30, 135.39]	2017
Colom-Beauchamp E et al 2017	0	26	0	41		Not estimable	2017
Bains R et al 2017	73	5987	47	4382	56.8%	1.14 [0.79, 1.65]	2017
Total (95% CI)		**22318**		**83774**	**100.0%**	**1.21 [0.93, 1.59]**	
Total events	119		150				

Heterogeneity: Chi² = 16.05, df = 7 (P = 0.02); I² = 56%
Test for overall effect: Z = 1.40 (P = 0.16)

Odds Ratio M-H, Fixed, 95% CI
0.2 0.5 1 2 5
Treatment (BMP) Control

B



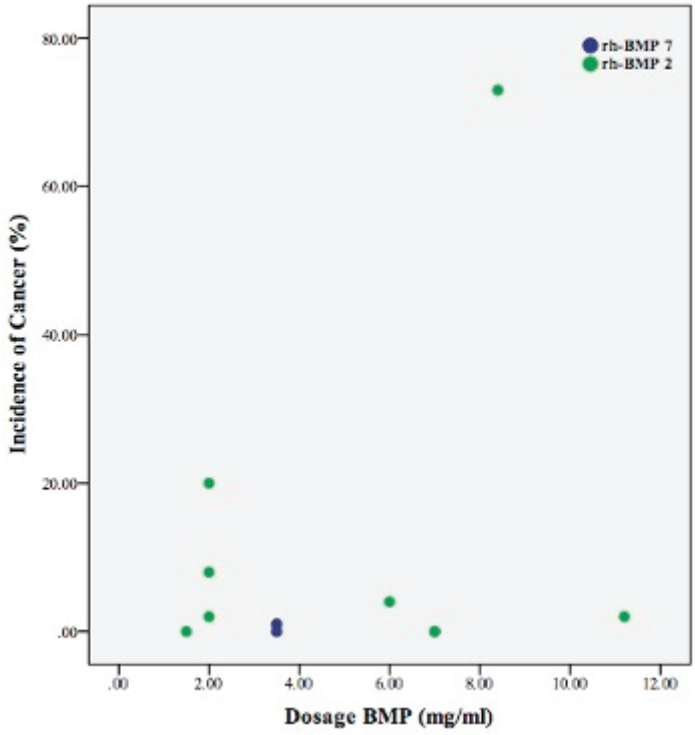
Study or Subgroup	Treatment (BMP) Events	Total	Control Events	Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Vaccaro A et al 2005	0	24	0	12		Not estimable	2005
Vaccaro A et al 2007	3	24	1	12	65.4%	1.57 [0.15, 16.94]	2007
Delawi D et al 2010	1	18	0	16	34.6%	2.83 [0.11, 74.46]	2010
Total (95% CI)		**66**		**40**	**100.0%**	**1.93 [0.28, 13.18]**	
Total events	4		1				

Heterogeneity: Tau² = 0.00; Chi² = 0.08, df = 1 (P = 0.78); I² = 0%
Test for overall effect: Z = 0.67 (P = 0.50)

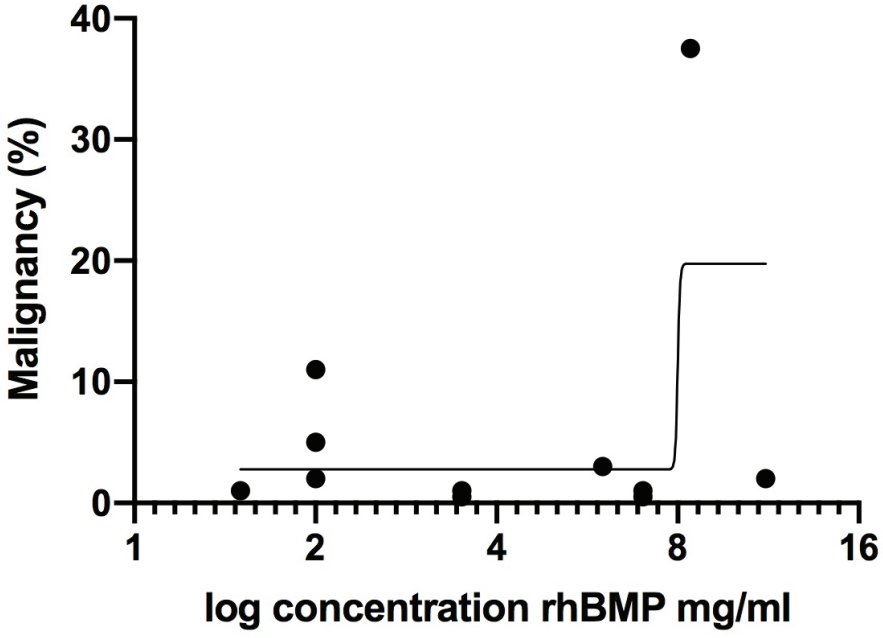
Odds Ratio M-H, Random, 95% CI
0.1 0.2 0.5 1 2 5 10
Treatment (BMP) Control

C

PRESENTATION #30 continued



PRESENTATION #30 continued



PRESENTATION #31

Cervical Myelopathy and Hip Fractures: Co-incidence, Epidemiology, and Costs of Care

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Introduction: Hip fractures are devastating injuries for the elderly and an increasing burden to the healthcare system. Cervical myelopathy, as a common cause of disability, instability, and falls in this population, places patients at risk for hip fracture, and myelopathic patients are associated with increased complications after hip surgery. Myelopathy's co-incidence with hip fractures and impact, however, is not well understood. This study sought to determine the incidence of myelopathy among hip fracture patients and hypothesized that hip fractures in myelopathic patients were associated with greater complexity and costs.

Materials and Methods: In this institutional review board-exempt study, Medicare 1) hip fracture and 2) cervical myelopathy patients between 2005 and 2012 were identified using the PearlDiver Patient Records Database (PearlDiver Technologies, Inc., CO) with International Classification of Diseases, Ninth Revision, (ICD-9) and Common Procedural Terminology (CPT) codes. Myelopathic hip fracture patients were compared with non-myelopathic counterparts by age, comorbidities, average payments, and average lengths of stay (LOS). Myelopathic patients who were treated with cervical decompression prior to hip fracture were also compared with those without prior decompression. Statistical analysis with t-test and Chi-squared test was performed, with statistical significance set at $p<0.05$.

Results: 22,884 of 2,309,972 hip fracture patients (1.0%) from 2005-2012 had cervical myelopathy. Hip fracture patients with myelopathy were significantly younger ($p<0.001$) but had significantly greater incidence of hypertension, coronary artery disease, stroke, obesity, tobacco use, diabetes, and osteoporosis ($p<0.001$) than non-myelopathic counterparts, as well as significantly greater average per-patient payments ($16,549.21 v. $10,300.88, $p<0.001$) and average LOS (6.66 v. 6.38 days, $p<0.001$). 461 of these myelopathic patients (461/22,884; 2.0%) underwent cervical decompression for myelopathy prior to hip fracture. When compared with myelopathic patients who did not undergo cervical decompression prior to hip fracture (22,423/22,884, 98.0%), post-decompression myelopathic hip fracture patients were seen to have significantly increased incidence of all medical comorbidities ($p<0.001$) but also significantly decreased average payments ($7,376.97v. $16,607.81 $p<0.001$) and LOS (6.04 v. 6.67 days, $p=0.011$).

Conclusion: Although a small fraction of overall hip fractures, hip fractures in cervical myelopathic patients are significantly more complex than non-myelopathic counterparts and incur significantly greater costs and longer admissions. Cervical decompression prior to hip fracture appears to decrease costs and lengths of stay in this population, suggesting faster recovery from hip fracture despite medical complexity. This supports that early treatment of cervical myelopathy may be an important part of hip fracture prevention.

PRESENTATION #32

Racial and social determinants of health disparities in patient presentation for cervical spine surgery: census tract level disparities reveal greater preoperative morbidity and worse POD 90 patient reported outcomes

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University of Pennsylvania[1]

Introduction: Timeliness of care consists of the healthcare system's ability to recognize and identify a patient's need and to provide appropriate care, and is one of the Institute of Medicine's priorities 1. The literature thus far suggests that marginalized patients are more likely to present for surgical intervention later in the course of disease process, leading to greater pain and functional impairment. We hypothesized that racial and socioeconomic disparities contribute to worsened pre-operative functionality, and in turn, to attenuated healing trajectories by three months(90D) post-op.

Materials and Methods: Patients must have had a Patient-Reported Outcome Measurement Information System (PROMIS) Global Physical Health (GPH) score, a PROMIS Global Mental Health (GPH) score, and a Visual Analog Scale (VAS) pain score upon presentation. The five most prominent spinal procedures within the cohort: 1-2 segment cervical decompression and fusion, multi-level cervical or thoracic laminotomy, 1-2 segment lumbar laminotomy, 1-2 level lumbar interbody fusion, and arthrodesis to correct long, spinal deformity but limited to 8 segments. Our primary outcome of interest was the PROMIS Global Physical Health Score. Social determinants of health were garnered from publicly available databases. A multivariable linear regression model with stepwise selection (cutoff: P=0.05) was constructed to quantify the degree to which a patient's preoperative PROMIS Global Physical Health (GPH) score was related to social determinants of health characteristics.

Results: When compared to White patients undergoing the same procedure, Black/African American patients had median VAS pain scores that were 16.7% higher, indicating greater pain, among those undergoing cervical decompression and fusion (P= 0.047) and had median VAS pain scores that were 60% higher among those undergoing cervical/thoracic laminotomy (P=0.0005) when compared to White patients. Additionally, Black/African American patients had significantly lower median PROMIS mental scores among those undergoing cervical/thoracic laminotomy (P=0.0012) as well as significantly lower median PROMIS physical scores among those undergoing cervical decompression and fusion (P=0.0028) and cervical laminotomy (P=0.0024) (Table 1). When compared to the highest pre-operative PROMIS GPH Scores (GPH =14+), patients with GPH scores in the lowest quartile (Score= 1-8) reported POD 90 PROMIS GMH scores that were 36.8% worse (P<0.0001) and POD90 GPH scores that were 37.5% worse (P<0.0001). Patients who reported the lowest GPH scores resided in communities where the median household income was 26% lower (P<0.0001) and the area deprivation index was 45.4% higher, indicating greater deprivation (P<0.0001). Further, the neighborhoods of patients who reported lowest quartile GPH scores are characterized 10.7% higher population per primary care provider (P=0.0031 (Table 2). Black race (B = -1.011, P=0.012), reduced access to primary care (B = -1.616, P<0.0001), and low SES (B = -1.504, P=0.001) were independent drivers of worse presenting GPH scores (Table 3).

Conclusion: Racial and socioeconomic disparities exist in patients' pre-operative physical

PRESENTATION #32 continued

and mental health when presenting for spine surgery and their post-operative outcomes. As it is well-established that patients with more severe baseline pathological impairments demonstrate worse post-operative outcomes after spine surgery, it is imperative that the orthopedic community mitigate these causes of delays in referral and strive to prioritize timeliness of care.

Table 1. Characteristics of patients who self-identified as racially White versus Black/African American, stratified by the type of procedure.

	Cervical Decompression and Fusion [1-2 Levels]		Cervical or Thoracic Laminectomy [Multilevel]		Lumbar Laminectomy [1-2 Levels]		Lumbar Interbody Fusion [1-2 Levels]		Arthrodesis for Spinal Deformity [<8 Segments]	
Demographic Characteristics	*White*	*Black/African American*	*White*	*Black/African American*	*White*	*Black/African American*	*White*	*Black/African American*	*White*	*Black/African American*
Age in Years	59.03	53.07	64.31	67.57	60.09	58.69	64.09	63.52	63.39	58.32
95% C.I	(56.87 - 61.18)	(49.16 - 56.98)	(61.13 - 67.49)	(63.73 - 71.41)	(57.88 - 62.3)	(55.16 - 62.22)	(62.27 - 65.91)	(59.96 - 67.08)	(60.34 - 66.43)	(52.39 - 64.25)
P Value	**P= 0.025**		P= 0.2627		P=0.4776		P=0.8077		P=0.1516	
Charleson Comorbidity Score	1.76	1.56	1.67	1.26	1.67	1.65	1.63	1.66	1.7	1.75
95% C.I	(1.55 - 1.98)	(1.22 - 1.9)	(1.33 - 2.12)	(1.18 - 1.44)	(1.51 - 1.83)	(1.37 - 1.93)	(1.47 - 1.78)	(1.3 - 2.12)	(1.43 - 1.96)	(1.31 - 2.19)
P Value	P= 0.4542		P=0.0851		P=0.7704		P=0.6501		P=0.9337	
Visual Analog Scale Pain	6	7	5	8	5	8	6	7	5	8
Interquartile Range	(3 - 10)	(5 - 10)	(3 - 7)	(5 - 10)	(3 - 8)	(6 - 9)	(4 - 8)	(5 - 9)	(4 - 7)	(5 - 8)
P Value	**P= 0.0474**		**P=0.0005**		**P<0.0001**		**P=0.0167**		**P=0.0012**	
Presenting Mental PROMIS Score	13	13	12	6.5	13	12	13	11	12	12
Interquartile Range	(10 - 14)	(8 - 14)	(10 - 14)	(3.5 - 12)	(9 - 16)	(8.5 - 14)	(10 - 15)	(2 - 14)	(9 - 14)	(5.75 - 15)
P Value	P= 0.3489		**P=0.0012**		**P=0.0195**		**P=0.0208**		P=0.5417	
Presenting Physical PROMIS Score	12	9	11	6.5	11	9	11	10	10.5	9.5
Interquartile Range	(10 - 12)	(5.5 - 12)	(8 - 13)	(2 - 10.25)	(9 - 13.5)	(7 - 11)	(9 - 13)	(5 - 11)	(9 - 12)	(5.75 - 11)
P Value	**P=0.0028**		**P=0.0024**		**P<0.0001**		**P=0.0100**		**P=0.0261**	
90 D Mental PROMIS Score	17	14	16	11.5	17	13	16	14	16	14
Interquartile Range	(13 - 16.5)	(10 - 16.5)	(12 - 20)	(6 - 15.25)	(13 - 21)	(11 - 16)	(13 - 20)	(9 - 16)	(13 - 20)	(10 - 17)
P Value	**P=0.0119**		**P=0.0248**		**P<0.0001**		**P=0.0029**		**P=0.0788**	
90 D Physical PROMIS Score	21	12	21	13	21	15	19	13	20	13.5
Interquartile Range	(14 - 17)	(9 - 17)	(15 - 24)	(11.75 - 17.5)	(15 - 25)	(11 - 18)	(15 - 24)	(10 - 19)	(16 - 24)	(9.75 - 18.5)
P Value	**P=0.0007**		**P=0.0124**		**P<0.0001**		**P<0.0001**		**P=0.0007**	

Legend: PROMIS Physical [Patient Reported Outcome Information System Global Physical Health Score]; PROMIS Mental [Patient Reported Outcome Information System Global Mental Health Score]. Significant values are bolded. Values are reported as means along with 95% confidence intervals. Significance is assessed via unpaired t tests. For VAS Pain Score, PROMIS mental score, and PROMIS physical score, values are reported as medians along with interquartile range (IQR). Significance is assessed via Mann-Whitney Test between Black/African American patients and White patients.

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.

PRESENTATION #32 continued

Table 2. Socioeconomic comparison of patients that report the highest functional physical health PROMIS score with patients that report the lowest functional PROMIS scores

	Quartile 1 of Physical PROMIS Scores (1-8)	Quartiles 2-3 of Physical PROMIS Scores (9-13)	Quartile 4 of Physical PROMIS Scores (14+)	P Value ANOVA with Post-Hoc Bonferroni's Test for Multiple Comparisons or Kruskal-Wallis Test with Post-Hoc Dunn's Test
Patient Reported Outcomes at 90 Days Post-Op				
Mental PROMIS Score 90 D Post-Op	12	16	19	$P_{Kruskal-Wallis}$ = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
Interquartile Range	(9 - 14)	(14 - 20)	(15.75 - 22.25)	$P_{(\Delta Mental\ PROMIS\ Kruskal-Wallis)}$ = 0.0254 $P_{(\Delta Mental\ PROMIS\ Q1\ vs.\ Q4)}$ = 0.0233
Physical PROMIS Score 90 D Post-Op	15	20	24	$P_{Kruskal-Wallis}$ = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
Interquartile Range	(11 - 18)	(13 - 24)	(16 - 27)	$P_{(\Delta Physical\ PROMIS\ Kruskal-Wallis)}$ = 0.0008 $P_{(\Delta Physical\ PROMIS\ Q1\ vs.\ Q4)}$ = 0.0005
Economic Metrics of a Patients Community				
Median Household Income	$64,116.82	$79,359.82	$86,656.10	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
American Community Survey, Census Tract	(60612.99 - 67620.65)	(76673.55 - 82046.09)	(81740.06 - 91572.15)	
Median Household Value	$216,134.23	$275,330.72	$300,135.69	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
American Community Survey, Census Tract	(201891.97 - 230376.5)	(263566.1 - 287095.34)	(280245.66 - 320025.71)	
Percentage of Families living under the FPL	12.43	8.48	6.68	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
American Community Survey, Census Tract	(11.1 - 13.76)	(7.69 - 9.27)	(5.6 - 7.76)	
Area Deprivation Index	71.37	43.64	38.94	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
Neighborhood Atlas, Census Tract	(68.14 - 74.6)	(41.34 - 45.94)	(35.41 - 42.47)	
Health Metrics of a Patients Community				
Obesity Prevalence	36.09	34.47	33.18	P_{ANOVA} = 0.0022 $P_{(Q1\ vs.\ Q4)}$ = 0.0015
Prevalence Zip Code, CDC	(34.83 - 37.35)	(33.77 - 35.17)	(32.1 - 34.27)	
Diabetes Prevalence	9.87	9.30	9.01	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
Prevalence Zip Code, CDC	(9.66 - 10.08)	(9.14 - 9.45)	(8.78 - 9.25)	
Population in Thousands /PCP	1.34	1.25	1.21	P_{ANOVA} = 0.0021 $P_{(Q1\ vs.\ Q4)}$ = 0.0031
Behavioral Risk Factor Surveillance System, County	(1.28 - 1.39)	(1.21 - 1.28)	(1.17 - 1.26)	
Population Density of Patient's Community	2763.42	1976.35	1324.95	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
American Community Survey, Zip Code	(2401.15 - 3125.69)	(1733.41 - 2219.29)	(1011.49 - 1638.4)	
Percentage with Education Less than College	66.50%	59.43%	55.42%	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
American Community Survey, Zip Code	(64.26 - 68.73)	(57.82 - 61.04)	(52.6 - 58.24)	
Non-White Population in Community (%)	38.10%	27.02%	22.52%	P_{ANOVA} = <0.0001 $P_{(Q1\ vs.\ Q4)}$ = <0.0001
American Community Survey, Zip Code	(34.23 - 41.97)	(24.76 - 29.27)	(19.45 - 25.59)	
Metrics Pertaining to Community Health by CDC Surveys				
% Report Engaging in Any Physical Activity	69.77%	72.91%	73.49%	P_{ANOVA} = 0.0105 $P_{(Q1\ vs.\ Q4)}$ = 0.0497
Behavioral Risk Factor Surveillance System, County	(67.68 - 71.85)	(71.68 - 74.14)	(71.25 - 75.73)	
% Report Engaging in CDC Recommednded Activity	48.02%	51.19%	52.20%	P_{ANOVA} = 0.0003 $P_{(Q1\ vs.\ Q4)}$ = 0.0012
Behavioral Risk Factor Surveillance System, County	(46.45 - 49.6)	(50.22 - 52.15)	(50.49 - 53.91)	

Legend: PROMIS Physical [Patient Reported Outcome Information System Global Physical Health Score]; PROMIS Mental [Patient Reported Outcome Information System Global Mental Health Score]. Significant values are bolded. Values are reported as means along with 95% confidence intervals. For these values, significance is assessed via One-Way ANOVA with Bonferroni-corrected post hoc t tests. Bonferroni-corrected post hoc t tests in the rightmost column compre the cohort with the lowest quartile of Physical PROMIS Scores [worsened functionality] with the highest quartile of Physical PROMIS Scores [best functionality]. For post-operative PROMIS metrics, values are reported as median along with interquartile range. For these values, significance is assessed via Kruskal-Wallis Test with post-hoc Dunn's test for multiple comparisons. Δscore for Physical and Mental PROMIS refers to a Kruskal-Wallis, non-parametric test with post-hoc Dunn's test for multiple comparison on the difference between pre-op and post-op scores. The leftmost column indicates the socioeconomic metric being assessed, the publically available database utilized, as well as the geographic granularity of the metric [zip code or county].

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #32 continued

Table 3.Unadjusted univariate and adjusted, multivariable linear regression model for PROMIS Global Physical Health Score among spine surgery patients.

	Physical Functionality, PROMIS Score n = 854	
	Unadjusted β Parameter (P Value)	Adjusted β Parameter (P Value)
Age in Years		
Age (Each 10 year increase)	-0.024 (0.8024)	
Gender		
Male	**0.613 (0.0168)**	**0.488 (0.0447)**
Female	*1.00 [Reference]*	
Self-Identified Race		
Non-Black Minority	-0.314 (0.5249)	-0.181 (0.7058)
Black/African American	**-2.47 (<.0001)**	**-1.011 (0.012)**
White	*1.00 [Reference]*	
Prevalence of Chronic Disease within Community		
Prevalence of Obesity	**-0.659 (<.0001)**	
Prevalence of Diabetes	**-0.437 (<.0001)**	
Access to Primary Care within the Community		
Population per Primary Care Provider [Each 1,000 Increase]	**-1.616 (<.0001)**	**-1.422 (<.0001)**
Proportion of Families under FPL		
Proportion of Families under FPL [Each 10% Increase]	**-1.101 (<.0001)**	
Community Metrics		
Percentage of Non-White Residents in Community [Each 10% Increase]	**-0.336 (<0.0001)**	
Percentage of Population without College Education [Each 10% Increase]	**-0.476 (<.0001)**	
Charleson Comorbidity Score		
Score = 0	*1.00 [Reference]*	
Score =1-2	-0.52 (0.1212)	
Score > 2	0.064 (0.8508)	
Percentage of Six Figure Household Incomes (Census Tract)		
Quartile 1 (0 - 20.65)	**-2.895 (<.0001)**	
Quartile 2 (20.65 - 36.3)	**-1.086 (0.0017)**	
Quartile 3 (36.3 - 48.7)	-0.335 (0.3339)	
Quartile 4 (48.7 - 91)	*1.00 [Reference]*	
Median Household Value within a Census Tract		
Quartile 1 (< $169,693)	**-2.991 (<.0001)**	**-1.504 (0.001)**
Quartile 2 ($169,693 - 241,533)	**-1.184 (0.0007)**	**-0.556 (0.1561)**
Quartile 3 ($241,533 - 351,705.5)	**-1.101 (0.0016)**	**-0.901 (0.0109)**
Quartile 4 ($351,705.5 - 1,107,867)	*1.00 [Reference]*	
Median Household Income within a Census Tract		
Quartile 1 (< $53,498)	*1.00 [Reference]*	
Quartile 2 ($53,498 - 74,810.5)	**1.716 (<.0001)**	
Quartile 3 ($74,810.5 - 96,998)	**2.501 (<.0001)**	
Quartile 4 ($96,998 - 216,364)	***2.85 (<.0001)***	
Unemployment Rate within the Community		
Quartile 1 (0 - 4.1)	*1.00 [Reference]*	
Quartile 2 (4.1 - 5.2)	**0.073 (0.8339)**	0.472 (0.1726)
Quartile 3 (5.2 - 7.775)	**-0.782 (0.025)**	0.054 (0.8862)
Quartile 4 (> 7.775)	***-2.6 (<.0001)***	-0.575 (0.2807)
Population Density (Persons/Mile^2)		
Quartile 1 (10.3 - 325.1)	*1.00 [Reference]*	
Quartile 2 (325.1 - 730.45)	-0.422 (0.2293)	**-1.106 (0.0023)**
Quartile 3 (730.45 - 2942.5)	**-1.057 (0.0028)**	**-1.305 (0.0005)**
Quartile 4 (2942.5 - 13237.3)	***-2.498 (<.0001)***	***-1.055 (0.0315)***
Percentage of Community Reporting Engaging in Physical Activity		
Quartile 1 (< 69.1)	***-2.4 (<.0001)***	
Quartile 2 (69.1 - 75.65)	**-0.807 (0.0362)**	
Quartile 3 (75.65 - 79.1)	**-1.109 (0.0017)**	
Quartile 4 (79.1 - 82.7)	*1.00 [Reference]*	
Percentage of Community Reporting Engaging in Activity Meeting CDC Reccomendations		
Quartile 1 (< 43.8)	***-2.481 (<.0001)***	
Quartile 2 (43.8 - 54.6)	**-1.125 (0.0019)**	
Quartile 3 (54.6 - 58.1)	**-1.044 (0.003)**	
Quartile 4 (58.1 - 60.7)	*1.00 [Reference]*	
Spinal Pathology and Region of Spine		
Stenosis/Radiculopathy [Cervical Laminectomy]	*1.00 [Reference]*	
Stenosis/Radiculopathy [Cervical Decompression and Fusion < 3 Segments]	**2.001 (0.0001)**	**1.423 (0.0039)**
Stenosis/Radiculopathy [Lumbar Laminectomy]	**1.392 (0.0034)**	**1.03 (0.0219)**
Stenosis/Radiculopathy [Lumbar Fusion < 3 Segments]	**1.297 (0.0072)**	0.587 (0.2026)
Correction of Long Spinal Deformity <8 Segments	0.869 (0.1167)	0.738 (0.157)
Model Goodness of Fit		***F = 8.90; P < 0.0001***

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.

PRESENTATION #33

No Difference in Reoperation Rates in Posterior Cervical Fusions Stopping at C7 versus T1/T2 for Adjacent Segment Disease (Operative ASD): A cohort of 875 Patients – Part 1

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Introduction: There are surgical fusion treatment challenges to the anatomical complexities of the cervicothoracic junction (CTJ). Current posterior cervical spine surgery is based on the belief that adjacent segment disease (ASD) occurs if fusions are stopped at C7 although there is varying evidence to support this belief. The purpose of this study is to determine if there is a difference in reoperation rates for adjacent segment disease (operative ASD) in posterior cervical fusions (PCFs) that stop at -C7 versus at -T1/T2.

Materials and Methods: We conducted a retrospective cohort study using data from the Kaiser Permanente Spine Registry between 2009-2019. The cohort consisted of adult patients (=18 years old) with the diagnosis of cervical degenerative disc disease, cervical trauma, or cervical deformity who underwent primary PCFs between C3 to T1/T2 stopping at -C7 or -T1/T2. Reoperation for adjacent segment disease (we introduce the new term operative ASD) was the primary outcome of interest and patients were followed until validated operative ASD, membership termination, death, or 03/31/2020. Descriptive statistics and five-year crude incidence rates and 95% confidence intervals (CI) for operative ASD for PCF (between C3 to T1/T2) stopping at -C7 or -T1/T2. Time-dependent crude and multivariable Cox-Proportional Hazards models for operative ASD was used to evaluate operative ASD rates with adjustment for covariates or risk change estimates more than 10%.

Results: We identified 875 patients with PCFs (between C3 to T1/T2) stopping at either -C7 (n=470) or -T1/T2 (n=405) with average follow-up time of 4.6 (±3.3) years and average time to operative ASD of 2.7 (±2.8) yrs. Crude overall incidence rates for stopping at -C7 (2.12% (1.02%-3.86%)) and -T1/T2 (2.48% (1.25%-4.40%)) were comparable with no statistical difference in risk (adjHR=1.47, 95% CI=0.61-3.53, p=0.39), Table 1. Additionally, we observed no differences in the probability of operative ASD in time-dependent models accounting for a competing risk of membership termination (Grey's Test p=0.448), Fig 1.

Conclusion: We presented one of the largest series of patients in the literature reporting reoperation rates for adjacent segment disease in PCFs stopping at -C7 versus -T1/T2. In our cohort of 875 patients with PCFs ranging from C3 to T1/T2 stopping at -C7 or -T1/T2, with an average follow-up of > 4 years, we found no statistical difference in reoperation rates for adjacent segment disease (operative ASD).

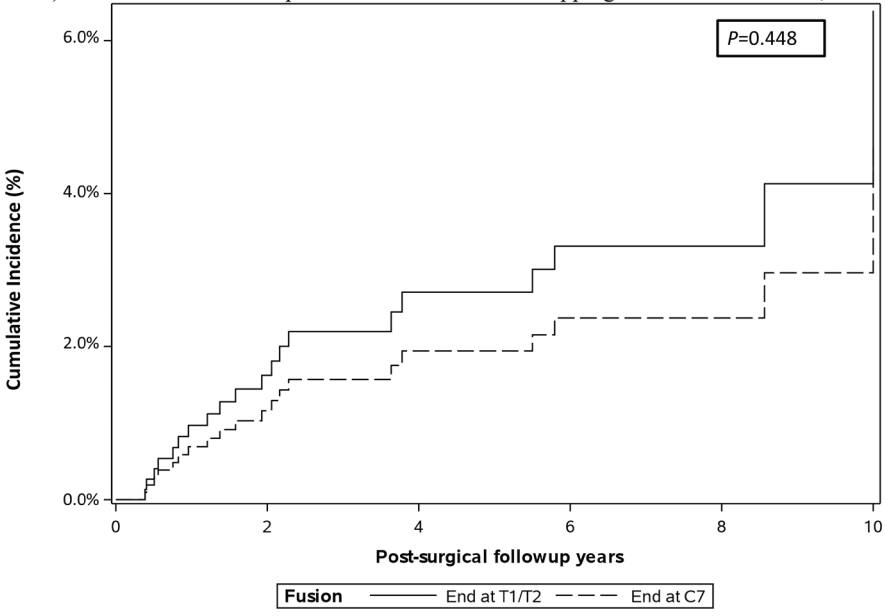
PRESENTATION #33 continued

Table 1. Crude and Adjusted Hazard Ratio and 95% CI for Operative ASD by Cephalad Level of construct Stopping at -C7 versus -T1/T2, N=875

Instrumented Levels		Fusion Cases	Operative ASD Events	Operative ASD Incidence Rate (95% CI)	Crude Hazard Ratio (95% CI)	Adj Hazard Ratio* (95% CI)
Cephalad C3						
	C3-C7	329	9	2.72% (1.25%-5.10%)	-	-
	C3-T1/T2	291	4	1.37% (0.37%-3.47%)	-	-
Cephalad C4						
	C4-C7	75	0	-	-	-
	C4-T1/T2	73	4	5.48% (1.51%-13.40%)	-	-
Cephalad C5						
	C5-C7	43	1	2.33% (0.06%-12.29%)	-	-
	C5-T1/T2	29	2	6.90% (0.85%-22.77%)	-	-
Cephalad C6						
	C6-C7	23	0	-	-	-
	C6-C7-T1/T2	12	0	-	-	-
All Levels						
	Stop at C7	470	10	2.12% (1.02%-3.86%)	(ref)	(ref)
	Stop at T1/T2	405	10	2.48% (1.25%-4.40%)	1.40 (0.59-3.32), *P*=0.44	1.47 (0.61-3.53), *P*=0.39

Note: 5 events per predictor variable were the minimum for Cox Regression analysis; CI=Confidence Interval.
**Adjusted for age at surgery and diabetes.*

Fig 1. Adjusted* cumulative incidence of reoperation for adjacent segment disease (operative ASD) between 2009-2019 in posterior cervical fusions stopping at -C7 versus -T1/T2, N=875.



**Adjusted for Age at surgery at surgery and diabetes*

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PRESENTATION #34

Physical Examination Findings of Patients With Myelopathy and Diabetes Mellitus

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Introduction: The diagnosis of cervical myelopathy relies heavily on a combination of history and physical examination findings. Patients with diabetes mellitus (DM) often present with unremarkable deep tendon reflexes (DTR) and absence of pathologic reflexes which are often seen in patients with cervical myelopathy. The objective of this study is to report on the reflex examination in a series of patients with cervical myelopathy and diabetes who underwent cervical spine surgery.

Materials and Methods: A retrospective, single-surgeon cohort study of consecutive patients operated on from 2016 to 2019 with a diagnosis of cervical myelopathy were analyzed. Demographic and operative data were collected. Preoperative physical examination was obtained from all patients which included the presence or absence of a Hoffman's sign, clonus, numbness of the arm or hand and weakness of the upper extremities. Deep tendon reflexes included the biceps, triceps, brachioradialis and lower extremity reflexes which were graded as either exhibiting findings of hyporeflexia, normal reflexes or hyperreflexia. Hand dexterity and a Romberg test were also assessed for difficulty. Statistical analysis included T-tests, chi-square and logistic regression.

Results: A total of 153 patients with myelopathy were identified during the study period, with 20.3% (31/153) of the patients presenting with DM. There was no significant difference in the incidence of spinal cord signal change or the surgical approach between non-DM and DM patients. There was an increased but nonsignificant incidence of preoperative weakness (50% vs. 36.9%; p=0.22) in patients with DM. Patients with DM more commonly presented with hyporeflexia in thier lower extremities (56.5% vs. 25.0%, p=0.012) when compared to non-DM patients. Although the incidence of hyporeflexia of the brachioradialis (43.4% vs. 23.5%; p=0.060), biceps (43.4% vs. 23.5%; p=0.073), and triceps (43.3% vs. 22.6%, p=0.058) were higher in patients with DM, this only approached significance. Patients with DM were 5.39 times more likely to have a positive Romberg (85% vs. 51.3%; OR:5.39; 95%CI: 1.46, 19.84; p=0.0062). However, non-diabetic patients were more likely to present with clonus (73.6% vs. 53.3%, p=0.033) and difficulty with tandem gait (72.5% vs. 51.7%; p=0.033).

Conclusion: In a large series of surgical patients with cervical myelopathy, 56% of patients with DM presented with hyporeflexia of the lower extremities. Nondiabetic patients often exhibited increased findings of clonus and hyperreflexia while patients with DM presented with a positive Romberg test and diminished reflexes throughout. Recognizing that DM may confound the clinical presentation of classic myelopathic symptoms is crucial for the timely diagnosis and treatment of such patients.

PRESENTATION #34 continued

Table 1. Demographic Information

	Non-Diabetic (N=122)	Diabetic (N=31)	*P*
Gender (F)	75 (61.5)	25 (80.7)	0.051
Age (median)	64.5 (16)	68.0 (17.0)	0.38
BMI (median0	26.5 (7.2)	30.0 (7.5)	0.0052
Smoking Status			
Never	97 (79.5%)	18 (58.1%)	
Current	3 (2.5%)	5 (16.1%)	0.0039
Former	22 (18.0%)	8 (25.8%)	
Duration of symptoms prior to surgery (median)	269 (696.0)	348 (1181.5)	0.21
Spinal Cord Signal Change	61 (50.0%)	15 (48.8%)	0.87
Preoperative weakness	41 (36.9%)	13 (50.0%)	0.22
Preoperative arm numbness	46 (38.0%)	6 (20.0%)	0.063
Preoperative hand numbness	80 (65.6%)	13 (43.3%)	0.025

Table 2. Surgical Approach

	Non-Diabetic	Diabetic	*P*
Single level surgery	22 (18.0%)	6 (19.4%)	0.87
Two Level surgery	34 (27.9%)	5 (16.1%)	0.18
>2 level surgery	66 (54.1%)	20 (64.5%)	0.30
Anterior approach	50 (41.0%)	8 (25.8%)	0.12
Posterior approach	64 (52.5%)	21 (67.7%)	0.13
Anterior/posterior approach	6 (4.9%)	2 (6.5%)	0.73

Table 3. Deep Tendon Reflex Examination of Myelopathic Patients

	Non-Diabetic			Diabetic			*P*
	Hypo	Normal	Hyper	Hypo	Normal	Hyper	
Brachioradialis	27/115 (23.5%)	16/115 (13.9%)	72/115 (62.6%)	13/30 (43.3%)	5/30 (16.7%)	12/30 (40.0%)	0.060
Biceps	27/115 (23.5%)	18/115 (15.7%)	70/115 (60.9%)	13/30 (43.3%)	5/30 (16.7%)	12/30 (40.0%)	0.073
Triceps	26/115 (22.6%)	14/115 (12.2%	75/115 (65.2%)	13/30 (43.3%)	4/30 (13.3%)	13/30 (43.3%)	0.058
Lower extremity	22/88 (25.0%)	24/88 (27.3%	42/88 (47.3%)	13/23 (56.5%)	5/23 (21.7%)	5/23 (21.7%)	**0.012**

PRESENTATION #35

Do Favorable Short-term Patient Reported Outcomes after ACDF Predict Loss to One- and Two-Year Follow-Up?

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Introduction: Because postoperative spine surgery patients are often lost to long-term follow-up, retrospective outcomes studies are subject to attritional bias. Controversy ensues in the literature whether adverse clinical outcomes fail to be captured due to lack of long-term follow-up. The factors associated with loss to follow-up after anterior cervical discectomy and fusion (ACDF) have yet to be elucidated. The primary aim of study was to determine if ACDF patients with greater improvement in patient reported outcomes measures (PROM) at early postoperative follow-up are more likely to be lost to follow-up at the one- year and two- year postoperative visits. The secondary aim was to elucidate the predictors of loss to long-term follow-up.

Materials and Methods: All patients over age 18 who underwent any primary or revision ACDF for radiculopathy and/or myelopathy at single academic institution were retrospectively identified. All patients attended a short-term (3 month) postoperative follow-up visit. Patients with traumatic injury, infection, malignancy, or incomplete medical records or outcome measures were excluded. Patient surgeries were stratified by revision status and number of fusion levels. Distance from patient residence to postoperative clinic site was determined. Patients lost to one- and two-year postoperative follow-up visits were identified. Preoperative and short- and long-term postoperative PROMs including Neck Disability Index (NDI), visual analog scale (VAS) Neck, VAS Arm, and Short Form-12 Physical Component (PCS) and Mental Component (MCS) Scores were collected. Univariate analysis compared patient demographics, surgical factors, and PROMs across groups with and without one- and two- year follow-up, respectively. Logistic regression isolated predictors of loss to follow-up.

Results: A total of 272 patients met the inclusion criteria. In the total cohort, 24.3% of patients were lost to one- year follow-up and 73.2% were lost to two-year follow-up. The clinical trajectory of all PROMs from the preoperative visit to the three-month (short-term), one-year, and two-year postoperative visits is visualized graphically in Figure 1. Loss to one-year ($p= 0.005$) and two-year ($p= 0.016$) follow-up was associated with significantly greater short-term VAS Neck pain reduction (Table 1). On the contrary, loss to two-year follow-up was associated with significantly decreased PCS improvement at one-year ($p= 0.039$) and reduced improvement in NDI between three-months and one-year ($p= 0.006$) (Table 1). All other short-term and long-term delta PROMs did not vary significantly by follow-up status. Multiple patient factors were found to predict loss to follow-up at one or two years after ACDF including: female gender, not being enrolled in Medicare, and single-level fusions (Table 2).

Conclusion: Patients lost to long-term follow-up after ACDF demonstrated greater improvements in neck pain but worse improvements in disability and functional status. Future

PRESENTATION #35 continued

efforts to mitigate retrospective cohort selection biases imparted from missing data should focus on adjusting outcome databases for patient specific factors associated with loss to long-term follow-ups. Many modalities including algorithmic and artificial intelligence-based approaches could be employed as a subject of future research.

Table 1: Comparison of Patient Outcomes Based on 1- and 2- Year Follow-up Status

Patient Outcome Measure	ΔPROM: Preop to 3 months Postop			ΔPROM: Preop to 3 months Postop			ΔPROM: Preop to 1 Year Postop			ΔPROM: 3 Months to 1 Year Postop		
	One Year Postop Follow-up			Two Year Postop Follow-up			Two Year Postop Follow-up			Two Year Postop Follow-up		
	No n= 66	Yes n= 206	P- value	No n=199	Yes n=73	P- value	No n=199	Yes n=73	P- value	No n=199	Yes n=73	P- value
PCS	5.73 (10.5)	3.84 (10.7)	0.234	3.82 (10.7)	5.61 (10.6)	0.248	5.85 (10.8)	9.66 (10.7)	**0.039**	2.85 (9.08)	4.18 (9.18)	0.534
MCS	3.45 (9.18)	1.77 (10.5)	0.249	2.45 (9.98)	1.40 (10.8)	0.508	-0.68 (11.0)	2.17 (12.3)	0.202	-0.71 (11.9)	1.89 (11.9)	0.318
NDI	-17.71 (14.6)	-13.63 (17.7)	0.124	-15.24 (16.9)	-12.82 (17.8)	0.383	-13.94 (19.3)	-19.60 (20.3)	0.153	0.88 (12.1)	-5.95 (14.4)	**0.006**
VAS Neck	-3.36 (2.53)	-1.98 (2.70)	**0.005**	-2.65 (2.70)	-1.52 (2.63)	**0.016**	-2.52 (2.74)	-2.25 (3.25)	0.845	0.17 (1.94)	-0.26 (2.06)	0.500
VAS Arm	-2.23 (3.35)	-1.56 (2.95)	0.300	-1.82 (3.02)	-1.53 (3.21)	0.654	-1.67 (2.93)	-2.22 (3.73)	0.309	0.71 (2.94)	-0.24 (2.64)	0.109

Table 2: Logistic Regression for Predictors of Office Follow-up After ACDF

Patient Variable	One Year Postop Follow-up		Two Year Postop Follow-up	
	Estimate	P-value	Estimate	P-value
Age	-0.01	0.641	-0.01	0.435
Sex: male	0.63	**0.040**	0.54	0.080
BMI	0.02	0.624	0.01	0.802
Smoking status: Never				
Current	Reference		Reference	
Former	-0.53	0.205	-0.63	0.182
CCI	-0.01	0.975	-0.11	0.756
Medicare insurance	-0.11	0.522	-0.34	0.058
Distance from patient residence to clinic	0.32	0.472	1.03	**0.014**
Revision spine surgery	0.01	0.334	0.01	0.205
Fusion status: Decompression only	0.67	**0.049**	1.12	**0.007**
Single level fusion	0.95	0.105	-0.51	0.358
Multi level fusion	-0.01	0.641	-0.01	0.435

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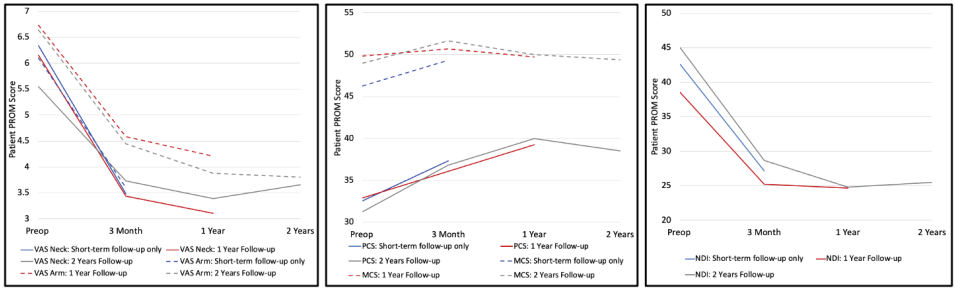
PRESENTATION #35 continued

Figure 1: ΔPROM Score by Follow-up Status



PRESENTATION #36

The Impact of Social Determinants of Health (SDOH) on 30- and 90-Day Readmission Rates Following Spine Surgery

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Introduction: Since its inception in 2012, the CMS Hospital Readmissions Reduction Program (HRRP) has espoused cost-effective healthcare delivery by financially penalizing hospitals with 30-day readmission rates in excess of what would be considered acceptable. Given the high cost of spinal surgeries, this present inquiry into the effects of socioeconomic factors in spine patient readmission is paramount.

Materials and Methods: 2830 consecutive patients undergoing spinal surgery were retrospectively identified. Inclusion criteria were patients undergoing spinal surgical procedures to correct the following pathologies : (1) diagnoses of deformity [undergoing arthrodesis]; stenosis/radiculopathy of the cervical spine [undergoing anterior cervical discectomy and fusion (ACDF) or posterior cervical fusion (PCF) with decompression], lumbar spine [undergoing anterior lumbar interbody fusion (ALIF) or posterior lumbar interbody fusion (PLIF) with decompression], or cervico-thoracic spine [undergoing >3 segment PCF into the thoracic spine with thoracic decompression]; or patients undergoing isolated <3 segment laminotomy/laminectomy. Social determinants of health (SDOH) were garnered from publicly available databases. Income was estimated per patient at the Public Use Micro Area level based on U.S. Census Bureau American Community Survey data. Univariate and multivariable stepwise regression analyses were conducted. Significance was defined as $P<0.05$, with Bonferroni corrections as appropriate.

Results: Chi squared analyses were conducted to discern the socioeconomic factors contributing to readmission. There was a strong effect of a patient's surrogate personal income on readmission status by POD 30 ($X2 = 340.70$, $P<0.0001$). Race had a significant effect on readmission status only among patients whose surrogate incomes were less than $31,650 ($X2 = 18.9$, $P<0.0001$)(Table 1). Compared to non-readmitted patients, patients readmitted by POD 30 lived in neighborhoods where the GINI Income Inequality Index Score was 4.26% higher (0.49 vs 0.47, $P<0.0001$), 1.3 times as many families lived below the federal poverty line (FPL) (15.76% vs 10.55% , $P<0.0001$), and the median home values were 11.2% lower ($232,275.77 vs $261,676.77, $P=0.0002$. Importantly, patients readmitted by POD 30 ($P<0.0001$) and between POD30-90 ($P=0.015$) lived in census tracts with 44.9% (61.0 vs. 42.2) and 17.4% (49.5 vs. 41.2) higher ADI rankings respectively (Table 2). On multivariable stepwise regression, patients under 45 years of age were least likely to be readmitted by 30 days. Female patients (OR: 1.69 [95% CI: 1.27 – 2.25]) as well as those living in neighborhoods with higher diabetes prevalence (OR: 3.04 [95% CI: 1.70 – 5.59]), and higher population per primary care provider (OR: 1.38 [1.12 – 1.70]) had higher odds of 30-day readmission. Additionally, patients with surrogate incomes less than $31,000 were 11.24 [7.69 – 16.9] times more likely to be readmitted to the hospital by POD 30, compared to patients with incomes greater than $62,000. Lastly, each decile increase in area deprivation index of a patient's census tract was associated with 1.44 [1.34 – 1.59] higher odds of 30-day readmission (Table 3).

Conclusion: Overall, our findings support the notion that health care systems serving

PRESENTATION #36 continued

socioeconomically disadvantaged patients or areas of high socioeconomic deprivation are at risk of increased readmissions following spine surgery.

Table 1. Demographic characteristics of study participants, stratified by readmission status, income, and neighborhood inequality.

	Non-Readmitted Patients	Readmitted Patients		X^2 (P Value) Non-Readmits vs. POD 30 Non-Readmits vs. POD 30-90
		0-30 days	30-90 days	
Sex				
Female	1193 (49.9%)	171 (52.94%)	52 (44.83%)	
Male	1198 (50.1%)	152 (47.06%)	64 (55.17%)	
Self-Identified Race				
White Race	1757 (73.48%)	185 (57.28%)	82 (70.69%)	
Black or African American	455 (19.03%)	114 (35.29%)	27 (23.28%)	
Non-Black Minorities	179 (7.49%)	24 (7.43%)	7 (6.03%)	
Estimated Income by Location, Exact Age, Race, Gender, Employment Status, Health Insurance and Education [a]				**340.7 (P<0.0001)** 2.744 (P=0.43)
< $31,650 [b]	***472 (19.75%)***	***217 (67.18%)***	***27 (23.28%)***	
White Race	316 (66.95%)	109 (50.23%)	19 (70.37%)	**18.87 (P<0.0001)** **0.136 (P=0.93)**
Black or African American	136 (28.81%)	89 (41.01%)	7 (25.93%)	
Non-Black Minorities	20 (4.24%)	19 (8.76%)	1 (3.7%)	
$31,650- $42,425 [b]	***721 (13.17%)***	***43 (13.31%)***	***40 (34.48%)***	
White Race	435 (60.33%)	24 (55.81%)	23 (57.5%)	1.595 (P=0.45) 0.220 (P=0.89)
Black or African American	227 (31.48%)	17 (39.53%)	14 (35%)	
Non-Black Minorities	59 (8.18%)	2 (4.65%)	3 (7.5%)	
$42,425 - $59,198 [b]	***520 (21.76%)***	***37 (11.46%)***	***21 (18.1%)***	
White Race	453 (87.12%)	31 (83.78%)	18 (85.71%)	3.337 (P=0.19) 1.414 (P=0.49)
Black or African American	47 (9.04%)	6 (16.22%)	3 (14.29%)	
Non-Black Minorities	20 (3.85%)	0 (0%)	0 (0%)	
> $59,198 [b]	***677 (28.33%)***	***26 (8.05%)***	***28 (24.14%)***	
White Race	553 (81.68%)	21 (80.77%)	22 (78.57%)	0.058 (P=0.97) 0.776 (P=0.58)
Black or African American	44 (6.5%)	2 (7.69%)	3 (10.71%)	
Non-Black Minorities	80 (11.82%)	3 (11.54%)	3 (10.71%)	
χ^2 (race across income brackets) [c]	**χ^2 = 238.3 (P<0.0001)**	**χ^2 = 24.90 (P=0.0004)**	χ^2 = 9.641 (P=0.14)	
Self-Identified Race by GINI Index Score (0 - 1) [d]				**51.31 (P<0.0001)** 1.525 (P=0.68)
1st quartile (<= 0.457) [e]	***622 (26.03%)***	***57 (17.65%)***	***31 (26.72%)***	
White Race	549 (88.26%)	52 (91.23%)	25 (80.65%)	0.77 (P=0.68) 2.10 (P=0.35)
Black or African American	33 (5.31%)	3 (5.26%)	2 (6.45%)	
Non-Black Minorities	40 (6.43%)	2 (3.51%)	4 (12.9%)	
2nd quartile (0.457 - 0.469) [e]	***618 (25.86%)***	***60 (18.58%)***	***29 (25%)***	
White Race	519 (83.98%)	41 (68.33%)	23 (79.31%)	**10.71 (P=0.0047)** 1.609 (P=0.44)
Black or African American	46 (7.44%)	11 (18.33%)	4 (13.79%)	
Non-Black Minorities	53 (8.58%)	8 (13.33%)	2 (6.9%)	
3rd quartile (0.469 - 0.516) [e]	***463 (19.37%)***	***50 (15.48%)***	***18 (15.52%)***	
White Race	370 (79.91%)	38 (76%)	14 (77.78%)	3.325 (P=0.19) 0.102 (P=0.95)
Black or African American	65 (14.04%)	11 (22%)	3 (16.67%)	
Non-Black Minorities	28 (6.05%)	1 (2%)	1 (5.56%)	
4th quartile (>= 0.516) [e]	***687 (28.74%)***	***156 (48.3%)***	***38 (32.76%)***	
White Race	319 (46.43%)	54 (34.62%)	20 (52.63%)	**7.836 (P=0.019)** 3.54 (P=0.17)
Black or African American	310 (45.12%)	89 (57.05%)	18 (47.37%)	
Non-Black Minorities	58 (8.44%)	13 (8.33%)	0 (0%)	
χ^2 (race across GINI quartiles) [f]	**χ^2 = 460.4 (P<0.0001)**	**χ^2 = 78.83 (P<0.0001)**	**χ^2 = 22.08 P=0.0012)**	

[a] P values for chi squared analysis to determine the effect of estimated personal income on readmission status.
[b] P values for chi squared analysis to determine the effect of self-identified race on readmission status within the specified income quartile. Comparisons include patients who were not readmitted by POD90 versus POD 30 readmits and subsequently versus POD 30-90 readmits.
[c] P values for chi squared analysis to determine the relationship between self-identified race and estimated personal income within the following cohorts: non-readmitted patients, 30 POD cohort, and 30-90 POD cohort.
[d] P values for chi squared analysis to determine the effect of neighborhood inequality on readmission status and timepoint.
[e] P values for chi squared analysis to determine the effect of self-identified race on readmission status and timepoint within the specified GINI Inequality Index quartile. Comparisons include patients who were not readmitted by POD90 versus POD 30 readmits and subsequently versus POD 30-90 readmits.
[f] P values for chi squared analysis to determine the relationship between self-identified race and GINI Inequality Index quartile within the non-readmitted cohort, 30 POD cohort, and 30-90 POD cohort.

PRESENTATION #36 continued

Table 2: Differences in Socioeconomic Determinants of the Patient's Neighborhood. [a]

	Non-Readmitted Patients	Readmitted Patients			
		0-30 days		30-90 days	
	Mean (95% CI)	Mean (95% CI)	*P-value*[b]	Mean (95% CI)	*P-value*[b]
Economic Determinants					
Area Deprivation Index (Neighborhood Atlas, Census Tract)	**42.16** (41.2 - 43.12)	**61.01** (58.02 - 64.02)	<0.0001	**49.5** (44.59 - 54.41)	0.015
Income Inequality (Gini Index, Zip Code)	**0.47** *(0.47 - 0.47)*	**0.49** *(0.48 - 0.49)*	<0.0001	**0.48** *(0.47 - 0.48)*	0.8061
Families in FPL (% of families, Zip Code)	**10.55** *(10.15 - 10.95)*	**15.76** *(14.58 - 16.95)*	<0.0001	**10.29** *(8.49 - 12.09)*	0.9973
Median Household Value (Zip Code)	**$261,676.77** *(256057.24 - 267296.3)*	**$232,275.77** *(217594.09 - 246957.45)*	0.0002	**$259,491.41** *(232228.35 - 286754.46)*	>0.9999
Factors Affecting Community Health					
Obesity Prevalence (Zip Code)	**36.35** *(36.12 - 36.57)*	**38.64** *(38.01 - 39.28)*	<0.0001	**36.50** *(35.42 - 37.58)*	0.9977
Population in Thousands/ Primary Care Provider (PCP) (Zip Code)	**1.27** *(1.26 - 1.29)*	**1.39** *(1.34 - 1.44)*	<0.0001	**1.24** *(1.19 - 1.30)*	0.7359
Diabetes Prevalence (Zip Code)	**9.52** *(9.45 - 9.59)*	**9.89** *(9.71 - 10.08)*	0.0013	**9.51** *(9.2 - 9.83)*	>0.9999
Population Density (Zip Code)	**2359.23** *(2241.44 - 2477.01)*	**3658.98** *(3255.38 - 4062.58)*	<0.0001	**2650.90** *(2087.86 - 3213.93)*	0.7658

[a] Differences in socioeconomic determinants stratified by non-readmitted patients and patients readmitted by 30 POD and 30-90 POD.
[b] P values reflect significant differences in socioeconomic measures when compared to non-readmitted patients by the Kruskal–Wallis test followed by Dunn's post-hoc tests for multiple comparisons.

PRESENTATION #36 continued

Table 3: Unadjusted univariate and adjusted multivariable logistic regression models. [a]

	0-30 Day Readmission *n = 323*			30-90 Day Readmission *n = 116*	
	Unadjusted OR (95% CI)	Stepwise Model Adjusted OR (95% CI) [b]	Conceptual Model Adjusted OR (95% CI) [c]	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Community Prevalence of Obesity					
Per 5 increase in prevalence	**1.395 (1.256 - 1.549)**			1.038 (0.886 - 1.215)	
Community Prevalence of Diabetes					
Per 5 increase in prevalence	**1.793 (1.273 – 2.525)**	**3.039 (1.703 – 5.586)**		1.109 (0.606 - 1.714)	
Community Educational Attainment					
Per 10% increase in percentage with education less than college	1.062 (0.997 - 1.131)	**0.696 (0.597 – 0.812)**		1.035 (0.939 - 1.141)	
Community Diversity					
Per 10% increase in percentage of non-white residents	**1.130 (1.088 - 1.174)**			**1.067 (1.004 - 1.134)**	
Geographic Access to Primary Care					
Per 500 person increase per PCP	**1.320 (1.170 – 1.490)**	**1.384 (1.123 - 1.704)**	**1.169 (1.101 – 1.366)**	0.880 (0.689 - 1.124)	
Community Poverty					
Per 5% increase in the percentage of families living under the FPL	**1.223 (1.164 - 1.286)**	**1.303 (1.172 - 1.449)**	**1.006 (0.929 - 1.090)**	0.986 (0.90 - 1.078)	
Area Deprivation Index					
Per decile increase	**1.295 (1.239 - 1.353)**	**1.443 (1.336 - 1.580)**	**1.218 (1.147 - 1.293)**	**1.077 (1.008 - 1.151)**	**1.080 (1.010 - 1.155)**
Patient's Age Cohort					
< 45 Years		*1.00 [Reference]*		*1.00 [Reference]*	
46-55 Years	**1.913 (1.238 – 2.957)**	**1.753 (1.077 – 2.853)**	**1.618 (1.000 – 2.618)**	0.719 (0.409– 1.262)	
55-65 Years	**2.536 (1.584 – 4.060)**	**2.526 (1.487 – 4.921)**	**2.602 (1.545 – 4.380)**	0.955 (0.512 – 1.781)	
65+ Years	**2.018 (1.381 – 2.948)**	**1.385 (1.007 – 2.115)**	**1.364 (1.008 – 2.296)**	0.645 (0.409 – 1.105)	
Patient's Self-Identified Race					
White Race		*1.00 [Reference]*		*1.00 [Reference]*	
Black/African American Race	**2.238 (1.741 – 2.879)**		0.917 (0.641 – 1.312)	1.346 (0.890– 2.036)	
Other Racial Minorities	**1.300 (0.829 – 2.038)**		1.146 (0.677 – 1.939)	1.081 (0.535– 2.181)	
Patient's Self-Identified Gender					
Male Gender		*1.00 [Reference]*		*1.00 [Reference]*	
Female Gender	0.895 (0.711 - 1.128)	**1.686 (1.265 – 2.248)**	**1.703 (1.288 – 2.253)**		
Patient's Medical Comorbidities					
Per 1 Increase in Charleson Score	1.065 (0.996 - 1.138)		1.033 (0.944 - 1.131)	0.980 (0.871 - 1.102)	
Specific Comorbidity: Diabetes					
Comorbid Diabetes	**1.353 (1.101 - 1.711)**		1.113 (0.753 - 1.643)	0.900 (0.527 - 1.537)	
Community Economic Inequality (GINI)					
Per 0.05 Increase in GINI Index	**1.752 (1.455 -2.110)**			1.143 (0.866 – 1.509)	
Median Household Value					
1st quartile (< $163, 988.0)	**1.926 (1.39 - 2.67)**	**0.525 (0.141 – 0.946)**		1.382 (0.837 - 2.281)	
2nd quartile ($163,988- 233,277)	1.365 (0.97 - 1.92)	1.690 (0.881 - 3.57)		1.098 (0.647 – 1.864)	
3rd quartile ($233, 277-333,830)	0.862 (0.59 - 1.25)	1.170 (0.703 – 1.950)		1.092 (0.646 - 1.845)	
4th quartile (> $333, 830.0)		*1.00 [Reference]*		*1.00 [Reference]*	
Estimated Patient Total Income					
1st quartile (< $31,000)	**12.02 (7.691 - 14.46)**	**11.238 (7.69 – 16.89)**	**12.149 (7.390 – 17.973)**	1.205 (0.707 – 2.055)	
2nd quartile ($31,000- $46,000)	**1.770 (1.04 – 2.419)**	1.408 (0.816 - 2.427)	1.325 (0.781 - 2.247)	1.298 (0.797 – 2.111)	
3rd quartile ($46,000 - $62,000)	1.729 (0.996 – 3.002)	1.765 (0.994 – 3.132)	1.631 (0.926 – 2.872)	0.744 (0.398 – 1.426)	
4th quartile (> $62,000)		*1.00 [Reference]*		*1.00 [Reference]*	
Population Density (Persons/Mile [2])					
Each 500 persons/mile[2] increase	**1.055 (1.038 – 1.073)**	1.036 (1.01 – 1.07) [++]		1.104 (0.987 - 1.043)	
Spinal Pathology and Procedure					
Arthrodesis for lumbar deformity	0.912 (0.71 - 1.16)		0.739 (0.55 – 0.99) [++]	0.882 (0.60 - 1.31)	
Lumbar stenosis/radiculopathy [1-2 Level ALIF/PLIF with Decompression]	0.969 (0.77 - 1.23)		0.854 (0.650 - 1.122)	1.221 (0.83 - 1.80)	
Arthrodesis for thoracic deformity	1.602 (0.81 - 3.18)	2.273 (1.106 –5.08) [++]	2.046 (0.918 – 4.588)	0.805 (0.19 - 3.33)	
Thoracic stenosis/radiculopathy [Long PCF with Thoracic Decompression]	**2.322 (1.25 - 4.33)**	3.217 (1.564 - 6.616)	2.832 (1.37 - 5.86) [++]	1.281 (0.40 - 4.15)	
Arthrodesis for Cervical Deformity	0.904 (0.63 - 1.31)		0.747 (0.489 - 1.142)	**0.461 (0.21 - 0.99)**	**0.461 (0.21 - 0.99)**
Cervical stenosis/radiculopathy [1-2 Level ACDF/PCF with Decompression]	0.991 (0.77 - 1.27)		0.857 (0.637 - 1.154)	0.959 (0.64 - 1.43)	
Other [<3 Level Laminotomy, Laminectomy)	1.207 (0.88 - 1.67)		1.453 (1.09 - 1.94) [++]	0.959 (0.64 - 1.43)	
Model Goodness of Fit		$X^2_{df=19}$ = 492.2741****	$X^2_{df=21}$ = 442.2211****		$X^2_{df=1}$ = 4.9642**

[a] Odds ratios for readmission at POD 30 and POD 30-90 among spine surgery patients. Bolded OR indicates significance at α=0.05 for unadjusted models, α=0.0035 for the adjusted 0-30 day readmission model, α=0.0030 for the conceptual model of POD 30 readmissions, and α=0.25 for the adjusted 30-90 day readmission model.
[b] Variables added to the adjusted 0-30 day readmission model were discerned using a forward, stepwise selection method.
[c] Variables added to the adjusted 0-30 day readmission model were discerned using literature review.
[++] indicates that OR found significance at P≤0.05 but not at $\alpha_{adjusted}$

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PRESENTATION #37

Safety Evaluation of Hydroxyapatite-Demineralized Bone Matrix Composite Scaffold for Spinal Fusion

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Introduction: Recombinant human bone morphogenetic protein-2 (rhBMP-2) is a potent stimulator of new bone formation utilized in spine fusion procedures to reduce the risk of pseudarthrosis, but it can also cause serious complications. To address these limitations, we developed a 3D-printed hydroxyapatite (HA)/demineralized bone matrix (DBM) scaffold as a recombinant growth factor-free bone graft substitute. Here, we evaluated the safety of the HA-DBM scaffold in a preclinical model of spine fusion, comparing it to rhBMP-2 in eliciting a host hyperinflammatory response.

Materials and Methods: This study employed a previously-established modified bilateral posterolateral lumbar spinal fusion (PLF) model whereby 0.5 g of tissue adjacent to the fusion bed was excised bilaterally and test implants were placed to bridge the transverse processes. Implants consisted of either (1) type I absorbable collagen sponge alone (ACS; negative control; n=20), (2) 10 µg rhBMP-2/ACS (positive control; n=20), or (3) HA-DBM composite scaffold (HA-DBM; n=20). Local soft tissue edema volume was quantified using MRI longitudinally out to eight weeks post-operative, and serum levels of inflammatory cytokines were quantified by ELISA.

Results: rhBMP-2 treatment resulted in significantly greater soft tissue edema volume on MRI relative to both ACS alone and HA-DBM treatment groups at post-operative day (POD) 2 (Fig. 1A-B). At POD 5, edema volume was also significantly greater in the rhBMP-2 group relative to the HA-DBM group. Similar trends in relative cytokine levels were also observed among treatment groups. At POD 2, the rhBMP-2 treatment group had significantly higher serum levels of TNF-α and MCP-1 expression, and higher IL-18 levels at POD 5 when compared with the ACS control. In contrast, HA-DBM treatment did not significantly induce any of the target cytokines

Conclusion: MRI analyses showed that rhBMP-2 treatment elicited a significant inflammatory response which peaked in the early post-operative period and decreased at later time points. In contrast, HA-DBM treatment resulted in no such local fluid collection. Similar trends were seen with rhBMP-2-mediated induction of IL-18, TNF-α, and MCP-1, with no such induction with HA-DBM treatment. This study demonstrates that the HA-DBM scaffold does not produce the same hyperinflammatory response associated with rhBMP-2 treatment.

PRESENTATION #37 continued

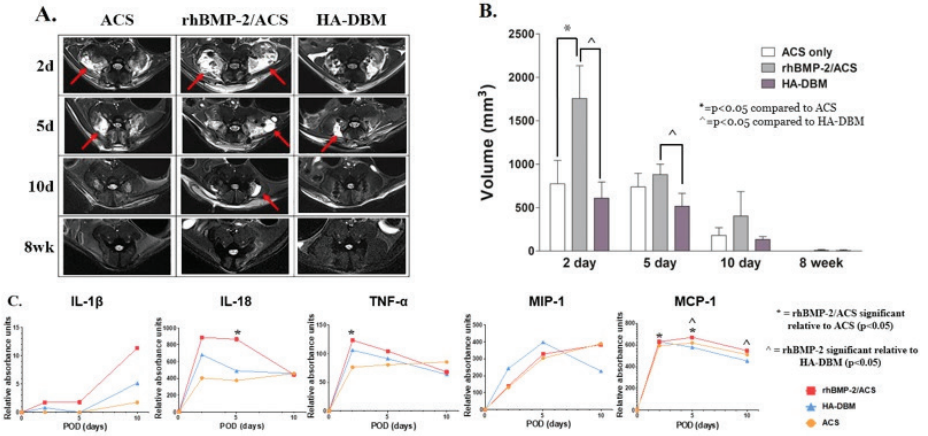

Figure 1: A. Representative T2-weighted MRI cross-section images at increasing postoperative time points in ACS only-, rhBMP-2/ACS-, and HA-DBM-treated animals. Red arrows indicate areas of greater fluid collection. **B.** Quantification of fluid collection volume at the fusion bed on axial T2-weighted MRI. **C.** Relative levels of IL-1β, IL-18, TNF-α, MIP-1, and MCP-1 in serum from animals treated with ACS only, rhBMP-2/ACS, and HA-DBM scaffolds as determined by ELISA.

PRESENTATION #38

Computed Tomography Osteoabsorptiometry (CT-OAM) Evaluation of Subchondral Bone Mineral Density in Cervical Endplates and Uncovertebral Joints: Implications for Subsidence and Clinical Practice

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Introduction: Poor subchondral bone mineral density (SBD) has been implicated with subsidence after anterior cervical surgery with interbody devices, which are traditionally placed centrally on the endplates. Subsidence can lead to significant morbidity including segmental kyphosis, disc height collapse, and vertebral body fracture, among others. Considering that SBD reflects long-term stress distributions on joints, we hypothesize that the uncinate process and corresponding articulating bone on the inferior endplate have denser subchondral bone than the central endplate region. Based on this hypothesis, these regions may be a target for more modern implants which leverage this increased bone strength. This study sought to investigate this relationship using computed tomography osteoabsorbptiometry (CT-OAM).

Materials and Methods: Twelve fresh human cervical spines (6 female, 6 male; age range 27-89 years) from C3-C7 (60 vertebrae, 120 endplates) were imaged with CT and segmented to create 3D reconstructions. The superior and inferior endplates were isolated, and the SBD of the whole endplate, endplate center, and uncus was then evaluated using CT-OAM from a depth of 0 mm to 4 mm. Normality of data was established using the Shapiro-Wilk test. SBD measurements were compared using ANOVA and post-hoc pairwise dependent t-test to evaluate the differences in SBD by cervical level. The threshold for statistical significance was set to $p < .05$.

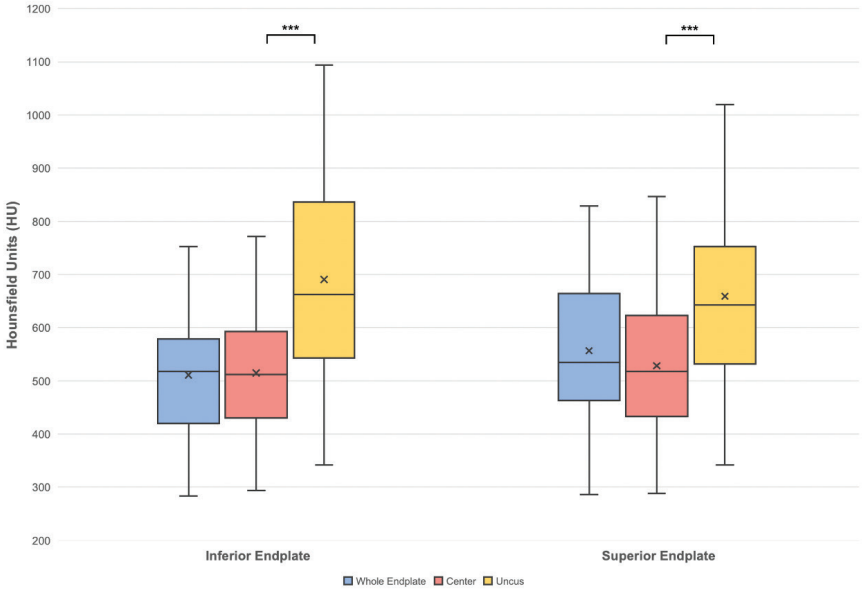
Results: Whole-group SBD evaluation (C3-C7) demonstrated significantly greater density at the uncus when compared to the endplate center for the inferior ($p < .0001$) and superior endplates ($p < .0001$; Figure 1). Sub-analysis by cervical level further corroborated these findings at all vertebral levels ($p < .01$, Figure 2). Whole-group comparison of inferior and superior endplate SBD demonstrated decreased whole endplate density in the inferior endplates ($p < .0001$), but no differences at the endplate center or uncus (Table 1). Further sub-analysis by vertebral level demonstrated greater density at the C4 inferior uncus relative to the superior uncus ($p < .0001$). At C7, the inferior endplate was significantly less dense than the superior endplate when measuring the whole endplate ($p = .0002$), endplate center ($p = .020$), and uncus ($p = .006$). This latter finding is contradictory to the overall trend seen at all other levels. Therefore, further analysis was performed excluding C7 (C3-C6 only). This demonstrated significantly greater SBD in the inferior uncus of C3-C6 than the superior uncus ($p < .0001$). Analysis comparing SBD between vertebral levels demonstrated significantly lower SBD at the C7 inferior whole endplate ($p = .001$), endplate center ($p = .009$), and uncus ($p = .014$) relative to cephalad levels. There were no differences in SBD by level in the superior endplates.

Conclusion: The subchondral bone of the cervical uncovertebral joints is significantly denser than the central endplates. Furthermore, while the superior endplate in its entirety is denser than the inferior endplate, the inverse was true for the subchondral bone of the uncovertebral joints. Further investigations are necessary to elucidate the biomechanical and clinical

PRESENTATION #38 continued

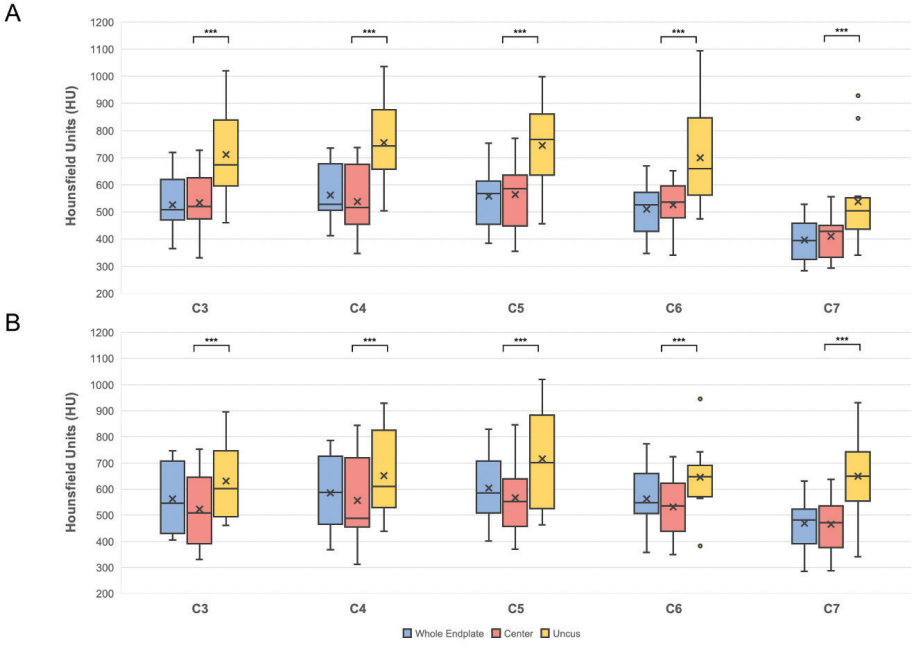
implications of these findings.

Figure 1. Box plot demonstrating subchondral bone mineral density in the regions of interest of the inferior and superior endplates. *Asterisks denote statistical significance.*



PRESENTATION #38 continued

Figure 2. Box plots demonstrating subchondral bone mineral density by cervical vertebral level in the (A) inferior endplate and (B) superior endplate. *Asterisks denote statistical significance.*



PRESENTATION #38 continued

Table 1. Comparison of inferior and superior endplate subchondral bone mineral density in Hounsfield units (HU) at all levels and by cervical vertebral level.

Level	Whole Endplate	Center	Uncus
All Levels			
Inferior Endplate	510.97 ± 114.75	514.77 ± 117.00	690.60 ± 177.01
Superior Endplate	**556.52 ± 127.55******	528.52 ± 135.08	658.88 ± 166.63
C3			
Inferior Endplate	526.92 ± 111.57	535.17 ± 117.80	710.92 ± 630.42
Superior Endplate	562.00 ± 133.45	524.08 ± 143.70	630.42 ± 145.75
C4			
Inferior Endplate	562.42 ± 110.28	538.33 ± 124.31	**755.92 ± 146.38******
Superior Endplate	585.50 ± 142.08	555.75 ± 161.65	652.33 ± 162.41
C5			
Inferior Endplate	558.67 ± 107.55	563.92 ± 118.25	746.42 ± 149.09
Superior Endplate	604.75 ± 121.99	567.67 ± 134.89	716.17 ± 189.03
C6			
Inferior Endplate	510.08 ± 95.45	526.17 ± 92.26	700.67 ± 179.53
Superior Endplate	561.75 ± 115.49	530.75 ± 124.29	645.25 ± 131.05
C7			
Inferior Endplate	396.75 ± 73.90	410.25 ± 76.48	539.08 ± 176.46
Superior Endplate	**468.58 ± 95.34*****	**464.33 ± 102.18***	**650.25 ± 156.80****

Bolding denotes statistical significance; * p < .05, ** p < .01, *** p < .001, **** p < .0001

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PRESENTATION #39

Novel In Vivo Imaging System of Grafted Human iPS Cell-Derived Neuron Activity after Spinal Cord Injury

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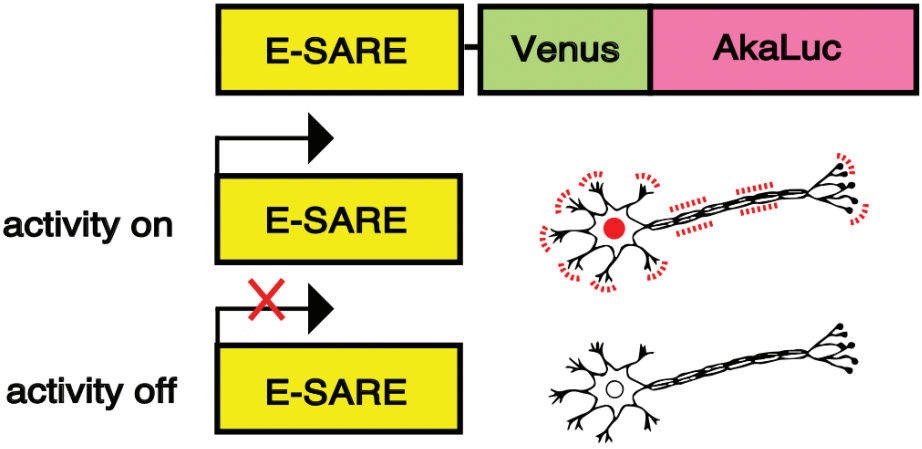
Introduction: Spinal cord injury (SCI) is a devastating and incurable disease. NS/PCs (Neural stem/progenitor cells) transplantation is one of the most promising therapies for SCI. NS/PCs integrate into lesional area and enhance motor function recovery[1]. The grafted cells can mainly differentiate into neurons, but only a little has been reported whether grafted neurons show action potential in vivo. The aim of this project is to establish a novel in vivo imaging system of neural activity of grafted neurons, and to reveal the connectivity between host circuit neurons projecting to the lesion and grafted neurons.

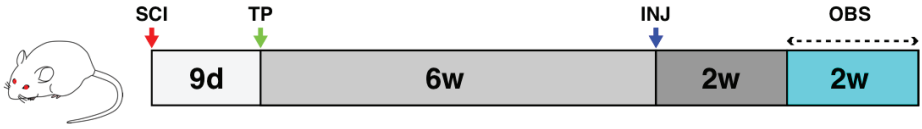
Materials and Methods: Dorsal column lesion was induced at the level of C4 spinal cord, and human iPSC-derived NS/PCs were transplanted into the lesional area at subacute phase of injury. For the transplanted NS/PCs, AkaBLI (Aka bioluminescence) system was used to clearly detect expression of Immediate early gene (IEGs; a marker of neuronal activity) promotor[2] [3]. Then, we introduced excitatory DREADD (Designer Receptors Exclusively Activated by Designer Drugs) transgene, hM3Dq, into corticospinal neurons injecting AAV vector into host sensorimotor cortex at six weeks after transplantation[4]. Three to four weeks after corticospinal tract (CST) labeling when viral vector permits efficient anterograde access to the C4 lesion, we assessed the effect of activation of corticospinal neurons on grafted cells measuring their photoncounts.

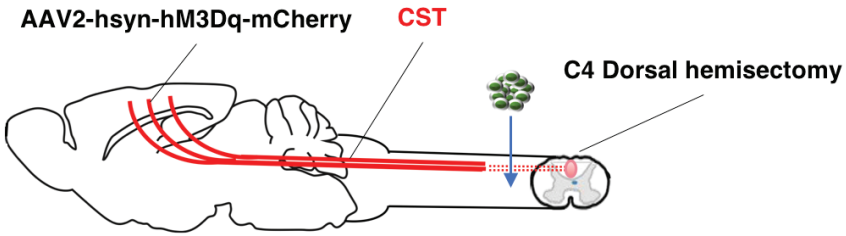
Results: In vitro, the photoncount of differentiated neurons from NS/PCs significantly increased when stimulated adding KCl. After transplantation of the NS/PCs, they survived well and differentiated into neurons and glial cells. The photoncount of transplanted cells elevated after CST stimulation by DREADD system, reached 1.5 times as high as the count without stimulation on average. We also visualized the photoncount of grafted cells in free moving animals using EM-CCD camera. The increased photons were positively correlated with the expression of fluorescence which was histologically detected depending on the neuronal activity of NS/PCs. Immunoelectron microscopic examination also detected robust synaptic connectivity of host-to-graft neurons.

Conclusion: Grafted neurons were activated after CST stimulation by DREADD system. This evidence directly demonstrates that synaptic connectivity was formed and functionally activated between host corticospinal and grafted neurons. This activity was visualized using EM-CCD camera in free moving animals. The results of this study emphasize on the significance of synaptic connectivity between the host spinal cord tracts and transplanted cell-derived neurons, using novel in vivo imaging techniques.

PRESENTATION #39 continued







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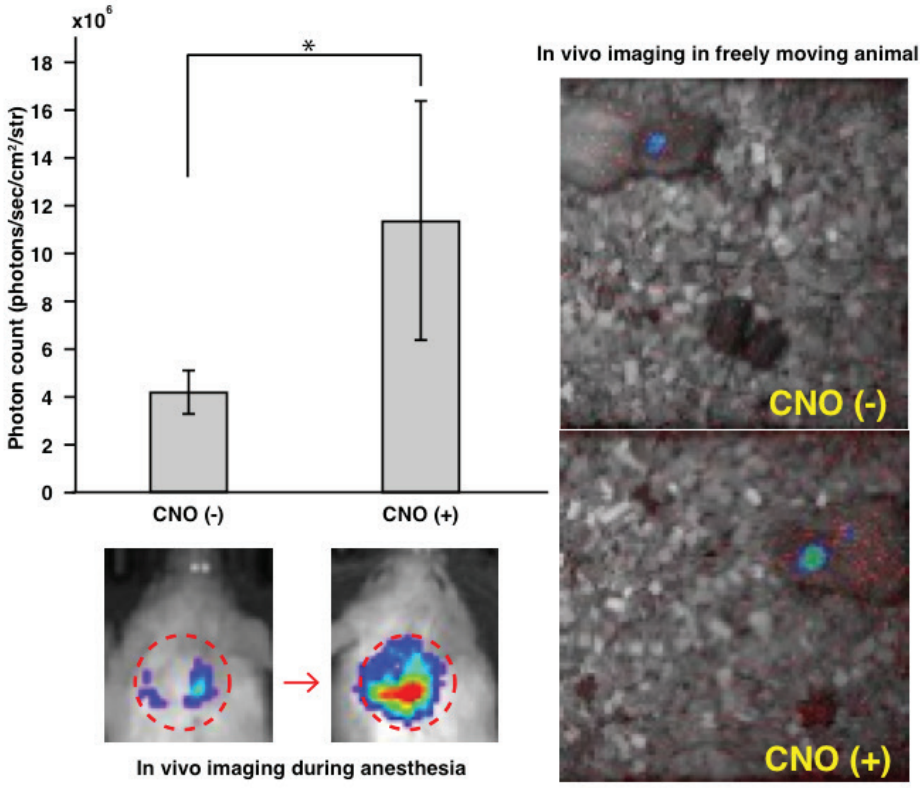


The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

PRESENTATION #40

Long-term Selective Stimulation of Transplanted Neural Stem/Progenitor Cells for Spinal Cord Injury Improves Locomotor Function Mediated by Increased Synaptic Transmission

Momotaro Kawai, MD[1], Narihito Nagoshi, MD, PhD, Takahiro Kitagawa, MD, Kentaro Ago, MD, Kent Imaizumi, MD, PhD, Mitsuru Ishikawa, PhD, Shinsuke Shibata, MD, PhD, Munehisa Shinozaki, MD, PhD, Morio Matsumoto, MD, PhD, Hideyuki Okano, MD, Masaya Nakamura, MD, PhD
Keio University School of Medicine[1]

Introduction: Transplantation of human-induced pluripotent stem cell-derived neural stem/progenitor cells (hiPSC-NS/PCs) is effective for functional recovery after spinal cord injury (SCI) (1, 2). The main mechanism of this recovery is to make synaptic formation between the host and the graft and restore the disrupted neuronal circuits (3). In the field of embryology, the activity of immature neurons is important to make and maintain synaptic connections (4). This evidence provided an idea to evaluate how enhanced activity of transplanted hiPSC-NS/PCs affects themselves and the host tissue.

We hypothesized that long-term selective stimulation of transplanted hiPSC-NS/PCs after SCI can enhance motor function recovery by enhancing synaptic connections between the host and the graft. Therefore, the present study aims to investigate the effect of long-term repetitive stimulations of transplanted hiPSC-NS/PCs on the gene and protein expressions, histological change of the surrounding spinal cord tissue, and the consequent functional recovery.

Materials and Methods: For selective stimulation of transplanted cells, we used hM3Dq, one of the Designer Receptors Exclusively Activated by Designer Drugs. First, hM3Dq was lentivirally transfected to hiPSC-NS/PCs. These hM3Dq-NS/PCs-induced neural cells (hM3Dq neural cells) were treated with Clozapine N-oxide (CNO), and the intracellular response was investigated by RNA sequence and Fluo-8 calcium indicator. Second, the extracellular response from CNO administered hM3Dq neural cells to neighboring neurons was recorded using the GCaMP calcium indicator. Cell cytotoxicity by CNO treatment and consequent calcium elevation were examined.

Next, the hM3Dq-NS/PCs were transplanted into the lesion epicenter of mouse spinal cords nine days after contusive SCI. Then, CNO was intraperitoneally injected daily to the transplantation-CNO group, and saline was similarly injected to the control group. RNA sequence, protein quantifications by capillary electrophoresis, and histological analyses were performed on days 14 and 42 after SCI. Motor functions were assessed by the Basso Mouse Scale (BMS) score, Rota-rod test, DigiGait analysis, and kinematics.

Results: RNA sequence revealed that CNO-administered hM3Dq neural cells expressed significantly higher levels of immediate early genes which were related to neuronal activity. CNO-administered hM3Dq neural cells enhanced their intracellular calcium concentration and activated neighboring GCaMP-positive/hM3Dq-negative neurons in vitro. Additionally, CNO treatment and subsequent calcium elevations did not adversely affect the hM3Dq neural cells.

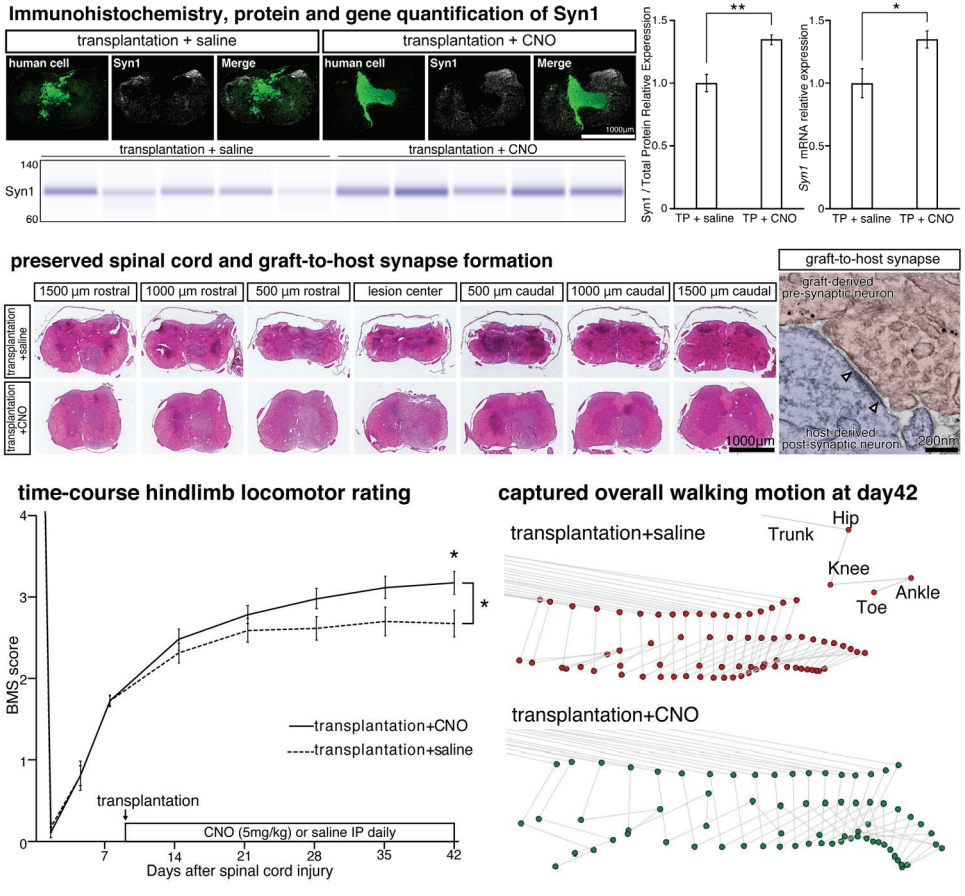
After hM3Dq-NS/PCs transplantation into injured spinal cords, RNA sequence and capillary electrophoresis revealed that expressions of synapse-related genes and proteins were significantly enhanced on day 14 after SCI in the transplantation-CNO group (fig 1).

On day 42, axial spinal cord areas were significantly larger in the transplantation-CNO group.

PRESENTATION #40 continued

Synapse formations between the transplanted cells and host neurons were detected in immunoelectron microscopic examination (fig 2). Consequently, the transplantation-CNO group presented significant improvement of motor functions such as hindlimb locomotor rating, stride length, coordination, and captured overall walking motion (fig 3).

Conclusion: Long-term repetitive and selective stimulations of transplanted hiPSC-NS/PCs after SCI enhanced synaptic transmission, increased synapse-related genes and proteins expressions, preserved host spinal cord tissue, and improved motor functions. Our results first revealed the importance of the activity of the transplanted cells in SCI, and provide a novel strategic concept to enhance activity within the graft.



PRESENTATION #41

Chemical control of grafted human iPSC derived neurons demonstrated the contribution of graft neuronal activity to the recovery following spinal cord injury

Takahiro Kitagawa, MD, Narihito Nagoshi, MD, PhD, Yasuhiro Kamata, MD, PhD[1], Momotaro Kawai, MD[1], Kentaro Ago, MD, Morio Matsumoto, MD, PhD, Hideyuki Okano, MD, Masaya Nakamura, MD, PhD

Keio University School of Medicine[1]

Introduction: The therapeutic effect of human-induced pluripotent stem cell-derived neural stem/progenitor cell (hiPSC-NS/PC) transplantation to the subacute phase of spinal cord injury(SCI) animals has been previously reported, yet the mechanism of recovery has not been elucidated(1-3).Clarifying the therapeutic effect of engrafted cells indicates the necessity of NS/PC transplantation and could directly link to a further improvement of this therapy. The purpose of the present study was to evaluate the contribution of grafted neural function to the recovery of host locomotor activity.

Materials and Methods: To determine the functional effect of grafted neuronal activity, transplanting NS/PCs were genetically modified by lentiviral vectors. First, NS/PCs coding TRE-GFP-2A-WGA/EF1-rtTA (WGA-NS/PCs), which express a trans-synaptic tracer wheat germ agglutinin (WGA) in control of doxycycline administration, was transplanted to Th10 contusion injury model of mice. Ten weeks after transplantation, spreading of WGA in the spinal cord section was immunohistologically assessed to evaluate a synaptic formation of the grafted neurons. Second, NS/PCs coding hSyn-hM4Di-mCherry (hM4Di-NS/PCs), which express a chemogenetically-engineered receptor that permit temporal inhibition by synthetic ligand clozapine N-oxide (CNO), and NS/PCs coding hSyn-mCherry (mCherry-NS/PCs), as a control, were transplanted to SCI mice. Functional recovery by NS/PC transplantation was evaluated by Basso Mouse Scale (BMS) score and treadmill gait analyses compared with non-transplanted mice. Finally, neuronal activity inhibiting assay for hM4Di-NS/PCs mice and mCherry mice, evaluating the change of BMS score and treadmill gait analyses before and after CNO administration, was performed ten weeks after transplantation.

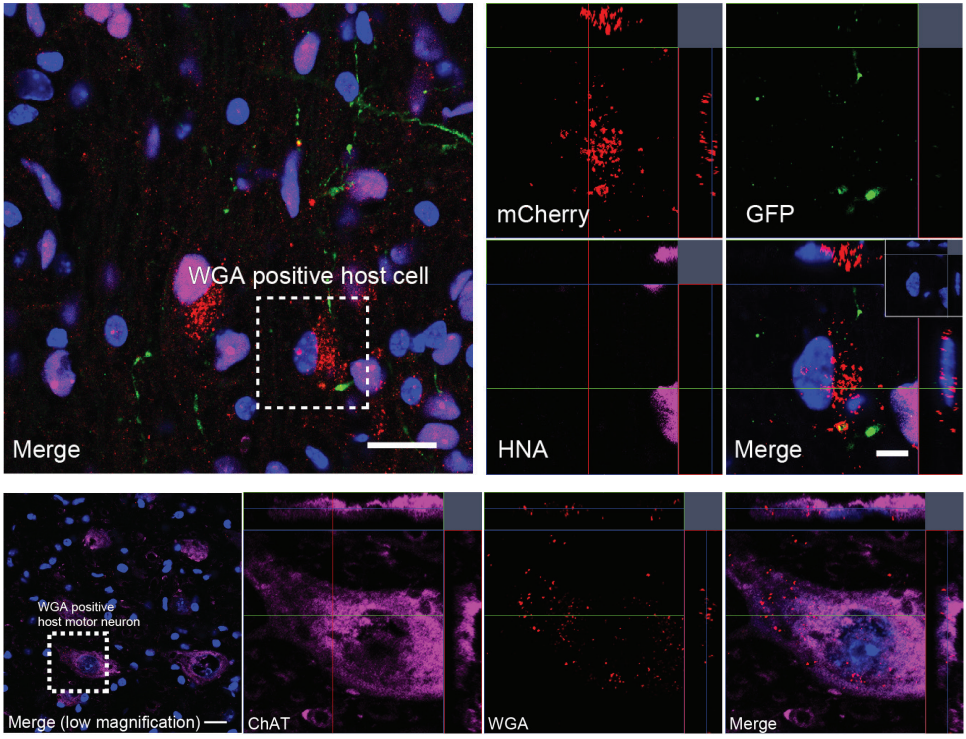
Results: Immunohistological analysis of WGA-NS/PC transplanted mice revealed a trans-synaptic migration of WGA to host neurons (fig 1). This represent the synaptic connectivity of graft neurons and host neurons. Furthermore, WGA migrated not only to the neurons nearby the graft cells, but also to the motor neurons in the caudal site; suggesting the integration of grafted neurons with the host motor circuits (fig 2).

As previously reported, NS/PCs transplanted into mice showed significant recovery of locomotor function compared with the non-transplanted mice. By neuronal activity inhibiting assay of hM4Di-NS/PC and mCherry-NS/PC- transplanted mice, significant deterioration of locomotor function after administrating CNO was observed in hM4Di-NS/PCs transplanted mice (BMS score: pre-CNO 3.3, post-CNO 3.1; P=0.021 (fig 3), stride length: pre-CNO 4.0cm, post-CNO 3.5cm; P=0.003, paw angle: pre-CNO 22.7°, post-CNO 31.0°; P=0.027).

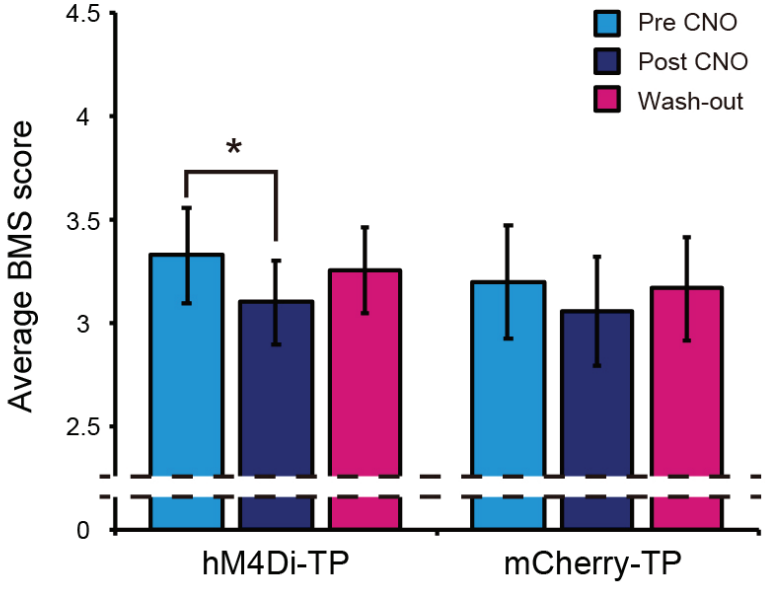
Conclusion: Inhibition of neuronal activity in grafted cells resulted in deterioration of recovered locomotor function in SCI animals. Therefore, grafted neurons derived from hiPSC-NS/PCs integrated with host neural circuits and directly contributed to the functional recovery of SCI animals.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #41 continued



PRESENTATION #41 continued



PRESENTATION #42

Longitudinal Changes in Adjacent Segment Disc Deformation After Cervical Arthrodesis

Clarissa LeVasseur, MS, Anna Martinez, BS, Samuel Pitcairn, BS, Jeremy Shaw, MD, William Donaldson, MD, Joon Lee, MD[1], William Anderst, PhD
Univ Health Center of Pittsburgh[1]

Introduction: In vitro studies suggest that adjacent segment disease (ASD) may be due to excessive motion and disc loading post-surgery[1,2]. However, it is unclear if arthrodesis leads to increased adjacent segment disc deformation in vivo. The aim of this study is to determine the change in disc deformation superior to the cervical arthrodesis. We hypothesized that compression, distraction, and shear deformation in the disc immediately superior to the arthrodesis will progressively increase from pre-surgery to 1-year and 3-years post-surgery.

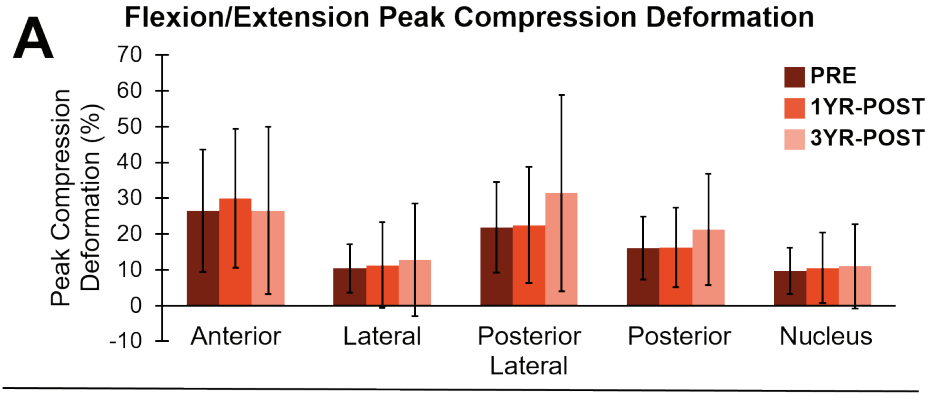
Materials and Methods: Thus far, 20 of the 80 patients who provided informed consent to participate in this ongoing IRB-approved study have completed pre-surgical (PRE), 1-year post-surgical (1YR-POST) and 3-years post-surgical (3YR-POST) testing. On each test day, participants sat upright with their head in the neutral position for a single static image, then performed 3 trials of full range of motion (ROM) head flexion/extension followed by 3 trials of full ROM axial rotation while synchronized biplane radiographs of the cervical spine were collected at 30 images per second for 3 seconds each trial. Three-dimensional vertebral motion was measured using a previously validated model-based tracking technique that matched subject-specific bone models (obtained from CT) to the radiographs[3]. Adjacent segment disc deformation during the dynamic trials was calculated based upon vertebral body endplate motion and normalized to the static trial PRE with a validated precision of 0.4 mm or better3. Five disc regions were identified based on endplate geometry (anterior, lateral, posterior-lateral, posterior, and nucleus)[4]. The maximum compression, distraction, and shear deformation of the superior adjacent discs were compared using a 2-way (test date by region) repeated-measures ANOVA with significance set at $p < 0.05$ with a post hoc Tukey's multiple comparisons test.

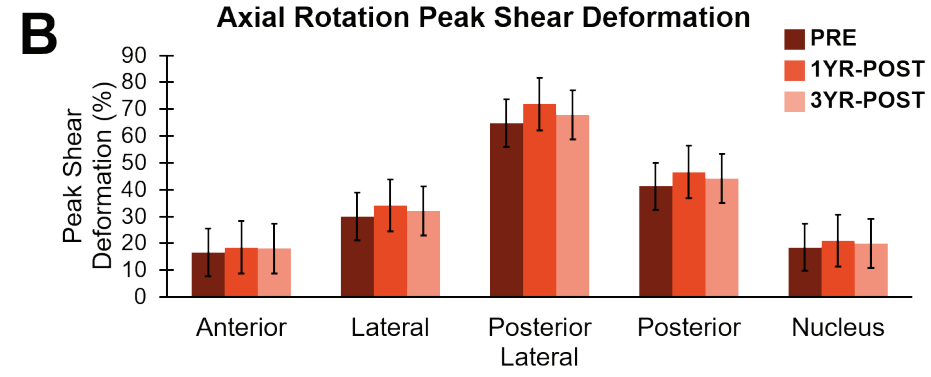
Results: During flexion/extension, the anterior region always underwent more compression and distraction than the lateral or nucleus regions, while the nucleus region underwent less compression than the posterior-lateral region (all $p < 0.03$, Figure 1A). Shear deformation was greater in the posterior, lateral and posterior-lateral regions than in the nucleus and anterior regions (all $p < 0.027$). There were no differences in peak compression, distraction, or shear deformation across test days (all $p > 0.28$, Figure 1A), nor were there any interactions between region and test dates (all $p > 0.054$, Figure 1A). During axial rotation, there were no differences in compression or distraction deformation between regions or across test dates (all $p > 0.14$). Shear deformation during rotation was greater in the posterior lateral region than in the anterior and nucleus regions (all $p < 0.036$, Figure 1B).

Conclusion: The results failed to support the hypothesis that adjacent segment disc deformation increases over the short-term after anterior cervical arthrodesis, contradicting in vitro results[1,2]. Greater shear deformation in the posterior-lateral region during rotation is a potential mechanical mechanism driving pathology in the posterior-lateral region. Longer follow-up may be needed to observe increased disc deformation due to excessive load after arthrodesis. Alternatively, arthrodesis may not lead to excessive load on adjacent motion

PRESENTATION #42 continued

segments in vivo, and other factors may drive adjacent segment degeneration.





PRESENTATION #43

Finite Element Modeling to Determine the Effect of a Hybrid Construct Adjacent to a Cervical Disc Arthroplasty

Jamie Baisden, MD[1], Yuvaraj Purushothaman, PhD, Hoon Choi, MD PhD[1], Narayan Yoganandan, PhD
Medical College of Wisconsin[1]

Introduction: C5-6 and C6-7 are the most common levels to undergo cervical disc degeneration and result in cervical radiculopathy or myeloradiculopathy. Cervical disc arthroplasty (CDA) has been shown to be similar in efficacy to anterior cervical discectomy and interbody fusion and plating (ACDF&P) while allowing for motion preservation and possibly decreasing adjacent segment degeneration which in turn may result in fewer revision surgeries. In cases where a single level fusion has been already performed we looked at the effect of 2 different CDA models adjacent to a fused segment in a hybrid construct. The purpose of this study is to determine if there is a benefit to placing different types of arthroplasty adjacent to a fusion at C5-6 or C-7 when performing a hybrid construct.

Materials and Methods: A previously validated C2-T1 finite element model (FEM) was used to simulate: an intact spine, a 2 level anterior cervical discectomy fusion and plating, and 2 different hybrid constructs one with ACDF&P at C5-6 with CDA at C6-7 and the other hybrid construct with CDA at C5-6 and ACDF&P at the C6-7 level. Two different CDA's were used: CDA 1, a metal on metal implant and CDA 2, a metal on polymer implant. Range of motion (ROM), intradiscal pressures, and facet forces were measured at the index levels and at the adjacent levels.

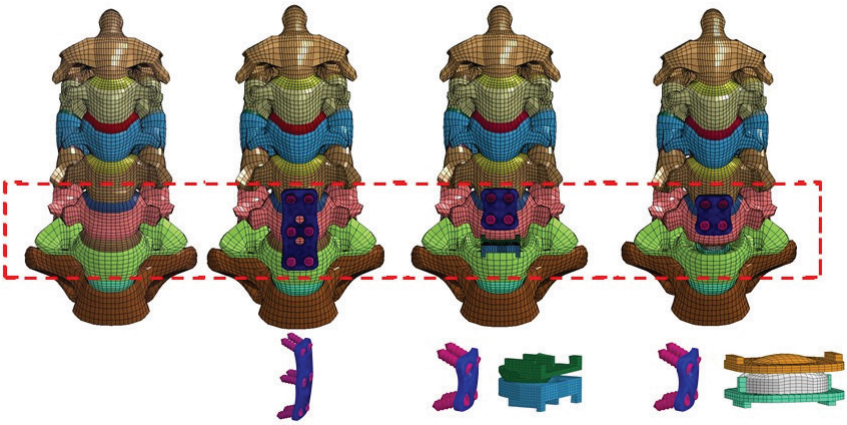
Results: The C5-6 intact specimen demonstrated the highest ROM on both flexion and extension. The CDA2 (metal on polymer) hybrid was closest to physiologic ROM in flexion, extension and lateral bending. CDA2 had highest index ROM regardless of position within the hybrid construct.

The closer the CDA2 is to C5-6 level the closer the ROM was to the intact specimen in flexion. Lowest index facet forces are seen in metal on polymer implants in both extension and lateral bending. The increase in ROM in both flexion and extension results in lower adjacent segment facet forces both cephalad and caudal to the hybrid construct.

Conclusion: ACDF&P increased adjacent segment motion, adjacent intradiscal pressures, and facet forces at adjacent levels. All 3 of these results contribute to the development of adjacent segment degeneration. The stiffer the CDA the more adjacent segment disease would be expected. The metal on polymer CDA is closest to physiologic in all ROM (F/E/LB). The closer the more mobile CDA is to the fused segment the less intradiscal pressure and the less facet force at the adjacent level and the less adjacent segment degeneration would be expected. Our findings agree with the predicted trends. Placing a more mobile CDA at C5-6 in a hybrid construct enhances ROM and would predicte less adjacent segment degeneration as compare to a stiffer CDA at the C5-6 level.

PRESENTATION #43 continued

Hybrid surgery in FEM (C5-C6(ACDF) C6-C7(CDA)



Hybrid moment

- Moment applied to achieve range of motion similar to Intact model

Model	Flexion (Nm)	Extension (Nm)	Lateral bending (Nm)
Intact	2	2	2
2 level ACDF	5	6	6
ACDF-CDA1	3.2	4	4.4
ACDF-CDA2	3	4	4.2

PRESENTATION #43 continued

Hybrid moment

- Moment applied to achieve range of motion similar to Intact model

Model	Flexion (Nm)	Extension (Nm)	Lateral bending (Nm)
Intact	2	2	2
2 level ACDF	5	6	6
CDA1-ACDF	3	3.9	4
CDA2-ACDF	2.86	2.5	2.8

PRESENTATION #44

In Vivo Deformation Patterns of Craniocervical Ligaments during Dynamic Head Axial Rotation

Chaochao Zhou, PhD[1], Runsheng Guo, MD, Cong Wang, BS, Tsung-Yuan Tsai, PhD, 研 于, MD, Wei Wang, MS, Guoan Li, PhD, Thomas Cha, MD
Massachusetts General Hospital[1]

Introduction: Upper cervical injury patterns can lead to potential craniocervical instability through fractures or disruption of important ligamentous constraints. Frequently, treatment decisions are based on imaging findings without understanding the in vivo craniocervical ligament kinematics, especially how it relates to motions of C0-1 and C1-2 needed for head axial rotation. This study attempted to establish the relationship between the axial rotation angles and deformations of primary craniocervical ligaments, including the alar ligaments, the accessory ligaments, as well as the cruciform ligament consisting of a transverse atlantal ligament (TAL), a superior longitudinal band (SLB), and an inferior longitudinal band (ILB).

Materials and Methods: Eight asymptomatic female subjects (ages: 28 ~ 46 years) were included in this study. The head and neck of each subject were CT-scanned to create 3D models of the skull, atlas, and axis. The ligament insertion areas on the bones were outlined according to anatomic landmarks. Each subject then performed maximal left and right head rotations, while the skull and cervical spine were dynamically imaged using a biplane fluoroscopic imaging system at 30 Hz. Using a registration technique, the in vivo positions and alignments of craniocervical segments were determined (Fig. 1). The overall AT rotation angles of the craniocervical junction were measured using Euler angles. An optimization algorithm was implemented to determine ligament wrapping paths and measure the lengths of the ligament at different head positions (Fig. 2). The resulting ligament deformation was represented by the percent elongation: (l - l0)/l0×100%, where l and l0 are the deformed and unloaded (during CT-scanning) ligament lengths, respectively.

Results: No significant differences were observed in the ranges of motion (ROMs, one-sided: 41.1 ± 6.0°) of left and right ATs ($p > 0.05$). The cruciform ligament (including the TAL, SLB, and ILB) were slightly deformed during head axial rotation (Fig. 3a). For the alar ligaments (Fig. 3b), the ipsilateral ligament was tensioned from -0.7 ± 13.8% to 16.6 ± 15.7% ($p < 0.05$), while the contralateral ligament was compressed by -4.0 ± 12.2% at 0°, -6.8 ± 14.4% at 20°, and -2.0 ± 13.7% at 40°, respectively ($p > 0.05$). For the accessory ligaments (Fig. 3c), the contralateral ligament was tensioned from -2.9 ± 7.5% to 10.1 ± 6.2% ($p < 0.05$), while the ipsilateral ligament was compressed from -6.1 ± 7.9% to -11.2 ± 7.3% ($p > 0.05$).

Conclusion: During head rotation, the TAL was minimally strained, such that the C2 odontoid process was held to achieve the pivot rotation. The ipsilateral alar ligament was tensioned, while the contralateral alar ligament was compressed; in contrast, the exact opposite occurred for the ipsilateral and contralateral accessory ligaments. The study enhances our understanding of craniocervical ligament function in response to dynamic head rotation, and could help guide the treatment decision of craniocervical instability.

PRESENTATION #44 continued

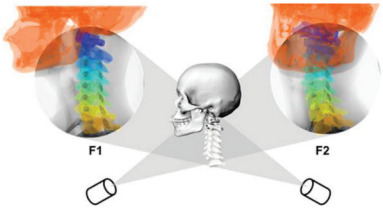


Fig. 1. Registration of the 3D craniocervical anatomic model to the biplane fluoroscopic images to reproduce segment positions in AT.

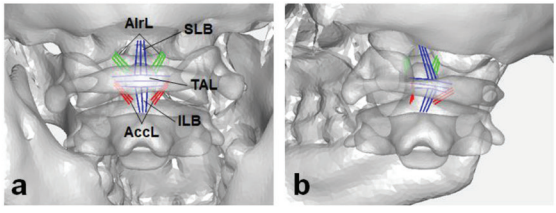


Fig. 2. Graphical representation of ligament wrapping. Note: AlrL = alar ligament; AccL = accessory ligament. (**a**) Ligament configurations in the neutral position. (**b**) Ligament configurations in the maximal AT position.

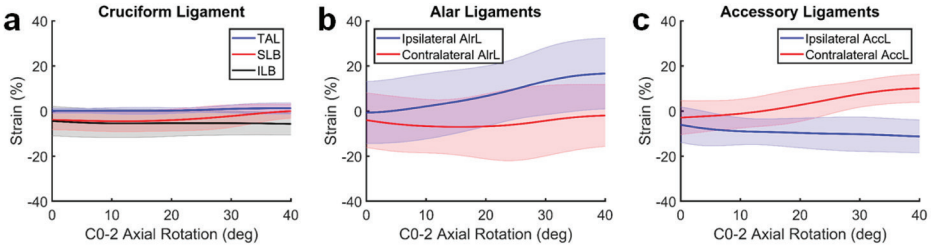


Fig. 3. The relation between ligament strains (%) and the C0-2 AT angels (°). Shaded bands represent ± one standard deviation. Note: AlrL = alar ligament; AccL = accessory ligament. (**a**) The TAL, SLB, and ILB of the cruciform ligament. (**b**) The ipsilateral and contralateral alar ligaments. (**c**) The ipsilateral and contralateral accessory ligaments.

PRESENTATION #45

Supplemental Fixation of Lateral Mass Screws: A Strategy to Improve Posterior Cervical Fusion Fixation Strength

Robert Havey, MS, Muturi Muriuki, PhD, Suguna Pappu, MD, Nader Dahdaleh, MD, Kenneth Blank, PhD, Sarah Brownhill, PhD, Benjamin Johnston, BS, Sean Selover, MS, Shawn Harris, MS, Robert Carruth, MS, Rina Britan, MS, Avinash Patwardhan, PhD

Introduction: Patients with suboptimal bone quality such as the elderly or those with osteoporosis, who have undergone posterior cervical fusion have increased risk of fixation failure of up to 5.4% and may require stronger forms of fixation. The addition of supplemental fixation to lateral mass screws (LMS) can increase fixation as measured by pullout strength.

We address the following hypotheses:

1. Pullout strength of C3-C6 LMS with supplementation using two unicortical screws (Fig. 1A) will be superior to LMS fixation alone.

2. Pullout strength of C3-C6 LMS with supplementation using a single tricortical transfacet screw (Fig. 1B) will be superior to LMS fixation alone.

Materials and Methods: Pullout testing was performed on fifteen C3-C6 vertebral bodies and fifteen additional motion segments (C3-C4 or C5-C6) (age: 49-67). Specimens were CT scanned with a phantom to obtain bone mineral density (BMD). The individual vertebral bodies and the cranial body of the motion segments were implanted with bilateral lateral mass screws. Supplemental fixation was added on one side of the vertebral body using two 2.4mm diameter unicortical screws (length 8-12mm). One side of the cranial vertebral body of the motion segments was supplemented with a single 2.4mm diameter transfacet tricortical screw (length 12-16mm). Screw constructs were subjected to posterior pullout coincident with the axis of the lateral mass screw at a rate of 5mm/min until failure.

Results: A paired comparison was made of the peak pullout force of the LMS alone and LMS with supplemental fixation. Analysis was also made comparing BMD and pullout force.

In the vertebral bodies with two supplemental unicortical screws, pullout force was significantly higher in the supplemented screw side. The average pullout force was 48.2% higher with supplemental screws (865±213N versus 637±206N; p=0.0038). There was moderate correlation between pullout force and bone mineral density for both the supplemented and LMS alone (correlation coefficients of 0.34 and 0.45 respectively).

In the motion segments, pullout force was significantly higher in the side supplemented with a tricortical transfacet screw. The average pullout force was 25.9% higher with supplemental tricortical transfacet screw fixation (1055±521N versus 912±508N; p=0.047). The pullout strength of the LMS with transfacet fixation was highly correlated with BMD (correlation coefficient of 0.71) while the LMS pullout strength was moderately correlated with BMD (correlation coefficient of 0.64).

Conclusion: Our findings support the hypotheses that the pullout strength of C3-C6 LMS fixation using LMS supplemented with two unicortical screws or LMS supplemented with one-tricortical transfacet screw is superior to LMS fixation alone. Adding supplemental screws to LMS can increase pullout strength.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #45 continued

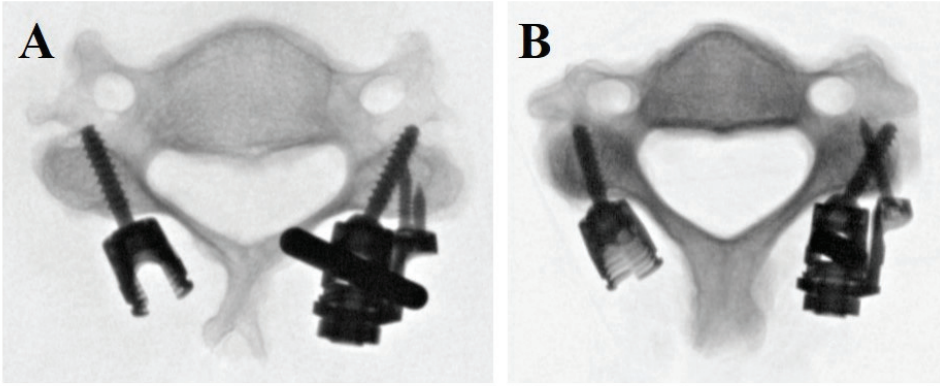


Fig 1. Supplemental fixation of lateral mass screws. A) LMS supplemented with two unicortical screws. B) LMS with one tricortical transfacet screw.

PRESENTATION #46

Biomechanical Analysis of 3-level ACDF Construct Using a Finite-element Cervical Spine Model

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Medical College of Wisconsin[1]

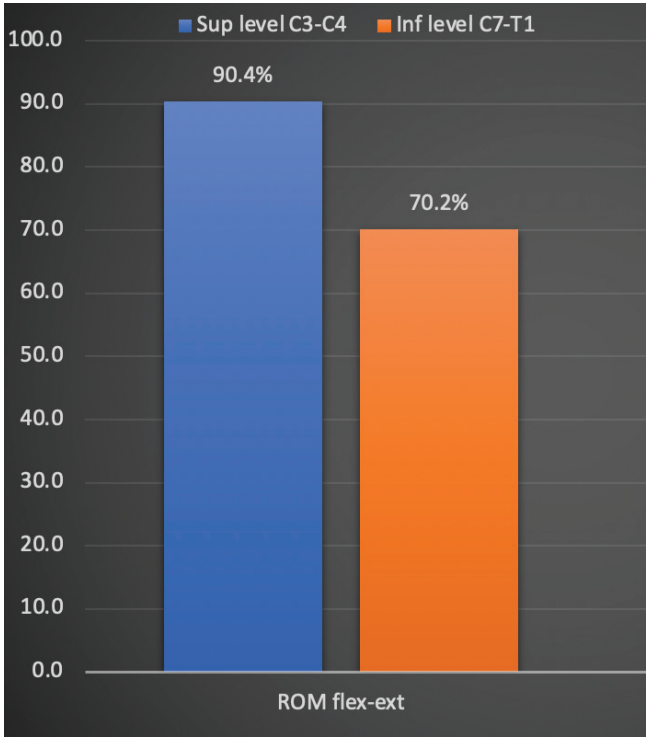
Introduction: Common complications after multi-level ACDF include adjacent level degeneration and pseudarthrosis. We aim to investigate the potential biomechanical factors contributing to these complications following 3-level ACDF using a finite-element cervical spine model.

Materials and Methods: A finite element model (FEM) of human cervical spine from C2 to C7 has been developed as a baseline to study the biomechanical factors in cervical spine intervention. This model has been validated with experimental data from cadaveric biomechanical study. For this study, the FEM model was programmed to simulate a 3-level ACDF with intervertebral spacers and anterior cervical plating and screw fixation from C4-7. The model was then constrained at the inferior nodes of the T1 vertebra, and physiological loadings were applied at the top vertebra. The pure moment load levels of 2 Nm were applied in flexion, extension and lateral bending. A follower axial force of 75 N to reproduce the head weight and muscle force was applied using standard procedures. The motion-controlled hybrid protocol was utilized to comprehend the adjustments in the spinal biomechanics.

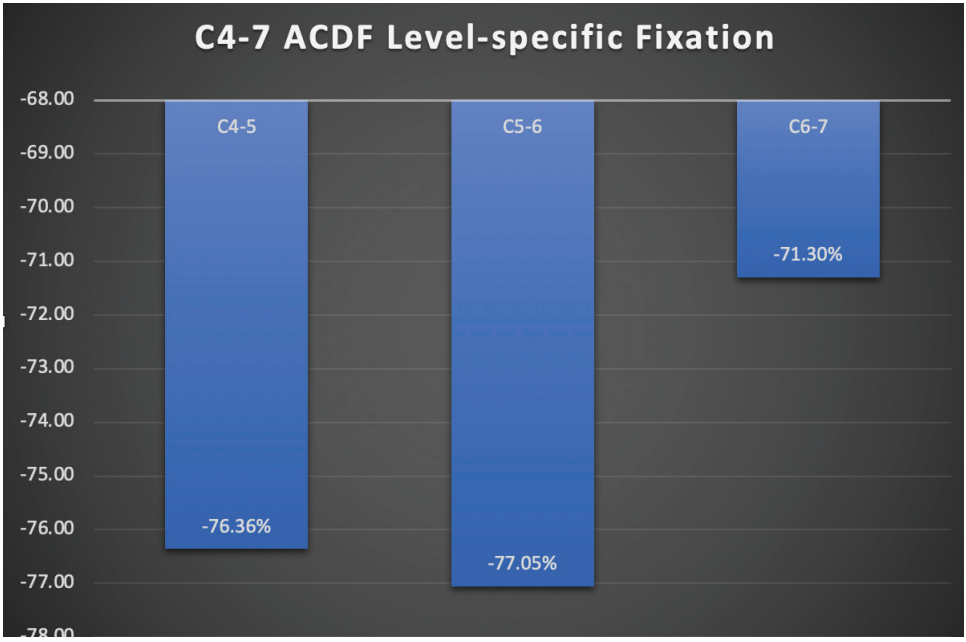
Results: Our cervical spine FEM with C4-7 ACDF demonstrated that the cranial adjacent level at C3-4 had significantly more increase in range of motion (+90.38%) compared to the caudal adjacent level at C7-T1 (+70.18%), indicating that the cranial adjacent level has more compensatory increase in ROM after 3-level ACDF (Figure 1), potentially predisposing it to earlier adjacent level degeneration than the caudal adjacent level. In addition, within the C4-7 ACDF construct, the C6-7 level had the least robust fixation during fixation compared to C4-5 and C5-6 (Figure 2), as reflected by the smallest reduction in ROM compared to intact spine (-71.30% vs -76.36% and -77.05%, respectively), potentially predisposing the C6-7 level to higher risk of pseudarthrosis.

Conclusion: Biomechanical analysis of C4-7 ACDF construct using a validated cervical FEM indicated that the C3-4 has more compensatory increase in ROM compared to C7-T1, and C6-7 has the least robust fixation. These findings can potentially help spine surgeons to predicate the areas with higher risks of post-operative complications and thus developing corresponding strategies to mitigate these risks and to optimize surgical outcome.

PRESENTATION #46 continued



PRESENTATION #46 continued



PRESENTATION #47

Adjacent Level Kinematics Following One- and Two-Level Anterior Cervical Disectomy and Fusion

Clarissa LeVasseur, MS, Samuel Pitcairn, BS, Jeremy Shaw, MD, William Donaldson, MD, Joon Lee, MD[1], William Anderst, PhD
Univ Health Center of Pittsburgh[1]

Introduction: Biomechanical cadaver testing indicates that adjacent segment motion increases after one-level arthrodesis1, and two-level arthrodesis exacerbates these effects2. There is a lack of in vivo evidence to support those biomechanical studies. The purpose of this study was to assess the effects of one and two-level arthrodesis on adjacent segment motion during dynamic flexion/extension and axial rotation. We hypothesized that adjacent segment motion would increase more after two-level compared to one-level arthrodesis, and that adjacent segment motion would be greater in both groups compared to corresponding motion segments in healthy, age-matched controls.

Materials and Methods: Fifty patients scheduled for either one-level C56 arthrodesis (n = 19; average age: 46±8 years) or two-level C456 (n = 11; average age: 51±6 years) or C567 (n = 20; average age: 49±8 years) arthrodesis were tested preoperatively (PRE) and 1 year after (1YR-POST) surgery along with 23 asymptomatic, age-matched controls (average age: 47±7 years). All participants sat upright with their head in the neutral position for a single static image, then performed three trials of full range of motion (ROM) flexion/extension and three trials of full ROM axial rotation while biplane radiographs were collected at 30 images per second. Three-dimensional vertebral motion was measured using a previously validated tracking process that matched 3D subject-specific CT-based bone models to the biplane radiographs3 while head motion was measured using traditional motion-capture with reflective markers placed on the head and torso. Head and intervertebral end-range and mid-range (i.e. motion within ±20° of neutral4) ROM were compared from PRE to 1YR-POST in arthrodesis patients using a paired t-test as well as between arthrodesis groups and controls at corresponding motion segments using a one way ANOVA with a post-hoc Tukey's test. Significance was set at $p<0.05$.

Results: Adjacent segment end-range flexion/extension and axial ROM did not change from PRE to 1YR-POST for either arthrodesis group (Figure 1, all $p>0.052$). Mid-range flexion/extension ROM in the C67 motion segment inferior to both one- and two-level arthrodesis increased from PRE to 1YR-POST (Figure 2, all $p<0.022$) while mid-range axial rotation ROM in the C45 motion segment superior to both one- and two-level arthrodesis increased from PRE to 1YR-POST (Figure 2, all $p<0.024$). Global head flexion/extension and axial rotation ROM did not change from PRE to 1YR-POST, but was found to be consistently less both PRE and 1YR-POST than in age-matched controls (Figure 3, all $p<0.006$).

Conclusion: This study provides in vivo evidence that contradicts long-held beliefs based upon biomechanical testing of cadaver specimens that end-range motion increases adjacent to the arthrodesis and that end-range adjacent segment motion is increased more after two-level compared to one-level arthrodesis in the short-term following ACDF. However, new evidence is provided to indicate that mid-range ROM increases at the inferior motion segment during flexion/extension and at the superior motion segment during axial rotation after both one- and two-level arthrodesis. Excessive disc loading over the mid-range of motion,

PRESENTATION #47 continued

which encompasses the majority of activities of daily living, may be a potential mechanical mechanism influencing adjacent segment degeneration after cervical arthrodesis.

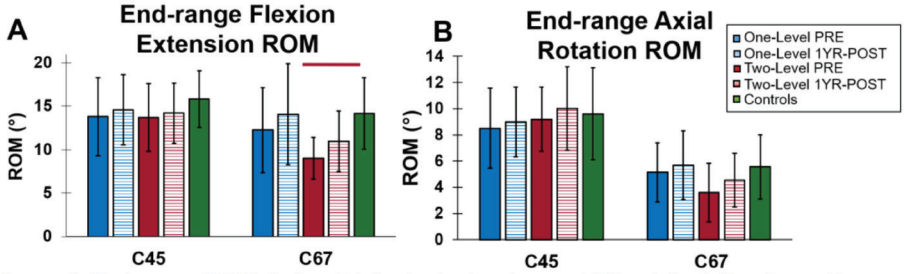


Figure 1. End-range ROM during (A) flexion/extension and (B) axial rotation for motion segments adjacent to one-level arthrodesis (blue), two-level arthrodesis (red), and corresponding motion segments in controls (green). The vertical axis shows total ROM while the horizontal axis shows each adjacent motion segment. For the arthrodesis groups, solid bars are PRE and striped bars represent 1 YR-POST. Error bars represent ±1SD. Red lines indicate differences between two-level arthrodesis and controls.

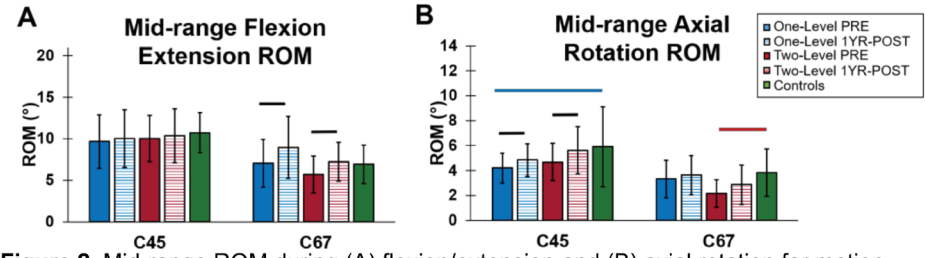


Figure 2. Mid-range ROM during (A) flexion/extension and (B) axial rotation for motion segments adjacent to single-level arthrodesis (blue), two-level arthrodesis (red), and corresponding motion segments in controls (green). The vertical axis shows mid-range ROM while the horizontal axis shows each adjacent motion segment. For the arthrodesis groups, solid bars are PRE and striped bars represent 1 YR-POST. Error bars represent ±1SD. Blue lines indicate differences between one-level arthrodesis and controls while red lines indicate differences between two-level arthrodesis and controls. Black bars indicate differences from PRE to POST in arthrodesis groups.

PRESENTATION #47 continued

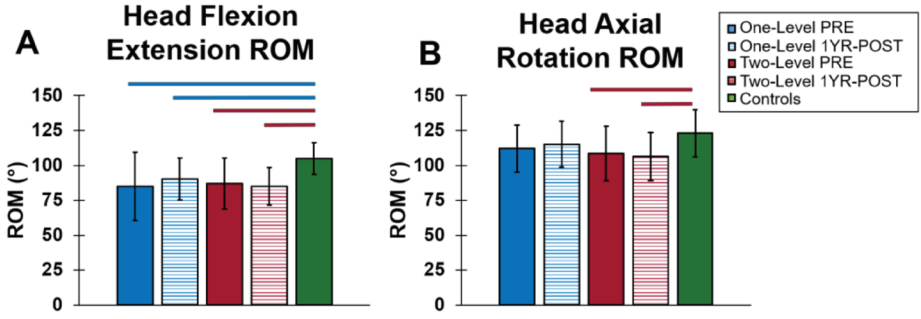


Figure 3. Head ROM during flexion/extension and axial rotation in one-level arthrodesis patients (blue), two-level arthrodesis patients (red), and controls (green). Error bars represent ±1SD. Red bars indicate differences between two-level arthrodesis groups and controls while blue bars indicate differences between the one-level arthrodesis group and controls.

PRESENTATION #48

***In Vivo* Kinematics of the Head-Neck Complex during Dynamic Head Axial Rotation**

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Massachusetts General Hospital[1]

Introduction: Although the kinematics of the lower cervical spine was widely reported, the in vivo motion characteristics of the upper cervical spine including the occipito-atlantal (C0-1) and atlanto-axial (C1-2) cervical segments were not clearly defined. In particular, head axial rotation may cause complicated primary and coupled intervertebral motions at the two upper cervical segments. This study holistically investigated the kinematics of both the upper (C0-2) and lower (C2-T1) cervical spines in a group of asymptomatic human subjects during head axial rotation. It was hypothesized that upper and lower cervical segments have unique motion roles to achieve the head axial rotation.

Materials and Methods: Eight asymptomatic female subjects (ages: 28 ~ 46 years) were recruited in this study. The head and neck of each subject were CT scanned to create 3D anatomical vertebral models from C0 to T1, and were dynamically imaged using a biplane fluoroscopic imaging system at 30 Hz, when each subject performed a motion cycle of head rotation (the subject stood upright initially, then rotate the head to left and right end positions, respectively, and finally returned to the neutral position). The captured dual fluoroscopic images and the 3D vertebral models were imported to a virtual dual fluoroscopic imaging system in a computer program. Using a previously validated registration technique, the positions and alignments of cervical segments were reproduced (Fig. 1). Local coordinate systems were established between each cervical segment, and their primary axial twisting (AT) rotations and coupled flexion-extension (FE) and lateral bending (LB) rotations were measured using Euler angles.

Results: Segment motions during left and right rotations were mirror-symmetric (Fig. 2). During left head rotation, the primary rotation of the overall head-neck complex (C0-T1) reached 56.3±11.8°, with a coupled extension of 17.2±13.4° and coupled right bending of 4.3±5.6° (similarly in right head rotation) (Fig. 3a). The upper cervical spine region (C0-2) had a primary axial rotation of 39.8±12.3° with a coupled extension of 22.5±5.7° and coupled right bending of 19.1±6.7° (Fig. 3b). The lower cervical spine region (C2-T1) had a primary rotation of 10.9±4.7° with a coupled extension of -1.6±7.1° and coupled left bending of 23.6±5.3° (Fig. 3c).

Conclusion: It is shown that distinct motion characteristics exist in the upper and lower cervical spines during head rotation. The coupled LB rotations of the upper and lower cervical spine regions occur in similar magnitude but in opposite directions, resulting in a compensatory lateral curvature (Fig. 2) that balances the head to rotate horizontally. In addition, the upper cervical spine provided main mobility (AT and FE) needed for head axial rotation. This study offers comprehensive baseline kinematic data of craniocervical segments during head axial rotation, that could assist in motion-preserving treatments and prosthesis design for craniocervical pathologies.

PRESENTATION #48 continued

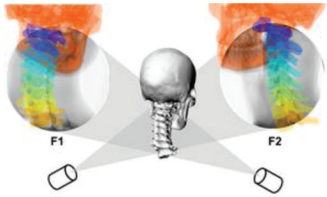

Fig. 1: Registration of the skull and vertebral anatomic models to the biplane fluoroscopic images to reproduce segment kinematics in head-neck left AT.

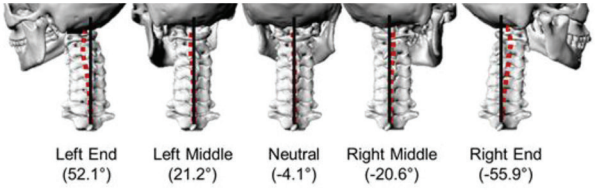

Fig. 2: Reproduced head-neck positions of a typical subject during the dynamic axial twisting motion of the head, where the dashed red lines represent compensate cervical scoliosis.

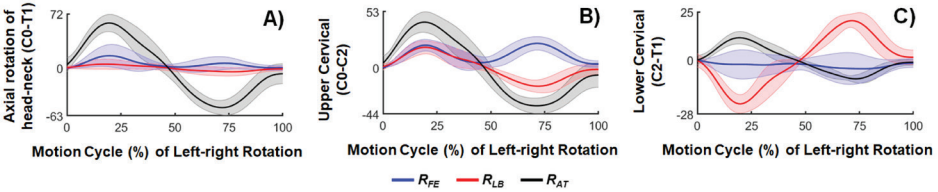

Fig. 3: Rotational kinematics of the **A)** head-neck complex (C0-T1); **B)** upper cervical segment (C0-2); and **C)** lower cervical segment (C2-T1) during the dynamic left-right axial twisting motion of the head. $\boldsymbol{R_{FE}}$**:** FE rotation, $\boldsymbol{R_{LB}}$**:** left-right LB rotation and $\boldsymbol{R_{AT}}$**:** left-right AT rotation.

PRESENTATION #49

Delayed Upper Aerodigestive Tract Perforation from Anterior Cervical Spine Hardware: Treatment and Swallowing Outcomes

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Vanderbilt University Medical Center[1]

Introduction: Anterior cervical discectomy and fusion (ACDF) has become one of the most common and effective treatments for traumatic and degenerative conditions of the cervical spine. Delayed upper aerodigestive tract (UADT) perforation is a rare complication of anterior cervical spinal hardware, but can cause significant morbidity, including dysphagia, local soft-tissue infection or osteomyelitis, hardware failure, sepsis, or even death. Despite the severity of UADT perforation, few studies have evaluated treatment approaches and outcomes.

Materials and Methods: A retrospective chart review was performed on patients with ACDF hardware and delayed UADT perforation who were treated at a large academic institution between 2000 and 2020. We defined a delayed perforation as that occurring more than 30 days from the initial anterior cervical spine surgery. This is based on the finding that the majority of esophageal perforations following ACDF are due to a chronic erosive process as compared to iatrogenic intraoperative injury. Study data was managed using a secure HIPAA-compliant electronic capture tool.

Results: The indications for initial anterior cervical spine surgery were reported in 9 of the 12 patients, with trauma as the most common (n = 5, 42%), followed by degenerative cervical myelopathy (n = 3, 25%). The level most commonly fused was found to be C5-6 (n = 9, 75%) followed by C4-5 (n = 6, 50%) and C6-7 (n = 6, 50%). The median time to diagnosis of delayed UADT perforation was 47 months (range, 5-93 months), and the median age at diagnosis of perforation was 51 years old (range, 22 – 71 years old). Of the twelve patients identified, most patients presented with dysphagia (n = 9, 75%) and/or neck pain (n = 7, 58%). Perforations generally occurred at the level of C6 (n = 6, 50%) and C7 (n = 4, 33%) and spanned only one spinal level (n = 8, 67%). The majority (n = 8, 67%) of patients were past or current cigarette users. Operative approaches included primary repair (n = 5, 42%) and rotational flap (n = 4, 33%); the rotational flap harvest sites included supraclavicular fasciocutaneous (n = 2), infrahyoid muscle (n = 1), and sternocleidomastoid muscle (n = 1). While most patients demonstrated penetration and/or aspiration on first postoperative swallow study (n = 6), this resolved completely within a median time of 31 days. There were no differences in swallowing outcomes between repair approaches.

Conclusion: In the largest study to date, we have described UADT perforations due to anterior cervical spine hardware and the swallowing outcomes. Although we hypothesized that traditional risk factors for impaired wound healing, such as poor nutritional state and systemic inflammatory disease, would contribute to the chronic erosive process that causes these perforations, only a minority of patients harbored these risk factors. Patient smoking history appears to be a clear risk factor for the development of delayed UADT perforation likely secondary to the direct effects of nicotine inducing cell apoptosis in pharyngeal and esophageal mucosa. A variety of repair techniques can be used, and there were no differences in swallowing outcomes between approaches.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #49 continued

Patient Characteristics	n = 12
Male	7 (58%)
Caucasian	12 (100%)
Charlson Comorbidity Index	2 (1-5)
Diabetes	2 (17%)
Immunosuppression use	1 (8%)
Prior neck radiation	1 (8%)
Cigarette use	8 (67%)
Pack-years	25 (4-90)
Age at anterior spine stabilization	44 (17-67)
Indication for anterior spine stabilization	
Vertebral fracture/dislocation	5 (42%)
Cervical spondylomyelopathy	3 (25%)
Ankylosing spondylitis	2 (17%)
Degenerative disc disease	1 (8%)
Disc herniation	1 (8%)
Additional posterior spine stabilization	2 (17%)
Indication	
Vertebral fracture/dislocation	1 (50%)
Cervical spondylomyelopathy	1 (50%)

PRESENTATION #49 continued

UADT Perforation and Repair Information	n = 12
Age at diagnosis	51 (22-71)
Months from spine surgery to diagnosis	47 (5-92)
Presenting symptom	
Dysphagia	9 (75%)
Neck pain	7 (58%)
Dysphonia	4 (33%)
Neck swelling	3 (25%)
Fever	2 (17%)
Cough	1 (8%)
Odynophagia	1 (8%)
Neck drainage	1 (8%)
Diagnostic modality	
Computed tomography	8 (67%)
Contrasted swallow study	6 (50%)
Plain film	3 (25%)
Magnetic resonance imaging	3 (25%)
Flexible esophagoscopy/EGD	3 (25%)
Direct laryngoscopy	2 (17%)
Rigid esophagoscopy	2 (17%)
Flexible fiberoptic laryngoscopy	2 (17%)
Pre-operative labs	
Albumin (g/dL)†	3.4 (2.2-4.4)
White blood cell count (x 10^3 / mcL)‡	10 (7.1-14)
C-reactive protein (mg/L)§	30 (7.7-230)
Erythrocyte sedimentation rate (mm/hr)¶	90 (53-92)
Red cell distribution width (%)††	15 (14-18)
Days from diagnosis to repair	49 (0-469)
Age at repair	51 (22-71)
BMI at repair	20 (13-29)
Operative repair	
No surgical intervention	2 (17%)
Primary repair	5 (42%)
Rotational flap	4 (33%)
Supraclavicular	2
Sternohyoid/sternothyroid	1
Sternocleidomastoid	1
Free flap	1 (8%)
Fasciocutaneous radial forearm	1
Intraoperative findings	
Loose hardware	3 (25%)
Purulence	3 (25%)

†7 patients
‡9 patients
§3 patients
¶3 patients
††7 patients

PRESENTATION #49 continued

Post-Operative Outcomes	**n = 10**
Disposition	
Home	8 (80%)
Skilled nursing facility	1 (10%)
Home with hospice care	1 (10%)
Discharge diet	
Regular	1 (10%)
Clear liquid diet	2 (20%)
NPO with enteral feeds	7 (70%)
First post-operative swallow study	n = 8
Days from operative repair	12 (3-42)
Aspiration	5 (63%)
Penetration only	1 (13%)
No aspiration/penetration	3 (38%)
Residual leak	4 (50%)
Diverticulum	1 (13%)
Recommended diet after first swallow study	
NPO with enteral feeds	7 (88%)
Advance diet as tolerated	1 (13%)
Most recent post-operative swallow study	n = 5
Days from operative repair	31 (5-275)
Aspiration	0 (0%)
Penetration only	1 (20%)
No aspiration/penetration	4 (80%)
Residual leak	0 (0%)
Diverticulum	3 (60%)
Recommended diet after most recent swallow study	
NPO with enteral feeds	2 (40%)
Regular diet	1 (20%)
Soft feeds, ADAT	1 (20%)
No recommendations	1 (20%)
Post-operative complications	
Sepsis	2 (20%)
Need for reoperation (hardware revision)	1 (10%)
Tracheotomy	1 (10%)
Pneumonia	1 (10%)

PRESENTATION #50

The Effect of Undercorrection on Distal Junctional Kyphosis in Adult Cervical Deformity Patients

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New York Spine Institute/NYU Medical Center[1]

Introduction: Distal junctional kyphosis (DJK) development after cervical deformity (CD) corrective surgery is a growing concern for surgeons and patients. Although proper realignment is known to help mitigate the development of DJK, there has yet to be a study that critically analyzes under correction in certain parameters and the effects on development of DJK. The objective of this retrospective cohort study of a single-center database was to determine the effects of under correction in the development of DJK.

Materials and Methods: Inclusion criteria: operative CD patients (Cervical kyphosis>10°, with cSVA>4cm or CBVA>25°) and >18yrs with up to 2Y radiographic and HRQL follow-up. Significant differences in surgical, radiographic, and clinical factors and outcomes were determined. Under correction was defined by a deformity in TS-CL or cSVA Ames Modifier. Moderate Ames Cervical Lordosis deformity (CL) was TS-CL >15 and High >20, High cSVA deformity was >8cm.

Results: 195 CD patients met inclusion criteria (58.3yrs, 46% Female, 28.3 kg/m2). Overall, 40 (21%) of these patients developed DJK. At BL patients presented with the following radiographic profile: PT (18.3), PILL (-.65), SVA C7-S1 (-6.54), cSVA C2-C7 (9.7), and TS-CL (24). Patients under corrected in TS-CL developed DJK at a greater rate (28% vs 15%, p=.02), and patients under corrected in cSVA developed more DJK (65% vs 16%) and underwent more reoperations (42% vs 17%, both p<0.05). Controlling for BL deformity, frailty, and age, patients who maintained a high cSVA deformity had a 3.2x higher likelihood of developing DJK (3.2[1.6-6.8], p=.002). Patients with a post-operative moderate CL deformity had a 1.8x higher likelihood of DJK (1.8[.9-3.8], p=.105), and with a high CL deformity, a 2.8x higher likelihood (2.8[1.1-7.2], p=.03). Controlling for the same factors, patients who remained under corrected in both cSVA and TS-CL had a 6x times higher likelihood of developing DJK (6[1.9-17], p=.002). Using CIT to find a threshold cutoff, the risk of DJK was considerably increased for patients with a TS-CL greater than 13.5, (2.4[1.14-5], p=.026), and a cSVA deformity greater than 6cm (3.2[1.5-6.6], p=.026). Patients who were adequately corrected in cSVA and under corrected in TS-CL demonstrated no significant increased vulnerability to DJK, (p>0.05).

Conclusion: The TS-CL and cSVA components of Ames criteria show a strong correlation with development of distal junctional kyphosis (DJK). Thresholds for DJK development suggest that even patients who fall into a mild deformity as per the Ames criteria are still at an increased risk, and more strict alignment goals may further prevent mechanical failure. Under correction in cSVA was found to have a greater impact on DJK development than TS-CL.

PRESENTATION #51

Failure in Cervical Total Disc Arthroplasty: Single Institution Experience, Systematic Review of the Literature, and Proposal of a Novel TDA Failure Classification System

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Rush University Medical Center[1] Midwest Orthopedics at Rush[2]

Introduction: Due to its more recent introduction in clinical practice and low complication rates, the modes by which cervical total disc arthroplasty (TDA) may fail remain to be described. This study aims to fill this gap in clinical knowledge by retrospectively reviewing an institutional experience with TDA and systematically reviewing the literature in order to highlight the frequency and modes of cervical TDA failure by proposing a novel TDA failure classification system.

Materials and Methods: This study retrospectively reviewed 169 patients (201 levels) who underwent single or two-level TDA with one of three senior surgeons at a single institution. Patients who experienced failure defined specifically as subsequent surgical intervention at the index segment were identified. Statistical analysis included between-group comparisons of Non-Failed and Failed patients and frequencies of each failure type among Failed patients. A systematic review and meta-analysis of the literature was also performed of mid- to large-sized prospective studies in order to further investigate the frequency of failures. Based on these two data sources, a novel classification system for TDA failure was developed.

Results: Institutional retrospective review of TDAs performed at our institution identified 8 failures, for a failure rate of 4.7%. Additionally, 7 failed patients were revised who had index surgery at an outside institution. At final follow-up, Non-Failed and Failed (post-revision) patients reported similar outcomes on all patient-reported outcomes (PROs) aside from VAS Arm (2.3 ± 2.6 vs 5.1 ± 4.2, $p = .042$). Through systematic review of high-quality prospective studies, 168 (4.3%) failures were identified. Using these data, six primary failure types were classified (Table 1). These include recurrent or persistent index-level stenosis (Type I); migration (Type II) presenting as gross extrusion (A) or endplate failure with subsidence/acute fracture (B); instability (Type III) due to mechanical loosening (A), septic loosening (B), or device fracture (C); device motion loss (Type IV) such as "locking" of the device in kyphosis; implantation error (Type V) due to malposition (A) or improper sizing (B); and wear (Type VI) either without osteolysis (A) or with wear-particle-induced osteolysis (B). Stenosis (Type I) was the most common mode of failure at our institution and in the literature (Figure 1). Device-specific meta-analysis of the literature demonstrated lower all-cause failure rates with Mobi-C (1.7%, 95% CI: 0.6%-2.7%) and Bryan prostheses (1.4%, 95% CI: 0.5%-2.3%), whereas failure was more frequent with Kineflex (8.1%, 95% CI: 3.5-12.7%) (Figure 2). Mobi-C was less likely to fail due to stenosis (Type I) relative to the overall pooled rate (0.7%, 95%CI: 0.0%-1.5% vs 1.4%, 95%CI: 0.9%-1.9%), while gross extrusion of the device (Type II. A) was more frequent with PCM (2.8%, 95%CI: 0.6%-4.9% vs 0.4%, 95%CI: 0.2%-0.6%).

Conclusion: Cervical TDA fails through six primary mechanisms. While rates of certain failures requiring subsequent surgical intervention are low, it is possible that these complications may become more prevalent upon further longitudinal observation. Therefore, we believe a classification system helps track and communicate TDA failure. Future application and validation of this classification system is warranted to evaluate how failure frequencies change

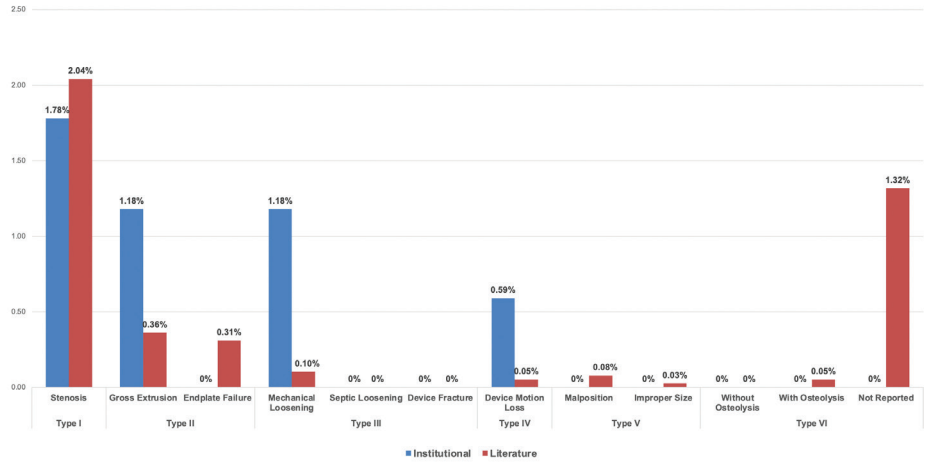
PRESENTATION #51 continued

over time with larger patient samples.

Table 1. Proposed classification system for mechanisms contributing to cervical TDA failure.

Failure Type	Description
Type I. Stenosis	Central or foraminal stenosis, potentially attributed to HO or OPLL
Type II. Migration	
A. Gross Extrusion	Migration with extrusion out of the disc space
B. Endplate Failure	Subsidence (> 3mm) or acute endplate fracture
Type III. Instability	
A. Mechanical Loosening	Non-infectious loosening due to biomechanical stress or poor ingrowth
B. Septic Loosening	Infectious endplate loosening
C. Device Fracture	Device core or endplate fracture contributing to instability
Type IV. Device Motion Loss	Loss of ROM (< 2º) with the device "locked" in hyper-lordosis or kyphosis
Type V. Implantation Error	
A. Malposition	Laterality, depth
B. Improper Size	Too small or large
Type VI. Wear	
A. Without Osteolysis	Elevated ion levels, radiographic polyethylene wear
B. With Osteolysis	Inducing osteolysis with/without pseudotumor formation

HO, Heterotopic Ossification; OPLL, Ossification of the Posterior Longitudinal Ligament; ROM, Range of Motion



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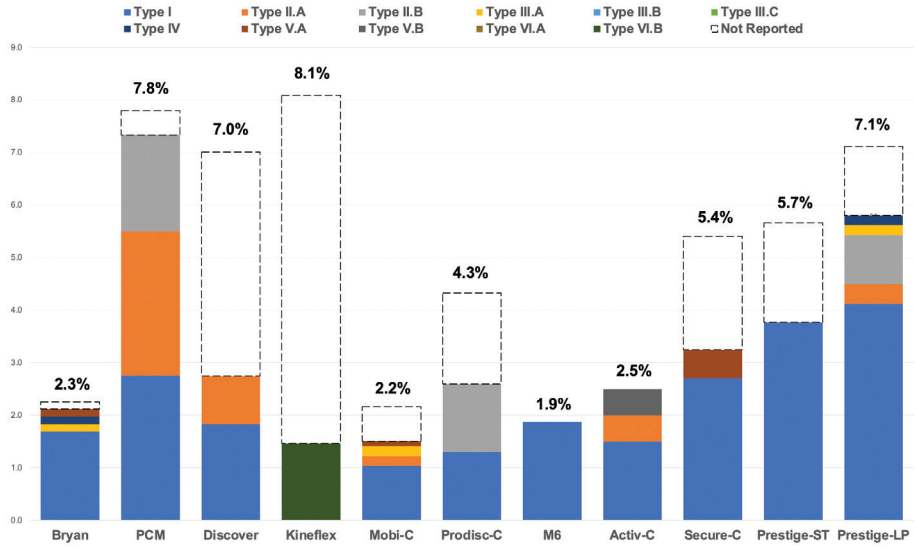
PRESENTATION #51 continued



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.

PRESENTATION #52

Cervical Stiffness Disability Index (CSDI): Validation of a Novel Scoring System Quantifying the Effect of Post-Arthrodesis Cervical Stiffness on Patient Quality of Life

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Introduction: Although a common treatment strategy for cervical spondylotic myelopathy/radiculopathy, arthrodesis also results in increased neck stiffness as a collateral outcome. No current patient reported outcome measure (PROM) exists quantifying the impact of postoperative cervical stiffness on patient quality of life in a similar manner to what exists for the lumbar spine. [1-7] Here, we created and validated a PROM to determine what, if any, stiffness-related functional limitation patients can expect postoperatively.

Materials and Methods: The Cervical Spine Research Society-Cervical Stiffness Disability Index (CSRS-CSDI) was created through a modified Delphi process. The resultant 10-item questionnaire yields a score out of 100 with higher scores indicating increased functional difficulty related to neck stiffness.

A cross-sectional study was then completed for CSRS-CSDI validation. Healthy control and postoperative spondylotic patients completed the questionnaire. Retest reliability (intraclass correlation coefficient (ICC)), internal consistency (Cronbach alpha (CA)), responsiveness (levels fused vs CSRS-CSDI scores), and discriminatory validation (CSRS-CSDI vs Neck Disability Index scores) were completed.

Results: Initially, 24 questions were refined into a 10-item questionnaire through expert consensus (Figure 1, left). A total of 57 spondylotic and 24 healthy controls then completed the questionnaire (Table 1 of Figure 1, right). Spondylotic patients had undergone a variety of procedures: 11 (19%) Motion Preserving decompressions (6 laminoplasties and 5 disc arthroplasties), 9 (16%) Subaxial 1-2 level fusions, 7 (12%) Subaxial 3-5 level fusions, 5 (9%) C1-Subaxial Cervical spine fusions, 20 (35%) C2-Upper Thoracic spine fusions, 5 (9%) Occiput-Subaxial/Thoracic spine fusions.

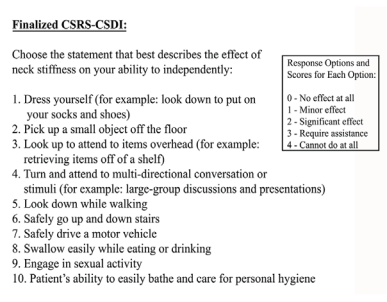
Questions scoring highest amongst experts as functions most likely to be affected by increased postoperative stiffness included (from most to least affected): Question (1) Dress his/herself, followed by Questions (2) Pick up a small object off of the floor, (4) Turn and attend to multi-directional conversation or stimuli, and (5) Look down while walking. In contrast, items spondylotic patients ranked as having the most difficulty with due to stiffness included (from most to least difficulty): Question 3. Look up to attend to items overhead (e.g. retrieving items off of a shelf), followed by Question 7. Safely drive a motor vehicle, and Question 4. Turn and attend to multi-directional conversation or stimuli (e.g. large-group discussions and presentations).

The questionnaire demonstrated high internal consistency (CA = 0.92) and excellent test-retest reliability (ICC = 0.95, $P < 0.001$). Average CSRS-CSDI and NDI scores were 25.7 (standard error (SEM): 2.32) and 15.3 (SEM: 1.91) for spondylotic patients and 8.5 (SEM: 1.49) and 9.3 (SEM: 1.56) for healthy controls, respectively (Table 2). Good responsiveness validity with a significant between fusion cohort difference was found (Figure 2, $P < 0.001$, $rs = 0.63$). Patient CSRS-CSDI scores also correlated well with NDI scores recorded ($P < 0.001$, $r = 0.70$).

Conclusion: This is the first study to create a PROM addressing the impact of cervical stiffness

PRESENTATION #52 continued

following surgical arthrodesis. The CSRS-CSDI was found to be a reliable and valid measure of postoperative stiffness on patient quality of life. This may prove useful in counseling patients regarding their expected outcomes with further investigation demonstrating its value in a prospective fashion currently underway.



Finalized CSRS-CSDI:

Choose the statement that best describes the effect of neck stiffness on your ability to independently:

Response Options and Scores for Each Option:
0 - No effect at all
1 - Minor effect
2 - Significant effect
3 - Require assistance
4 - Cannot do at all

1. Dress yourself (for example: look down to put on your socks and shoes)
2. Pick up a small object off the floor
3. Look up to attend to items overhead (for example: retrieving items off of a shelf)
4. Turn and attend to multi-directional conversation or stimuli (for example: large-group discussions and presentations)
5. Look down while walking
6. Safely go up and down stairs
7. Safely drive a motor vehicle
8. Swallow easily while eating or drinking
9. Engage in sexual activity
10. Patient's ability to easily bathe and care for personal hygiene

Table 1: Patient baseline characteristics.

Characteristics	Patient Cohorts							
	Control	MP	1-2 Level	3-5 Level	C2-UT	C1-SA	O-SA/UT	P-value
Number of patients	24	11	9	7	20	5	5	
Age at surgery (years)	NA	56	60	65	63	60	68	NS
Age at survey (years)	48	60	59	67	68	58	76	NS
Gender (% females)	16 (67%)	3 (27%)	2 (22%)	1 (14%)	10 (50%)	1 (20%)	2 (40%)	NS
Time surgery-survey (years)	NA	2.4	2.1	2.7	2.8	2.7	2.7	NS

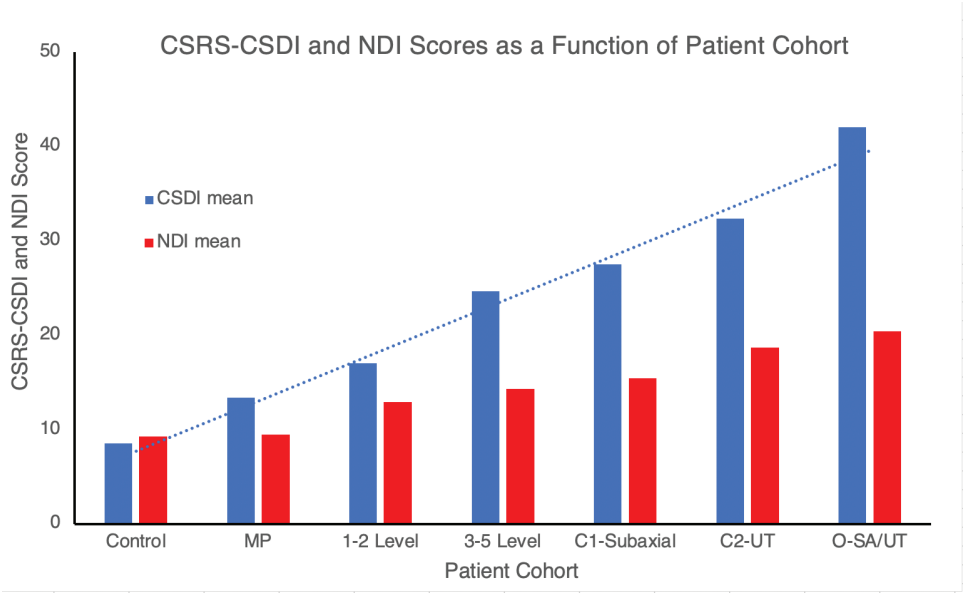
Control: normative/healthy patients; MP: motion preserving patients; 1-2 and 3-5 Level: Subaxial spine; C2-UT: C2 to Upper Thoracic spine; C1-SA: C1 to Subaxial Cervical spine; O-SA/UT: Occiput to Subaxial/Upper Thoracic spine; NS: Not significant; NA: Not applicable

Table 2: Average CSRS-CSDI scores for different patient cohorts.

Patient Cohort	Average CSRS-CSDI score (SEM)	CSRS-CSDI Range	Average NDI (SEM)	NDI Range
Control	8.5 (1.91)	0-30	9.3 (1.56)	0-28
MP	13.4 (3.41)	0-30	9.5 (1.69)	1-17
1-2 Level	17.0 (4.45)	2.5-33.3	12.9 (3.52)	0-35
3-5 Level	24.6 (4.98)	12.5-52.5	14.3 (5.24)	2-42
C1-SA	27.5 (6.75)	12.5-50	15.4 (2.25)	9-21
C2-UT	32.3 (4.04)	10-80	18.7 (2.73)	0-39
O-SA/UT	42.0 (9.57)	10-70	20.4 (7.00)	5-42

Control: healthy control patients; MP: motion preserving patients; 1-2 and 3-5 Level: Subaxial cervical spine; C1-SA: C1 to Subaxial cervical spine C2-UT: C2 to Upper thoracic spine; O-SA/UT: Occiput to Subaxial/Upper thoracic spine; SEM: Standard error of the mean

PRESENTATION #52 continued



PRESENTATION #53

Influence of preoperative smoking status on clinical outcomes of laminoplasty in patients with degenerative cervical myelopathy: a prospective study

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Introduction: Smoking is considered to be a risk factor for poor clinical outcomes after anterior cervical decompression and fusion surgery. However, it is unclear whether preoperative smoking status has similar effects on clinical outcomes after laminoplasty. The current research was carried out to determine whether smoking status before laminoplasty affects clinical outcomes in patients with degenerative cervical myelopathy (DCM).

Materials and Methods: A series of consecutive patients undergoing laminoplasty to treat DCM at a single institution between April 2017 and April 2020 were included and followed up for at least 6 moths. The primary outcome was the recovery rate of JOA (Japan Orthopaedic Association) at the last follow-up. Secondary outcomes included JOACMEQ(Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire) score and the NRS(numerical rating scale) for neck and arm pain.

Results: A total of 158 consecutive patients completed at least 6 months of follow-up. There were 108 men and 50 women. The mean (±standard deviation) age of this series was 57.7 ± 11.6 years. The average recovery rate of JOA, the improvement in the NRS for neck and arm pain, and the improvements in each domain of JOACMEQ did not differ significantly among the three groups($P>0.05$). When using 52.8% as the minimal clinically important difference (MCID) of the JOA recovery rate, active smokers (relative risk [RR]=0.950, 95% confidence interval [CI]=0.740-1.220) and passive smokers (RR=0.830, 95%CI=0.540-1.277) had similar likelihoods of reaching MCID compared with non-smokers. Logistic regression revealed that age (odds ratio[OR]=1.085, 95%CI=1.04-1.131, $P<0.001$) and preoperative JOA (OR=1.241, 95%CI=1.085-1.42**,** P=0.002) were risk factors of the recovery rate that did not reach MCID, but smoking status: AS (OR=2.034,95%CI=0.754-5.489,P=0.161),PS (OR=1.788, 95%CI=0.567-5.640, P=0.321), did not affect the clinical outcomes.

Conclusion: Over a follow-up period of at least 1-year, active smokers, passive smokers, and non-smokers had similar improvements in clinical outcomes after open-door laminoplasty. Thus, smoking status was not found to be an independent predictor of clinical outcomes after laminoplasty. And more importantly, understanding the effect of smoking status on clinical outcomes after laminoplasty will be helpful for specialized patient consultation and preoperative education.

PRESENTATION #54

Evaluating the paradigm shift from anterior cervical decompression and fusion to posterior muscle-preserving selective laminectomy – a single center study of degenerative cervical myelopathy

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Introduction: Muscle-preserving selective laminectomy (MSL) is reported as a less invasive posterior decompression technique in patients with degenerative cervical myelopathy (DCM) and spares the segment from fusion surgery.1,2 Therefore the treatment guideline for DCM has changed from anterior cervical discectomy/corpectomy and fusion (ACDF/ACCF) to MSL at our institution. Comparisons between ACDF/ACCF, laminoplasty and posterior decompression and fusion have been described but the information about ACDF/ACCF versus MSL is sparse. Our aim was to evaluate the surgical outcomes before and after the paradigm shift with patient reported outcome measures (PROMs) as well as complications, reoperations and cost effectiveness.

Materials and Methods: This study was a retrospective register-based single-center cohort study. All patients with DCM who underwent ACDF/ACCF or MSL in Uppsala University Hospital from 2008 to 2019 were reviewed. Inclusion criteria were subaxial DCM and with minimum of 1 year follow-up. Using analysis of co-variance (ANCOVA), changes in PROMs were compared between the two groups, adjusted for patients characteristics (sex, age, smoking, and BMI) and PROMs at baseline, number of decompressed levels, and radiological measurements on preoperative MRI (C2-7 Cobb, C2-7 SVA, slip, modified K-line interval3). PROMs included the European Myelopathy Score (EMS), Neck Disability Index (NDI), European quality of life 5 dimensions (EQ-5D) and were received from the National Swespine register. Length of hospital stay (LOS), complications and reoperations were compared between the two groups. Average cost per patient was calculated based on the LOS and the standardized implant-related costs.

Results: Ninety patients (51 men and 39 women, mean age 60.7) were included in the ACDF/ACCF group and 63 patients (41 men and 22 women, mean age 68.8) were included in the MSL group. ACDF/ACCF and MSL groups presented no differences in PROMs at baseline (13.3 vs 13.1 [EMS], 38.6 vs 38.4 [NDI], 0.32 vs 0.36 [EQ-5D], 47.3 vs 45.6 [EQ-5D health]) or at 2 years after surgery (14.1 vs 13.3 [EMS], 33.8 vs 31.3 [NDI], 0.43 vs 0.42 [EQ-5D], 58.7 vs 60.7 [EQ-5D health]). The preoperative MRIs presented similar C2-7 Cobb values (10.7 for ACDF/ACCF vs 14.1 for MSL, P=0.12), modified K-line interval (4.08 vs 4.88, P=0.07) but different C2-7 SVA values (16.2 vs 19.3, P=0.04). ANCOVA-adjusted comparison of 2-year changes in PROMs presented no significant differences between the groups (P-value: 0.618 [EMS], 0.904 [NDI], 0.085 [EQ-5D], 0.096 [EQ-5D health]). Perioperative complication rate was twice as high in the ACDF/ACCF group (20/90 [22.2%] vs 6/63 [9.5%], P=0.04) and reoperation rate was similar between the two groups (15/90 [16.7%] vs 5/63 [7.9%], p=0.12). LOS did not differ significantly (4.6 vs 4.1, p=0.31). The average cost per patient was 6,870 USD for MSL (on average 2.1 decompressed levels), 7,737 USD for ACDF (on average 1.4 decompressed levels), and 14,953 USD for corpectomy (on average 2.2 decompressed levels).

Conclusion: MSL perform equal in PROMs after 2 years of follow-up but has significantly lower complication rate and is more cost-effective compared with ACDF/ACCF in patients with DCM.

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #55

Does diabetes affect the surgical outcomes in cases with cervical ossification of the posterior longitudinal ligament?

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Keio University School of Medicine[1]

Introduction: The morbidity rate of diabetes mellitus (DM) is more than 20% in patients with ossification of the posterior longitudinal ligament (OPLL), and this is a larger ratio compared to those in the general population which is estimated as 8.8% (1). Because DM has an adverse effect on the microvascular and nervous systems, a concern remains regarding the relation of this metabolic pathology with surgical outcomes for the cervical OPLL. Although significant evidence-based rationale has been accumulated in the outcomes of cervical spondylotic myelopathy, few studies examined the influence of DM on clinical outcomes among OPLL patients.

Recently, we have established the cervical OPLL database in collaboration with four facilities from three Asian countries, which will have the evidence to clarify the detailed pathology and clinical outcomes of the OPLL that mainly prevails in Asian region. The purpose of this study is to examine the impact of DM on surgical outcomes for cervical OPLL using this Asian population-based dataset.

Materials and Methods: This retrospective multicenter study included 253 cervical OPLL patients who underwent surgical decompression with or without fixation at four institutions in three Asian countries (China, Korea, Japan). They were followed up for at least 2 years. Demographics and surgical information were collected, and cervical Japanese Orthopaedic Association (JOA) scores and the visual analog scale (VAS) for the neck were used for evaluation. All these factors were compared between the DM and non-DM groups, using unpaired t-test for continuous variables and chi-square test for categorical variables. Pearson's product moment correlation coefficient was performed to analyze the association of hemoglobin A1c levels with the cervical JOA scores. $P < 0.05$ was considered statistically significant.

Results: Forty-seven (18.6%) patients had DM, showing higher hypertension ($p = 0.01$) and cardiovascular disease prevalence ($p < 0.01$). Of the surgical techniques, laminoplasty was performed most frequently in both the DM (78.7%) and the non-DM groups (80.1%) (Table 1). Although they presented worse preoperative JOA scores than non-DM patients (10.5 ± 3.1 vs. 11.8 ± 3.2; $p = 0.01$), the former showed comparable neurologic recovery at the final follow-up (13.9 ± 2.9 vs. 14.2 ± 2.6; $p = 0.41$). No correlation was noted between the hemoglobin A1c level in the DM group and the pre- and postoperative JOA scores. No significant difference was noted in VAS scores between the groups at pre- and postsurgery. Regarding perioperative complications, DM patients presented a higher C5 palsy frequency (14.9% vs. 5.8%; $p = 0.04$) (Table 2). A similar trend was observed when surgical procedure was limited to laminoplasty.

Conclusion: This is the first multicenter Asian study to evaluate the impact of DM on cervical OPLL patients. Surgical results were favorable even in DM cases, regardless of preoperative

PRESENTATION #55 continued

hemoglobin A1c levels or operative procedures. However, caution is warranted for the occurrence of C5 palsy after surgery.

Table 1. Surgical methodology and clinical outcomes

	DM group (n = 47)	Non-DM group (n = 206)	*P*-value
Surgical methodology			
Laminoplasty (%)	78.7	80.1	0.51
Laminectomy (%)	0	1.9	
Posterior fixation (%)	14.9	8.3	
Anterior fixation (%)	6.4	9.2	
Anterior and posterior fixation (%)	0	0.5	
Cervical JOA score			
Preoperation	10.5 ± 3.1	11.8 ± 3.2	0.01
Final follow-up	13.9 ± 2.9	14.2 ± 2.6	0.41
ΔJOA score	3.3 ± 3.0	2.4 ± 2.9	0.04
VAS for neck			
Preoperation	34.6 ± 31.5	35.3 ± 28.9	0.70
Final follow-up	19.9 ± 26.7	21.4 ± 25.2	0.73
ΔVAS	−15.0 ± 34.7	−14.0 ± 29.6	0.85

Table 2. Perioperative complications

	DM group (n = 47)	Non-DM group (n = 206)	*P*-value
C5 palsy (%)	14.9	5.8	0.04
Surgical site infection (%)	0	0.5	0.81
Dural tear (%)	2.1	0.5	0.34
Dysphagia (%)	0	2.3	0.54
Dysphonia (%)	0	0.5	0.81

PRESENTATION #56

Comparison of Laminoplasty and Posterior Fusion Surgery for Cervical Ossification of the Posterior Longitudinal Ligament: Data from a Prospective Multicenter Research Organization regarding Ossification of the Spinal Ligament

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Nagoya University School of Medicine[1] Tokyo Medical and Dental University[2]

Introduction: Surgeons often choose either laminoplasty (LP) or posterior fusion (PF) for the surgical treatment of cervical myelopathy due to ossification of the posterior longitudinal ligament (OPLL) needing multilevel decompression. Systematic review and meta-analysis that compared these procedures showed comparable postoperative results; however, the details were unclear due to limited small-scale prospective studies. The present study aimed to compare the postoperative outcomes between LP and PF for cervical OPLL in a propensity-score-matched analysis to adjust for baseline factors and radiographical characteristics of spinal cord compression.

Materials and Methods: A total of 479 patients were prospectively enrolled in the multicenter research for ossification of the spinal ligament conducted by the Japanese Ministry of Health, Labour and Welfare at 27 institutions. Among 369 patients treated with LM or PF, those with baseline comorbidities that affected the outcome or had missing values in any of baseline or prognosis variables were excluded from the analysis; the remaining 189 patients (137 treated with LM and 52 with PF) were included. Patients were evaluated using the Japanese Orthopaedic Association (JOA) scores, JOA cervical myelopathy evaluation questionnaire (JOACMEQ), and radiographical measurements. Baseline demographic and radiographical data were reviewed, and the propensity to choose a surgical procedure was calculated. A backward elimination logistic regression model was fitted to estimate the probability of treatment assignment, including all the relevant baseline variables with a p-value of <0.25.

Results: There was no significant difference in the patients' background data, preoperative radiographical measurements, and clinical status after adjustments. The overall risk of perioperative complications (odds ratio 0.40, p=0.006) and C5 palsy (odds ratio 0.11, p=0.0002) were significantly lower in patients treated with LM (Table 1). Range of motion (20.91±1.05° and 9.38±1.24°, p<0.0001) and cervical function score in JOACMEQ (67.64±2.78 and 55.46±3.29, p=0.005) in patients treated with PF were significantly smaller than those in patients treated with LP (Table 2). However, multivariable logistic regression analysis showed no significant difference in the JOA score and JOA recovery rate or any clinically significant improvement in the JOACMEQ results at 2 years (Table 3). Whereas, radiographical progression of OPLL was greater in the LM group (odds ratio 2.73, p=0.0002) (Table 3).

Conclusion: This nationwide, multicenter, prospective study provides a comprehensive evaluation of the relative efficacy of surgery in patients with cervical OPLL who underwent LP or PF. We found comparable improvement among patients with OPLL with both the surgical procedures at 2 years. The exceptions to this were scores on the JOACMEQ cervical function

PRESENTATION #56 continued

domain and cervical range of motion on X-ray, which were lower and smaller in the patients treated with PF. However, there was no significant difference in the logistic regression analysis with respect to whether there was any significant clinical improvement in the cervical function as per the JOACMEQ; thus, this difference may exert a limited effect on the clinical outcome of cervical function.

Table 1. Logistic regression analysis for complications and revision surgery in the weighed sample of Patients undergoing laminoplasty or posterior spinal fusion

	OR	95% CI	p
Overall complications	0.40	0.21-0.77	0.006
C5 palsy	0.11	0.03-0.34	0.0002
Dural tear	1.99	0.28-14.1	0.49
Wound disruption	0.26	0.02-3.62	0.32
Deep wound infection	0.54	0.11-2.60	0.44
Superficial wound infection	0.24	0.03-1.73	0.16
Revision surgery	0.31	0.01-11.10	0.52

OR indicates odds ratio; CI, confidence intervals. Weighted for IPTW and further adjusted for baseline age, sex, VAS【pain or numbness in the arms or hands】, preoperative CMEQ【bladder function】, preoperative comorbidity【cerebrovascular disease】

Table 2. Two years postoperative radiographical parameters and quality of life in the weighed sample of patients undergoing laminoplasty or posterior spinal fusion.

		Laminoplasty	Posterior spinal fusion	p
Radiographical measurements	Cervical lordosis (°)	9.69 (1.10)	7.66 (1.30)	0.24
	Range of motion (°)	20.91 (1.05)	9.38 (1.24)	<0.0001
	Thickness of ossification (mm)	6.11 (0.54)	4.80 (0.64)	0.12
JOA score		13.73 (0.21)	13.72 (0.25)	0.97
JOA RR		45.84 (3.08)	51.15 (3.65)	0.27
JOACMEQ	cervical function	67.64 (2.78)	55.46 (3.29)	0.005
	upper limb function	80.45 (1.76)	77.53 (2.08)	0.29
	lower limb function	63.44 (2.44)	56.19 (2.89)	0.058
	bladder function	77.19 (1.62)	76.12 (1.92)	0.67
	quality of life	53.63 (1.64)	50.77 (1.94)	0.27
Visual analogue scale	pain or stiffness in the neck or shoulder	35.85 (2.78)	38.18 (3.29)	0.59
	tightness in the chest	9.94 (1.80)	7.80 (2.13)	0.89
	pain or numbness in the arms or hands	39.84 (2.70)	44.20 (3.20)	0.30
	pain or numbness from chest to toe	33.10 (2.83)	34.78 (3.35)	0.70

Values are means and standard errors. Weighted for IPTW and further adjusted for baseline age, sex, VAS【pain or numbness in the arms or hands】, preoperative CMEQ【bladder function】, preoperative comorbidity【cerebrovascular disease】

PRESENTATION #56 continued

Table 3. Logistic regression analysis for postoperative functional outcome and progression of OPLL in in the weighed sample of Patients undergoing laminoplasty or posterior spinal fusion

		OR	95% CI	p
JOA score > MCID		0.98	0.57-1.68	0.94
JOA RR > MCID		0.88	0.50-1.53	0.64
Clinical improvement of JOACMEQ	cervical function	1.05	0.58-1.87	0.88
	upper limb function	1.04	0.57-1.89	0.90
	lower limb function	1.75	0.89-3.44	0.11
	bladder function	1.16	0.59-2.28	0.67
	quality of life	1.88	0.95-3.70	0.07
Progression of OPLL		2.73	1.60-4.67	0.0002

Weighted for IPTW and further adjusted for baseline age, sex, VAS【pain or numbness in the arms or hands】, preoperative CMEQ【bladder function】, preoperative comorbidity【cerebrovascular disease】

PRESENTATION #57

Highest Achievable Outcomes for Patients Undergoing Cervical Deformity Corrective Surgery by Frailty

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Introduction: Frailty is influential in determining operative outcomes. The present study is interested in how much it affects the highest achievable outcome for CD patients.

Materials and Methods: Adult CD patients with Baseline (BL) and 2 Year (2Y) NDI Score and Frailty data were included. Frailty Index was used to stratify patients by Miller et al thresholds: Not Frail (NF) < 0.3; 0.3 < Frail (F) < 0.5; Severely Frail (SF) > 0.5. Means comparison analyses distinguished descriptive factors. ANCOVA established estimated marginal means based on age, invasiveness, and BL deformity (Sacral Slope, Pelvic Tilt, Pelvic Incidence, PI-LL, and cSVA). Linear regression analyzed relationships between 1-year (1Y) NDI score and 2Y outcome (improvement: reduction of 5 points, deterioration: increase of 5, maintenance: remaining within ±5 points of 1Y score).

Results: 88 CD patients met inclusion criteria - 11 NF, 54 F, 23 SF. Controlling for BL deformity, age, and invasiveness, patient improvement in NDI after 2Y by frailty were as follows: NF: -18.310; F: -14.939; SF: -12.464. Between 1Y and 2Y, 27.3% of patients deteriorated in NDI, 28.6% maintained NDI, and 44.2% improved. F had the highest rate of improvement (50%), while SF had the highest rate of deterioration (38.9%) among the frailty cohorts. Linear regression analysis found that a higher NDI score at 1Y indicated a higher probability of improving at 2Y (1.799 [1.438-2.160], p=0.020). The top quartile of NF patients also had the lowest NDI at 1Y (3.0) compared to F (10.6) and SF patients (12.9).

Conclusion: In terms of cervical deformity, patients improved more in NDI if they had low frailty status compared to high frailty patients. Lower 1-year NDI score has reduced odds of improvement or maintenance at 2-years, and Severely Frail patients are more at risk for deterioration than their Frail and Not Frail counterparts. Thus, a patient's frailty status serves as both a ceiling effect for ability to improve and a risk factor for deterioration over time.

PRESENTATION #58

Surgical Apgar Score and Controlling Nutritional Status Score are significant predictors of major complications after cervical spine surgery

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Introduction: If major complications, such as those related to vital organs and sepsis, occur after spine surgery, poor surgical outcomes will result, and increased medical costs will be incurred. Thus, it is obvious that it is important to predict the risk of postoperative complications after surgery. Nutritional screening scores, including the Controlling Nutritional Status (CONUT) Score and the Surgical Apgar Score (SAS), which reflect intraoperative hemodynamics, have been reported to be useful for predicting the occurrence of major postoperative complications in various kinds of surgery, such as abdominal and vascular surgery. The goal of this study was to assess independent risk factors for major complications after cervical spine surgery.

Materials and Methods: We retrospectively reviewed the medical records of patients who underwent cervical spine surgery at our institution from 2014 to 2019. Their clinical diagnoses are shown in Table 1. Clinical baseline information including age, sex, body mass index (BMI), comorbidities (diabetes mellitus, hypertension, coronal artery disease), ongoing treatment (anticoagulation therapy, antiplatelet therapy), preoperative hemoglobin, and the American Society of Anesthesiologists (ASA) physical status classification were collected. Controlling Nutritional Status (CONUT) score was evaluated by laboratory examination of serum albumin, total lymphocyte count, and total serum cholesterol, establishing preoperative nutritional condition. Surgical factors, including surgical approach, use of implants, and multisegment surgery were accounted for. The surgical Apgar score (SAS) was calculated using the estimated blood loss, lowest heart rate, and lowest mean blood pressure during surgery. We established the major postsurgical complications as shown in Table 2. Logistic regression analyses with stepwise selection of variables were performed to estimate which independent factors were significantly associated with postoperative major complications after cervical surgery. A receiver operating characteristic (ROC) curve analysis was used to determine the cut-off value.

Results: We analyzed 261 patients. Major postoperative complications occurred in 40 cases (15.3%). The results of the univariate analyses are shown in Table 3. The univariate analyses showed the following significant risk factors for major complications: the presence of diabetes mellitus, high ASA classification, high CONUT score, long operative time, low SAS, combined anterior-posterior surgery, and multisegment surgery. Moreover, SAS (OR, 0.42; $p<0.01$), CONUT score (OR, 1.39; $p<0.01$), and operative time (OR, 1.42; $p<0.01$) were significant independent risk factors for major complications after cervical surgery in the multivariate analyses (Table 3). The area under the SAS curve was 0.852 in ROC curve analysis. Postoperative hospitalization duration was significantly longer in the major complications group.

Conclusion: This study showed that lower SAS, higher CONUT Score and longer operative time were significant independent risk factors for major complications after cervical spine surgery. Both scoring measurements are easily calculated, objective evaluations. Thus,

PRESENTATION #58 continued

evaluation of preoperative nutritional status and intraoperative hemodynamics using the SAS and the CONUT Score may be essential for predicting major postoperative complications after cervical spine surgery. Perioperative management utilizing scoring measurements such as preoperative nutritional intervention and more careful postoperative management for patients with poor intraoperative hemodynamics seems possible to prevent major postoperative complications.

Table 1. Patients' diagnoses

	n	(%)
CSM and/or CSR	98	(37.5)
OPLL	64	(24.5)
AAS	29	(11.1)
SCT	18	(6.9)
CDH	17	(6.5)
CSA	12	(4.6)
Trauma	6	(2.3)
Deformity	5	(1.9)
Others	12	(4.6)

CSM; Cervical Spondylotic Myelopathy, CSR; Cervical Spondylotic Radiculopathy,
OPLL; Ossification of Posterior Longitudinal Ligament, AAS; Atlanto-Axial Subluxation,
SCT; Spinal Cord Tumor, CDH; Cervical Disc Herniation, CSA; Cervical Spondylotic Amyotrophy

PRESENTATION #58 continued

Table 2. List of major complications

	n	(%)
Overall complication	40	(15.3)
Pneumonia	14	(5.4)
Unplanned intubation for 48h or longer	9	(3.4)
Bleeding with >4U red blood cell transfusion within 72h after surgery	8	(3.1)
Sepsis	7	(2.7)
Severe delirium	6	(2.3)
Deep venous thrombosis	4	(1.5)
Stroke or cerebral hemorrhage	3	(1.1)
Pulmonary embolism	2	(0.8)
Wound disruption	2	(0.8)

PRESENTATION #58 continued

Table 3a. Results of univariate analyses between complication and no-complication groups (Mean ± SD)

			All cases n=261	Complication n=40	No-Complication n=221	P value
Background	Sex					0.55†
		Men	172	28	144	
		Women	89	12	77	
	Age (yrs.)		63 ± 13	67 ± 12	63 ± 13	0.078§
	BMI		24.1 ± 4.6	23.8 ± 5.1	24.2 ± 4.5	0.47§
	Diabetes mellitus		64	15	49	0.038†
	Hypertension		108	20	88	0.23†
	Coronary artery disease		11	3	8	0.38‡
	Anticoagulant therapy		5	0	5	1‡
	Antiplatelet therapy		41	10	31	0.079†
	Preoperative hemoglobin (g/dl)		13.7 ± 1.8	13.0 ± 2.2	13.8 ± 1.7	0.024§
	ASA					0.0013‡
		1,2	149	13	136	
		3,4	112	27	85	
Nutrition	CONUT					0.0047‡
		0-1	167	16	151	
		2-4	83	19	64	
		5-8	7	3	4	
		9-12	4	2	2	
Surgery	Operative time		288 ± 138	412 ± 185	265 ± 114	<0.0001§
	SAS		6.5 ± 1.6	4.6 ± 1.7	6.9 ± 1.4	<0.0001§
	Approach					<0.0001†
		Anterior	49	2	27	
		Posterior	194	29	165	
		AP combined	18	9	9	
	Use of implants		168	30	138	0.13†
	Multisegment surgery (> 5levels)		39	12	27	0.0037†
Outcome	Postoperative hospitalization		23 ± 14	37 ± 17	20 ± 11	<0.0001§

†Chi square test, ‡Fisher exact test , §Mann-Whitney U test
ASA; the American Society of Anesthesiologists physical status classification,
CONUT; Controlling Nutritional Status, SAS; Surgical Apgar Score

Table 3b. Results of multivariate analyses for independent predictors of major complications

	OR	(95%CI)	P value
Age	1.01	(0.98-1.05)	0.41
CONUT	1.39	(1.10-1.77)	0.0061
Operative time	1.42	(1.17-1.72)	0.0001
SAS	0.42	(0.30-0.59)	<0.0001

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #59

What is the fate of pseudarthrosis detected 2 years after anterior cervical discectomy and fusion? Results of a minimum of 5-years follow-up

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Introduction: Pseudarthrosis is a common complication of anterior cervical discectomy and fusion (ACDF) and is related to unsatisfactory long-term clinical outcomes. It has been reported that 70% of pseudarthrosis detected at 1-year postoperatively, eventually fuse by the 2-year follow-up. However, the prognosis of pseudarthrosis with a longer follow-up has not been described in detail. Therefore, we investigated the consequences of pseudarthrosis detected 2 years after ACDF.

Materials and Methods: The medical records of 229 patients who underwent ACDF and underwent a minimum of 5-year follow-up were retrospectively reviewed. The Presence of pseudarthrosis was evaluated at 2-years postoperatively and then patients with non-union were re-evaluated at 5-years postoperatively. Patients with pseudarthrosis at 5-year follow-up were defined as the non-union group, and those who achieved fusion at 5-year follow-up were classified as the union group. Patient characteristics, neck pain visual analogue scale (VAS), arm pain VAS, and neck disability index (NDI) were compared between the two groups.

Results: Of the 299 patients, pseudarthrosis was detected in 27 (11.8%) patients at 2-years postoperatively; among them, 8 (29.7%) patients achieved solid union at the final follow-up (union group) and the rest (n=19; 70.3%) remained unfused at the final follow-up (non-union group). The two groups did not show significant differences in patient characteristics and preoperative patient reported outcome measures (Table 1 and 2). Neck pain VAS, arm pain VAS, and NDI all significantly improved in both groups after the operation. In the union group, neck pain VAS ($p=0.03$) and NDI ($p=0.02$) showed further improvement at 5-year follow-up compared with 2-year follow-up. However, in the non-union group, the patient-reported outcome measures did not show further improvement at 5-year follow-up; furthermore, arm pain was aggravated at 5-year follow-up compared with 2-year follow-up in the non-union group (1.5±2.2 to 3.0±2.2, $p=0.03$). The union group had significantly lower 5-year follow-up values of arm pain VAS (0.3±0.5 vs. 3.0±2.2, $p<0.01$) and NDI (2.5±2.8 vs. 8.5±7.1, $p=0.02$) compared with the non-union group (Table 2, Figure 1).

Conclusion: In our study cohort, the majority (70.3%) of the cases of pseudarthrosis diagnosed at 2-year postoperatively did not achieve solid fusion at long-term follow-up. Furthermore, patients with non-union at 5-year follow-up had significantly worse clinical outcomes than those in the union group in terms of arm pain VAS and NDI; therefore, considering the higher possibility of clinical aggravation, pseudarthrosis at 2-years follow-up could be considered a poor prognostic factor after ACDF. Yet, considering that most patient-reported outcome measures significantly improved after operation regardless of the fusion status, the necessity of revision surgery should be carefully evaluated based on individual assessment.

PRESENTATION #59 continued

Table 1. Patient characteristics

Variables	Union group	Nonunion group	P value
Number	8	19	
Age	63.3±16.0	63.8±9.5	0.91
Sex			
Male	5 (62.5%)	12 (63.2%)	1.00
Female	3 (37.5%)	7 (36.8%)	
Smoking	3 (37.5%)	6 (31.6%)	1.00
Diagnosis			
Myelopathy	4 (50.0%)	2 (10.5%)	0.06
Radiculopathy	1 (12.5%)	9 (47.4%)	
Myeloradiculopathy	3 (37.5%)	8 (42.1%)	
BMI	25.6±2.9	24.3±2.2	0.22
Number of levels			
Single-level	4 (50.0%)	4 (21.1%)	
Two-level	2 (25.0%)	9 (47.4%)	
Three-level	2 (25.0%)	6 (31.6%)	
Mean	1.8±0.9	2.1±0.7	0.29

BMI, body mass index

Age and BMI were analyzed using a student's t-test

Sex, smoking, and diagnosis were analyzed using a chi-square test

Number of levels was analyzed using a Mann-Whitney test

PRESENTATION #59 continued

Table 2. Patient reported outcome measures

		Union group	Nonunion group	P value
Neck pain VAS	Preop	4.6±2.9	3.5±2.8	0.45
	Postop 2y			
	Score	2.4±2.1	2.5±2.1	0.81
	P value (Pre-2y)	<0.01*	<0.01*	
	Postop 5y			
	Score	0.8±1.0	2.5±2.4	0.08
	P value (Pre-5y)	<0.01*	<0.01*	
	P value (2y-5y)	0.03*	0.92	
Arm pain VAS	Preop	5.8±2.4	6.0±1.6	0.67
	Postop 2y			
	Score	1.5±2.0	1.5±2.2	0.94
	P value (Pre-2y)	<0.01*	<0.01*	
	Postop 5y			
	Score	0.3±0.5	3.0±2.2	<0.01*
	P value (Pre-2y)	<0.01*	<0.01*	
	P value (2y-5y)	0.06	0.03*	
NDI	Preop	13.6±6.6	16.2±9.2	0.36
	Postop 2y			
	Score	7.7±6.6	7.8±8.5	0.96
	P value (Pre-2y)	<0.01*	<0.01*	
	Postop 5y			
	Score	2.5±2.8	8.5±7.1	0.02*
	P value (Pre-2y)	<0.01*	<0.01*	
	P value (2y-5y)	0.02*	0.67	

VAS, visual analogue scale; NDI, neck disability index

* P value <0.05

† Comparison between two groups were performed by using a Mann-Whitney test

‡ Comparison between different two time periods were performed by using a Wilcoxon signed rank test

PRESENTATION #59 continued

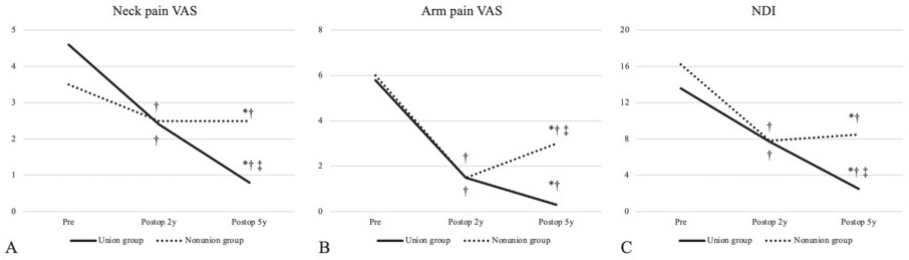

Figure 1. Patient reported outcome measures (A) Neck pain visual analogue scale (B) Arm pain visual analogue scale (C) Neck disability index

* Significant difference between the two groups

† Significant difference compared to preoperative measurements

‡ Significant difference compared to 2-years postoperative measurements

PRESENTATION #60

The associations between radiological and neurological findings of degenerative cervical myelopathy: Radiological analysis based on kinematic CT myelography and evoked potentials of spinal cord

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Introduction: Neurological and imaging findings play significant roles in the diagnosis of degenerative cervical myelopathy (DCM). Specifically, consistency between neurological and imaging findings is important for diagnosing DCM. Although neurological findings exhibit varying sensitivity for DCM, there are few detailed reports about their associations with imaging findings. The aim of the present study was to characterize the imaging findings associated with various neurological findings using multivariate analysis and determine the importance of concordance between imaging and neurological findings for diagnosing DCM.

Materials and Methods: At our institute, between January 2013 and May 2018, a total of 226 DCM patients received cervical surgery. We retrospectively collected demographic, neurological, and radiographic data on the patients. Those with: atlantoaxial subluxation, cervical radiculopathy, thoracic myelopathy, peripheral neuropathy, lumbar spinal canal stenosis, supraspinal central nervous system disease, or tumors; a history of trauma; a history of surgery for the cervical spine; did not exhibit ≥1 of the relevant neurological findings; or had not undergone the required radiological or electrophysiological examinations were excluded. One hundred and twenty-one DCM patients were enrolled. The JOA score, radiological parameters, MRI and kinematic CT myelography (CTM) parameters, and the affected spinal level (according to multi-modal spinal cord evoked potential examinations) were assessed. Kinematic CTM was conducted with neutral positioning or at maximal extension or flexion of the cervical spine. The cross-sectional area of the spinal cord (CSA), dynamic change in the CSA, C2–7 ROM, and C2–7 angle were measured. The associations between radiological parameters and hyperreflexia, the Hoffmann reflex, the Babinski sign, and positional sense were analyzed via multiple logistic regression analysis.

Results: Demographic date was shown in Table 1.Among the examined neurological findings, the PTR exhibited the highest sensitivity (88.43%) for diagnosing DCM, followed by the Hoffmann reflex (76.03%), Babinski sign (61.16%), ATR (56.2%), and abnormal GTPS (38.8%) (Figure 1). In the multivariate analysis, a positive Hoffmann reflex was associated with a higher MRI grade (P=0.024, OR: 2.27, 95%CI: 1.11–4.64) and a responsible level other than C6–7 (P=0.0086, OR: 0.081). A small CSA during flexion was found to be significantly associated with a positive Babinski sign (P=0.021, OR: 0.90). The presence of OPLL (P=0.0051, OR: 0.31) and a larger C2–7 angle during flexion (P=0.009, OR: 0.89) were significantly associated with abnormal positional sense the great toe (GTPS).

Conclusion: The Hoffmann reflex would be associated with chronic and severe spinal cord compression but not the dynamic factors. The Babinski sign would be associated with severe spinal cord compression during neck flexion. The GTPS would be associated with large cervical lordosis. (Figure 2)

In patients with a positive Babinski sign, we recommend conducting radiological imaging

PRESENTATION #60 continued

during neck flexion, considering the involvement of spinal cord compression factors. Several studies have shown that posterior decompression without instrumented fusion is inadequate in cases of severe spinal cord compression during neck flexion [1-3] or in cases with a positive Babinski sign.[4] Therefore, additional posterior stabilization by instrumentation or anterior decompression and fusion may be considered for a better surgical outcome in such patients.

Figure 1

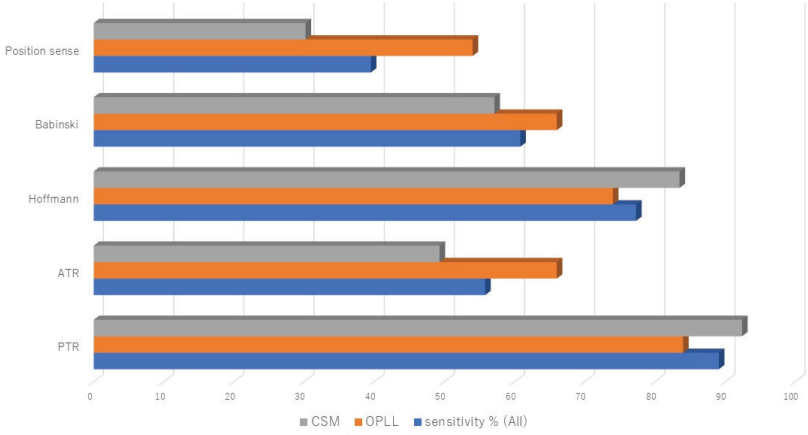
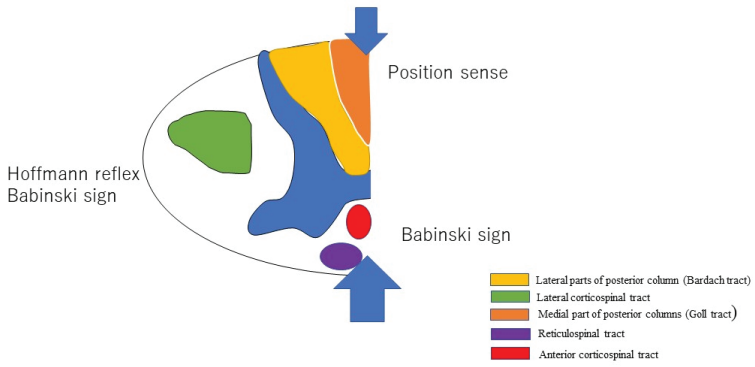


Figure 2



PRESENTATION #60 continued

Table 1. Patient demographics according to disease

		All patients (n=121)	CSM (n=71)	OPLL (n=50)	P-value
Age		68±11.1	72.2±9.7	62.1±10.4	<0.001*
Sex, female/male		36/85	23/48	13/37	0.44
BMI		23.52±4.69	22.86±3.90	24.45±5.53	0.06
Duration of disease, months		21.7±29.2	26.2±32.7	15.4±21.9	0.044*
JOA score		10.15±1.97	10.08±1.99	10.19±1.98	0.99
JOA score for upper limbs		3.05±1.26	2.87±1.34	3.29±1.11	0.07
JOA score for lower limbs		2.8±1.08	2.66±1.06	2.99±1.08	0.10
Exaggerated PTR		107 (88.4)	65 (91.5)	42 (84)	0.20
Exaggerated ATR		68 (56.2)	25 (49.3)	33 (66)	0.06
Positive Hoffmann reflex		92 (76)	54 (76.1)	38 (76)	0.99
Positive Babinski sign		74 (61.2)	41 (57.7)	33 (66)	0.36
Abnormal GTPS		47 (38.8)	20 (28.2)	27 (54)	0.004*
C2-7 angle in neutral position (°)		4.72±14.09	5.26±14.53	3.96±13.59	0.62
C2-7 angle during flexion (°)		-13.05±14.26	-12.24±13.51	-14.20±15.33	0.46
C2-7 angle during extension (°)		21.0±12.94	22.86±13.29	18.36±12.06	0.06
C2–7 ROM (°)		34.24±10.77	35.42±10.27	32.56±11.32	0.15
CSA in neutral position (mm²)		41.07±12.08	41.86±11.83	39.93±12.45	0.39
CSA during flexion (mm²)		42.24±13.79	41.67±11.53	43.03±16.56	0.59
CSA during extension (mm²)		37.01±12.64	36.69±11.51	37.45±14.21	0.74
ΔCSA (mm²)		9.36±7.02	8.98±7.25	9.89±6.69	0.48
ΔFCSA (mm²)		1.39±8.59	0.189±7.07	3.10±10.21	0.06
ΔECSA (mm²)		4.05±8.34	5.16±7.36	2.48±9.51	0.08
C7 slope (°)		27.79±10.2	29.91±10.98	24.78±8.18	0.006*
C2–7 SVA (mm)		31.12±16.05	34.26±18.03	26.66±11.48	0.009*
MRI grade (Yukawa)	0	23 (19)	10 (14.1)	13 (26)	
	1	66 (54.6)	41 (57.7)	25 (50)	
	2	32 (26.4)	20 (28.2)	12 (249)	0.21

PRESENTATION #61

Analysis of Clinical Deterioration Following Adult Cervical Deformity Realignment Surgery: Two Year Outcomes of a Consecutive, Prospectively Enrolled Database

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Introduction: Despite high complication rates, surgical correction of cervical deformity has promising short-term clinical and radiographic outcomes for the majority of patients. The patient profile predisposing to poor clinical outcomes has yet to be investigated. Our aim was to describe the profile of patients who experience clinical and functional deterioration postoperatively.

Materials and Methods: Operative CD patients >18yrs, with pre-(BL) and 2-year(2Y) postop radiographic/HRQL data were included. Univariate analysis assessed patient factors, surgical and radiographic parameters, clinical outcomes, and HRQL scores at BL and 2Y. A clinical deterioration was defined as decline =1HRQL score (mJOA, NDI, NRS back, NRS neck) by 2Y postop. Factors predicting deterioration were identified using multivariate regression with machine learning conditional inference tree (CIT) and ROC curve. A sub-analysis assessed the cohort clinical deterioration, radiographic deterioration in Ames modifiers, and a major complication or DJK.

Results: 162 operative CD patients were included (60.0yrs, 59%F, BMI 28.7kg/m2, CCI: 0.90, levels fused 6.7±3.9, EBL 842mL, op time 338min). By surgical approach, 22.8% anterior-only, 48.1% posterior-only, and 29.0% combined. 48% of patients underwent decompression, 74% had osteotomy. Mean HRQLs at baseline: mJOA 13.5, NDI 49.5, NRS back 5.2, NRS neck 6.8. Overall, 52.5%(n=85) of CD patients experienced a complication, of which 13 were classified as major. 26 patients(16.0%) had a reoperation by 2Y postop. 1 patient had instrumentation failure. 35.8%(n=58) developed DJK by 2Y, with 11 classified as severe and 14 cases of DJF.

87 patients(53.7%) met the deterioration(Det) criteria. 47 patients had decline in mJOA scores by 2Y postop, 36 declined in NDI, 46 in NRS Back, and 25 in NRS Neck. Overall, 42 patients deteriorated in one score, 25 deteriorated in two, 18 patients deteriorated in three, and 2 declined in all four HRQLs. Univariate analysis showed that Det patients had higher levels fused(7.7 vs. 5.5), were more likely to undergo posterior-only approach(59% vs. 36%), and were more likely to undergo osteotomy(87% vs. 59%); all $p<0.01$. Det patients were more likely to have a moderate or severe TS-CL deformity preoperatively($p=0.010$). Det patients also had more neurologic deficits at presentation(80% vs. 59%,$p=0.002$). Regression analysis with CIT for continuous variables determined a set of predictors of clinical deterioration: LIV below C7(OR: 4.98), levels fused >7(OR: 9.00), a preoperative diagnosis of osteoporosis(OR: 2.92), undergoing osteotomy(OR: 4.89), undergoing posterior-only approach(OR: 2.52), baseline TS-CL >15°(OR: 3.12), and having a neurologic deficit at baseline(OR: 2.90); all $p<0.05$. Multivariate regression and ROC curve including these predictors and controlling for age at baseline and CCI resulted in an AUC of 77.1%.

11 patients(6.8%) experienced a clinical and radiographic deterioration as well as a complication by 2Y postop(OpFail). Univariate analysis revealed that these patients had higher levels fused (9.1 vs. 6.6) with lower LIV(T5 vs T2); both $p<0.05$). They were also more likely to undergo osteotomy (100% vs. 72%, $p=0.042$). OpFail patients were more likely to have

PRESENTATION #61 continued

diagnosed gait abnormalities ($p<0.01$).

Conclusion: Clinical deterioration following cervical deformity correction can be predicted by perioperative patient factors including markers of higher invasiveness, poor bone quality, neurologic involvement, and more severe cervical deformity.

PRESENTATION #62

Restored inhibitory signalling via AAV-mediated KCC2 upregulation recruits microglia to reorganize spinal neural circuits

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Introduction: Traumatic spinal cord injury (SCI) impairs local neuronal conductance and induces a subsequent synaptic remodeling cascade in the rostro-caudal perilesional zone. K+/Cl– cotransporter 2 (KCC2) is a differentially expressed synaptic ligand-gated channel, which is pivotal for signal propagation in inhibitory spinal interneurons. Reduced KCC2 expression post-SCI disrupts the excitatory/inhibitory (E/I) ratio in the preserved spinal interneurons and blocks the relay of signals in the injured spinal cord. Gene therapy is a promising technique to alter the transcriptional profile of a cell, and recent advances in clinical translatability of adeno-associated virus 9 (AAV9) enables therapeutic KCC2 upregulation in the injured spinal cord. The objectives of this study are to characterize KCC2 expression following traumatic cervical SCI and to optimize the ability of gene therapy to induce KCC2 in a clinically relevant cervical SCI rodent model.

Materials and Methods: AAV9 particles expressing either enhanced GFP or KCC2 under a synapsin promoter were administered intrathecally either 15-mins or 1-week post-injury to Wistar rats. The animals were transcardially perfused 1-week after injection.

Results: The results validate the early downregulation of KCC2 following a clip-compression injury at both transcriptional and protein levels and demonstrate the ability of intrathecal AAV9 administration to induce KCC2 expression in the preserved neural tissue without any deleterious off-target effects. AAV9-mediated KCC2 upregulation increases the CXCL10 expression in neurons, which acts through the CXCR3 receptor to recruit microglia to the lesion site to enhance synaptic remodeling. Furthermore, KCC2 upregulation significantly changes to key transcriptional factors.

Conclusion: Future characterization and behavioral analysis of AAV9-mediated KCC2 upregulation would further improve the available treatment options to patients with traumatic cervical SCI.

PRESENTATION #63

Predictive Factors for the Aggravation of Cervical Alignment after Posterior Cervical Foraminotomy

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Introduction: Posterior cervical foraminotomy (PCF) is a common surgical option for cervical radiculopathy that maintains cervical mobility by avoiding the fusion of motion segments. However, PCF has the risk of progression to cervical kyphosis, likely arising from procedure-related injuries on the facet joint and musculature. Age and preoperative hypo-lordosis have been regarded as risk factors for postoperative cervical kyphosis; however, recent studies suggested that hypo-lordosis in patients with cervical radiculopathy may be a temporary finding resulting from a positive Spurling's sign. Therefore, we investigated the risk factors for the aggravation of cervical alignment after PCF and identified their relationships with aggravation in cervical curvature.

Materials and Methods: The medical records of 98 patients who underwent PCF for unilateral radiculopathy and followed for > 2 years were retrospectively reviewed. Segmental angle (SA), cervical angle (CA), Pfirrmann grade, foraminal stenosis, and clinical outcomes including neck pain, arm pain, neck disability index (NDI) were assessed. To identify the predictors for postoperative kyphotic changes, the patients were divided into two groups based on postoperative changes in the Cobb angle at C2–C7. Radiological and clinical outcomes were compared between groups C (Control group; CA kyphotic change < 5°) and K (Kyphotic group; CA kyphotic change ≥ 5°). Univariate and multivariate linear regression analyses were used to identify the risk factors for the kyphotic changes in CA. Pearson's correlation coefficient analysis was used to determine the relationships between the risk factors and the kyphotic changes in CA.

Results: Group K was significantly older than group C (P = .002) and had a higher Pfirrmann grade (P = .025) (Fig 1). In group K, neck pain was significantly increased at the last follow-up (P < .001). Univariate and multivariate linear regression analysis revealed that kyphotic changes of CA were significantly related to older age (P = .016, B = 0.420) and higher Pfirrmann grade of operative levels (P = .032, B = 4.560). Previous reported risk factors such as T1 slope and C2-C7 sagittal vertical axis had no significant relationship to kyphotic changes of CA (Table 1). Pearson correlation analysis showed that both age (R = 0.487, P < .001) and Pfirrmann grade (R = 0.249, P = .027) had a significant relationship with the kyphotic changes in CA. ROC curve analysis showed that the cut-off value of Pfirrmann grade was 3.417 for kyphotic changes in CA of ≥ 5° (P = .008, area under the curve = 0.703, sensitivity = 91%, specificity = 59%) (Fig 2).

Conclusion: Our results showed the potential utility of the preoperative measurement of Pfirrmann grade for assessing the risk of aggravation of cervical alignment following PCF. Although preoperative cervical alignment has been used for estimating postoperative kyphotic changes, independent risk factors for kyphotic changes in cervical curvature may be more useful in clinical situations. Collectively, our results suggest that careful consideration should be taken when treating older patients with a Pfirrmann grade of higher than IV for disc degeneration.

PRESENTATION #63 continued

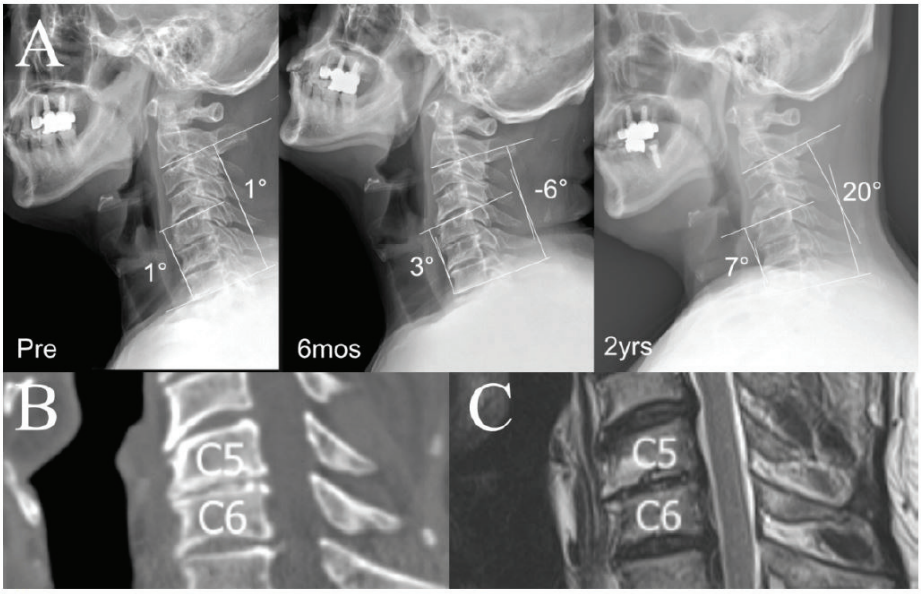

Figure 1. Representative images of patients from group K. (A) Neutral plain radiograph showing improvement of lordosis in CA (7°) at 6 months postoperatively but aggravation of lordosis (19°) at 2 years postoperatively. (B and C) Preoperative CT and MRI showing a Pfirrmann grade of V at C5–C6.

PRESENTATION #63 continued

Table 1. Univariate and multivariate linear regression analysis for kyphotic change after PCF

Variable	Univariate		Multivariate		
	B (SE)	*P*	B (SE)	95% CI	*P*
				(R^2 = 0.479, P < .001)	
Age	0.613 (0.143)	.003*	0.420 (0.165)	0.255 − 0.585	.016*
No. of levels	1.133 (2.496)	.65			
Op time	0.024 (0.063)	.70			
EBL	-0.018 (0.043)	.68			
SA	-0.581 (0.217)	.011*	-0.086 (0.236)	-0.322 − 0.150	.72
CA	-0.349 (0.144)	.020*	-0.149 (0.151)	-0.300 − 0.002	.33
C2-C7 SVA	-0.485 (0.190)	.015*	-0.223 (0.187)	-0.410 − 0.036	.24
SROM	-0.081 (0.192)	.68			
CROM	-0.051 (0.136)	.71			
T1 slope	0.173 (0.220)	.44			
SAF+SAE	-0.026 (0.108)	.81			
CAF+CAE	0.007 (0.079)	.93			
Pfirmann grade	4.946 (2.365)	.035*	4.560 (2.030)	2.530 − 6.590	.032*
Foraminal stenosis	0.381 (0.677)	.57			
Facetectomy (%)	0.149 (0.183)	.43			
VAS NP	-0.7961 (0.813)	.34			
VAS AP	-0.432 (0.590)	.47			
NDI	0.212 (0.248)	.40			

PCF: posterior cervical foraminotomy, SE: standard error, CI: confidence interval, EBL: estimation of blood loss, SA: segmental angle, CA: cervical angle, SVA: sagittal vertical axis, ROM: range of motion, SAF: segmental angle in flexion, SAE: segmental angle in extension, CAF: cervical angle in flexion, CAE: cervical angle in extension, VAS: visual analog scale, NP: neck pain, AP: arm pain, NDI: neck disability index

*$P < 0.05$

PRESENTATION #63 continued

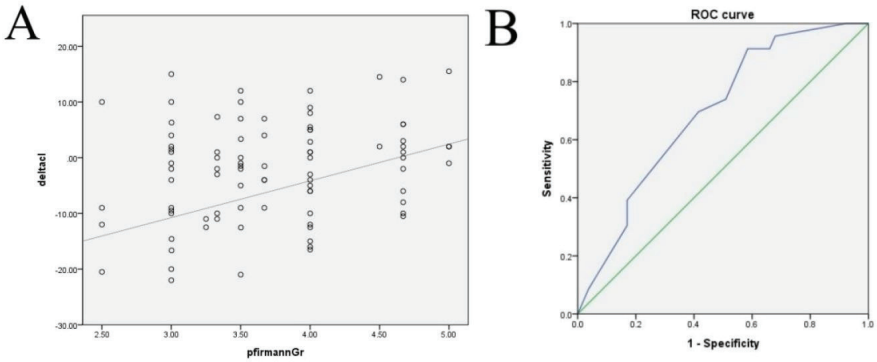

Figure 2. (A) Scatter plot showing a positive correlation between Pfirrmann grade and kyphotic changes in cervical curvature. (B) ROC curve analysis for the cut-off value of Pfirrmann grade for inducing kyphotic changes in cervical curvature of ≥ 5°.
ROC, receiver operating characteristics

PRESENTATION #64

Surgical Treatment of Single level Cervical Radiculopathy: A Comparison of Anterior Cervical Decompression and Fusion (ACDF) vs. Cervical Disc Arthroplasty (CDA) vs. Posterior Cervical Foraminotomy (PCF).

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Introduction: Surgical options for cervical radiculopathy include anterior cervical discectomy and fusion (ACDF), posterior cervical foraminotomy (O-PCF), minimally-invasive posterior cervical foraminotomy (MI-PCF), and cervical disc arthroplasty (CDA). The objective of this study is to retrospectively compare the clinical outcomes, complication rates and reoperation rates among the four treatments in patients with cervical radiculopathy.

Materials and Methods: Inclusion criteria for the study were patients over 18 years of age with single-level, unilateral cervical radiculopathy correlating with magnetic resonance imaging (MRI), failure of non-operative management, and one-level ACDF, O-PCF, MI-PCF, or CDA with a minimum of 24 months of follow-up. Exclusion criteria included a diagnosis of myelopathy or myeloradiculopathy and prior cervical spine surgery. Clinical and radiological parameters were compared between the groups.

Results: There were 384 patients in the study - 257 ACDF, 18 Open-PCF, 52 MI-PCF, and 56 CDA. Operative time was significantly shorter for MI-PCF. Median estimated blood loss was small, but greater with O-PCF compared to other interventions. The length of hospital stay was longest for the ACDF group. At two years' follow up, 36 subjects (9%) had subsequent neck surgery. The most common indication for additional surgery was recurrent symptoms (3.4% of surgeries) followed by adjacent segment disease (ASD) (2.6%), pseudoarthrosis (2.1%), ASD + pseudoarthrosis (0.5%), and implant-related complications (0.3%). Pseudoarthrosis rates among ACDF subjects differed by interbody material type: polyetheretherketone (PEEK): 8.9% (5/56); titanium: 3.7% (1/27) and cortico-cancellous allograft: 1.1% (2/174). The difference between PEEK and allograft was significant ($p=0.01$). Overall, there was no statistically significant difference in complication rates between groups. All groups had statistically significant postoperative clinical improvement in NDI, VAS neck pain and VAS arm pain ($p<0.01$), except with O-PCF, where there was no improvement in VAS arm pain scores ($p=0.10$). MCID in NDI was achieved in 40% of MI-PCF subjects, 42% of O-PCF subjects, 66% of CDA subjects and 46% of ACDF subjects.

Conclusion: These four treatment options confer good clinical results on patients surgically treated for cervical radiculopathy. MCID in NDI was achieved in a significant number of patients in all groups. Intra- and postoperative complications were low in all four groups. MI-PCF had the shortest surgical time and length of hospital stay. O-PCF had statistically significantly more estimated blood loss compared to the others. More CDA patients achieved MCID in NDI compared to the others, and the rate for additional surgery at 2 years was lowest in the CDA group.

PRESENTATION #65

Surgical and Radiographic Outcomes in Patients with High T1 and C2 Slopes

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Introduction: T1 slope (T1S) and C2 slope (C2S) are important radiographic parameters for cervical deformity (CD) patients, with higher T1S and C2S both corresponding to worse cervical alignment. In addition, prior research has shown higher T1S is associated with poor global sagittal alignment. These two parameters can be used to group patients into distinct spinal deformities with low T1S-high C2S (LTHC) representing CD only and high T1S-high C2S (HTHC) representing global deformity without cervical compensation. We hypothesized that HTHC would have worse global sagittal alignment and require more complex surgery than LTHC.

Materials and Methods: A prospective multicenter database of operative CD patients was retrospectively analyzed. Inclusion criteria was patients with at least 1 year of follow-up and preoperative high C2S. High C2S (>30°) was defined by 1 SD above the previously published mean for asymptomatic subjects with an overall kyphotic cervical morphotype. Patients were categorized as LTHC if T1S ≤ 30° and HTHC if T1S > 30°. Severe Distal Junctional Kyphosis (DJK) was defined as DJK angle change >20°. Outcome measures included surgical characteristics, post-operative complications, Neck Disability Index (NDI), and radiographic parameters, such as thoracic kyphosis (TK), T1 pelvic angle (TPA), and C7 sagittal vertical axis (cSVA). Statistical analysis included independent samples t-test and chi-square analysis with significance set to $p<0.05$.

Results: 92 patients met inclusion criteria (61 HTHC, 31 LTHC). HTHC had greater preoperative TK (-72.86 vs -46.59°), TPA (18.01 vs 10.56°), and cSVA (57.96 vs 38.77mm), all p<.010. At 1-year post-op, HTHC had higher TK (-69.40 vs -59.67°) and cSVA (48.95 vs 39.36mm), both p<.05; though there were greater improvements in TK and cSVA for HTHC, while TK worsened for LTHC. HTHC had more posterior levels fused (10.28 vs 6.65), fewer anterior levels fused (1.16 vs 2.23), and more circumferential fusions (66.7% vs 38.7%), all p<.05. Lower instrumented vertebrae (LIV) was more caudal in HTHC (13.65 vs 9.55, p<.001). Both groups had similar baseline Neck Disability Index (NDI) scores (49.55 vs 49.10), but HTHC had less NDI improvement at 1 year (-6.75 vs -15.47, p=.023). There were no significant differences in rates of post-op minor (18.0% vs 12.9%, p= 0.529) or major (11.5% vs 9.7%, p=0.793) complications, severe DJK (1.6% vs 6.5%, p= 0.219), or reoperation (4.9% vs 3.2%, p=0.707).

Conclusion: HTHC have worse global sagittal alignment than LTHC, both preoperatively and at 1 year post-operatively. They require more aggressive procedures with more levels fused, lower LIV, and more circumferential fusions, but have no differences in post-op complications. HTHC had smaller 1 year HRQL improvements, likely due to their continued worse global alignment post-operatively. The relationship of T1S and C2S is important in understanding the burden of global spinal deformity in operative cervical deformity patients.

PRESENTATION #65 continued

		Low T1S- High C2S (n=31)	High T1S- High C2S (n=61)	p value
Surgical Characteristics	Op Time (min)	592.67±306.73	497.82±294.43	0.491
	EBL (mL)	1231.00±1045.69	741.67±433.84	0.151
	Circumferential Fusion	38.7%	66.7%	**0.038**
	Anterior levels fused	2.23±2.11	1.16±1.79	**0.013**
	Posterior levels fused	6.65±3.78	10.28±5.43	**0.001**
	Lower Instrumented Level	9.55±2.83	13.65±4.97	**<0.001**
	Mean # Osteotomies	2.87±3.20	3.26±3.87	0.629
	3 Column Osteotomies	16.1%	24.6%	0.352
Postop Complications	Reoperation Required	3.2%	4.9%	0.707
	Severe DJK Incidence	6.5%	1.6%	0.219
	Minor Complications	12.9%	18.0%	0.529
	Major Complications	9.7%	11.5%	0.793
HRQL Scores	Baseline NDI	49.10±17.58	49.55±16.77	0.906
	1 Y NDI	32.06±19.14	40.49±19.67	0.111
	NDI Change (Baseline to 1Y)	-15.47±15.62	-6.75±13.15	**0.023**
Radiographic Characteristics	Baseline T1S	18.55±10.34	50.48±14.10	**<0.001**
	1Y T1S	34.81±12.40	45.28±14.01	**0.004**
	Baseline C2S	44.61±12.35	57.00±18.83	**0.001**
	1Y C2S	30.92±14.49	33.20±11.62	0.491
	Baseline TPA	10.56±10.95	18.01±12.48	**0.007**
	1Y TPA	15.06±10.48	18.65±13.59	0.285
	Baseline TK	-46.59±9.81	-72.86±18.26	**<0.001**
	1Y TK	-59.67±15.69	-69.40±14.64	**0.017**
	Baseline PT	18.61±10.92	22.64±10.92	0.120
	1Y PT	20.08±12.11	20.92±12.79	0.801
	Baseline cSVA	38.77±16.22	57.96±10.54	**<0.001**
	1Y cSVA	39.36±19.98	48.95±12.05	**0.024**

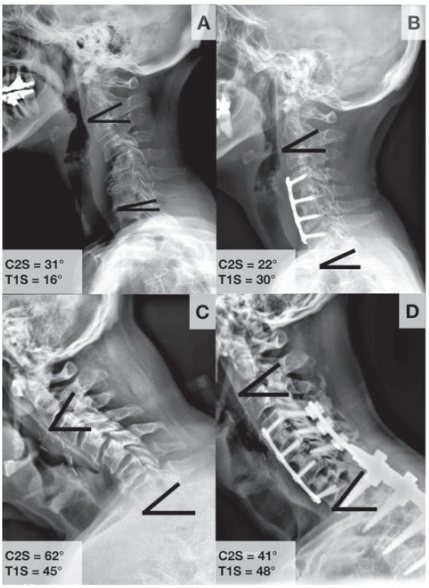

Figure 1: Lateral cervical radiographs of a LTHC patient pre- (A) and postoperatively (B), and a HTHC patient pre- (C) and postoperatively (D), demonstrating different radiographic parameters and surgical invasiveness between groups

PRESENTATION #66

No Difference in Reoperation Rates in Posterior Cervical Fusions Stopping at C7 versus T1/T2 for Nonunions (Operative Nonunions): A cohort of 875 Patients – Part 2

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Introduction: There are surgical fusion treatment challenges to the anatomical complexities of the cervicothoracic junction (CTJ). Current posterior cervical spine surgery is based on the belief that worse outcomes occur for fusions stopped at C7. However the consequence of such fusions is the possibility of increasing nonunions as it crosses the cervicothoracic junction. The purpose of this study is to determine if there is a difference in reoperation rates for nonunions (operative nonunions) in posterior cervical fusions (PCFs) that stop at -C7 versus at -T1/T2.

Materials and Methods: We conducted a retrospective cohort study using data from the Kaiser Permanente Spine Registry between 2009-2019. The cohort consisted of adult patients (≥18 years old) with the diagnosis of cervical degenerative disc disease, cervical trauma, or cervical deformity who underwent primary PCFs between C3 to T1/T2 stopping at -C7 or -T1/T2. Reoperation for nonunions (operative nonunions) was the primary outcome of interest and patients were followed until validated operative nonunion, membership termination, death, or 03/31/2020. Descriptive statistics and five-year crude incidence rates and 95% confidence intervals (CI) for operative nonunion for PCFs (between C3 to T1/T2) stopping at -C7 or -T1/T2. Time-dependent crude and multivariable Cox-Proportional Hazards models for operative nonunions were used to evaluate operative nonunion rates with adjustment for covariates or risk change estimates more than 10%.

Results: We identified 875 patients with PCFs (between C3 to T1/T2) stopping at either -C7 (n=470) or -T1/T2 (n=405) with average follow-up time of 4.6 (±3.3) years and average time to operative nonunion of 0.9 (±0.6) yrs. Crude overall incidence rates for stopping at -C7 (1.91% (0.88%-3.60%) and -T1/T2 (1.98% (0.86%-3.85%) were comparable. In crude models and models adjusted for age and smoking status, we found no difference in risk for constructs extended to T1/T2 compared to those stopping at -C7: (adjHR=1.09, 95%CI=0.42-2.84, P=0.86), Table 1. Additionally, we observed no differences in the probability of operative nonunions after adjusting for age and smoking status and accounting for a competing risk of membership termination (Grey's Test p=0.448), Fig 1.

Conclusion: We presented one of the largest series of patients in the literature reporting reoperation rates for nonunions in PCFs stopping at -C7 versus -T1/T2. In our cohort of 875 patients with PCFs ranging from C3 to T1/T2 stopping at -C7 or -T1/T2, with an average follow-up of > 4 years, we found no statistical difference in reoperation rates for nonunions (operative nonunions).

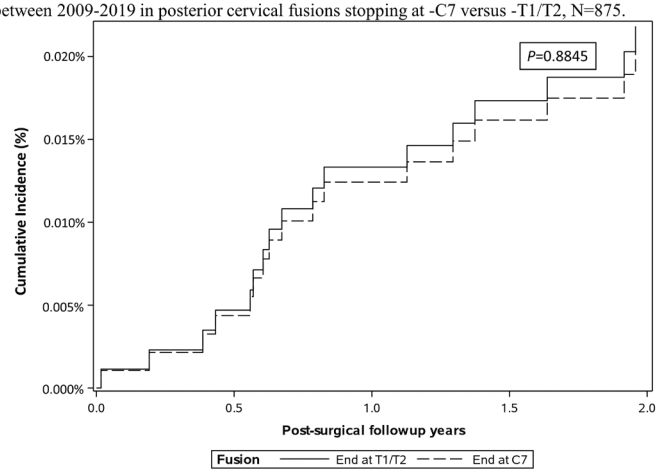
PRESENTATION #66 continued

Table 1. Crude and Adjusted Hazard Ratio and 95% CI for Operative Nonunions by Cephalad Level of construct Stopping at -C7 versus -T1/T2, N=875

Instrumented Levels		Fusion Cases	Operative Nonunion Events	Operative Nonunion Incidence Rate (95% CI)	Crude Hazard Ratio (95% CI)	Adj Hazard Ratio* (95% CI)
Cephalad C3						
	C3-C7	329	7	2.13% (0.86%-4.33%)	-	-
	C3-T1/T2	291	2	0.69% (0.08%-2.46%)	-	-
Cephalad C4						
	C4-C7	75	2	1.33% (0.03%-7.21%)	-	-
	C4-T1/T2	73	3	4.11% (0.86%-11.54%)	-	-
Cephalad C5						
	C5-C7	43	1	2.33% (0.06%-12.29%)	-	-
	C5-T1/T2	29	2	6.90% (0.85%-22.77%)	-	-
Cephalad C6						
	C6-C7	23	0	-	-	-
	C6-C7-T1/T2	12	1	8.33% (0.21%-38.48%)	-	-
All Levels						
	Stop at C7	470	9	1.91% (0.88%-3.60%)	(ref)	(ref)
	Stop at T1/T2	405	8	1.98% (0.86%-3.85%)	1.14 (0.44-2.98), *P*=0.78	1.09 (0.42-2.84), *P*=0.86

Note: 5 events per predictor variable were the minimum for Cox Regression analysis; CI=Confidence Interval.
**Adjusted for age at surgery and smoking.*

Fig 1. Adjusted* cumulative incidence of reoperation for nonunions (operative nonunions) between 2009-2019 in posterior cervical fusions stopping at -C7 versus -T1/T2, N=875.



**Adjusted for Age at surgery at surgery and smoking*

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.

PRESENTATION #67

Racial Disparities in Patients Undergoing Anterior Cervical Discectomy and Fusion: A Multi-Site Study

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Introduction: With the increasing aging population in the United States and rising healthcare costs several studies have demonstrated outcome measures such as length of stay (LOS) as a proxy for quality care and cost, which sheds light on disparities in outcomes between different racial groups. Recent studies have demonstrated that Black patients experience higher rates of complication and higher costs following spinal surgery including for anterior cervical discectomy and fusion (ACDF) surgery. This study sought to evaluate whether Black patients have different lengths of stay following ACDF surgery.

Materials and Methods: Utilizing an institutional database from three tertiary care facilities, 279 consecutive patients undergoing anterior cervical discectomy and fusion (ACDF) by 8 different surgeons between 2013 and 2018 were identified retrospectively. The primary outcome of interest was extended length of stay, which has been defined in the literature as 2 days following ACDF. Pre-operative health status was recorded, and comorbidities were scored by the Charlson Comorbidity Index. Demographic data including age at time of surgery, sex, smoking status, and self-identified race (White or Black/African American). Univariable and multivariable linear regression models were employed to quantify the degree to which a patient's LOS was related to their self-identified Race, demographics, and peri-operative clinical data. For regression modeling, variance inflation factors (VIF) were calculated to assess multicollinearity. The predictors that showed VIF<10 were retained for regression analyses. Statistical significance is defined by the two-sided test with a p-value <0.05. Statistical analyses were performed using SAS (SAS 9.4, SAS Institute Inc, Cary, NC, USA).

Results: Of the 278 patients who received an ACDF, 71.6% (199) identified as White and 28.4% (79) identified as Black. Black patients were nearly twice as likely to be smokers (p=0.003). Patients of both races underwent a statistically similar distribution of operative levels with an increasing number of operative levels occurring less frequently. Black patients had longer lengths of stay by a mean of half a day (p=0.001) and experienced more extended stays (p=0.002). Black patients experienced longer mean operative times (p=0.001) when compared to White patients undergoing the same number of levels for fusion. This was the case for one, two, and three level fusions. Black patients also had an increased rate of discharge to inpatient acute rehabilitation (p=0.031) and showed a trend towards increased rates of nonunion (p=0.050). Adjusted multivariable linear regression modeling of length of stay demonstrated that Black patients have an independent association with extended length of stay (ß=0.321; p=0.0263). Discharge to inpatient rehabilitation facility also was an independent driver of length of stay (ß=0.321; p=0.0263).

Conclusion: Black race was associated with increased operative times and increased length of stay in this study. Additional research is necessary to evaluate the underlying social determinants of health and other factors that may contribute to the results in this study including longer operative times for Black patients. The increased rate of discharge to sub-

PRESENTATION #67 continued

acute rehabilitation for Black patients may be secondary to factors such as more severe pathology at presentation or may reflect social determinants of health, such as less assistance at home.

Table 1. Demographic Characteristics of Patients Undergoing ACDF Surgery at a Tertiary Referral Center, Stratified by Race

Variables[a]	Characteristics of Referral[b]		P Values
	White 71.6% (N=199)	Black 28.4% (N=79)	Black vs. White
Age [Avg]	51.9 (0.8)	49.4 (1.0)	0.078
Sex			
Male [%]	51.8% (3.5%)	41.8% (5.5%)	0.133
Female [%]	48.2% (3.5%)	58.2% (5.5%)	0.133
Smoking			
Yes [%]	19.6% (2.8%)	36.7% (5.4%)	**0.003**
Quit [%]	26.1% (3.1%)	19.0% (4.4%)	0.209
Ever [%]	45.7% (3.5%)	32.9% (5.3%)	0.051
Never [%]	46.2% (3.5%)	55.7% (5.6%)	0.155
Not Reported [%]	8.0% (1.9%)	11.4% (3.6%)	0.378

Legend: a - Brackets in the variable column describe the type of data reported, with "%" representing percentages and "Avg" representing mean values; b - Standard errors for averages or percentages are found in parentheses

Table 2. Operative Characteristics of Patients Undergoing ACDF Surgery at a Tertiary Referral Center, Stratified by Race

Variables[a]	Characteristics of Referral[b]		P Values
	White 71.6% (N=199)	Black 28.4% (N=79)	Black vs. White
Estimated Blood Loss (mL) [Avg]	77.54 (10.26)	70.33 (6.75)	0.669
Levels of Fusion	.	.	.
One [%]	44.7% (3.5%)	46.8% (5.6%)	0.750
Two [%]	35.7% (3.4%)	29.1% (5.1%)	0.297
Three or More [%]	19.6% (2.8%)	24.1% (4.8%)	0.410
Length of Stay (days) [Avg]	1.9 (0.1)	2.4 (0.1)	**0.001**
Length of Stay	.	.	.
<2 Days [%]	59.8% (3.5%)	39.2% (5.5%)	**0.002**
≥2 Days [%]	40.2% (3.5%)	60.8% (5.5%)	**0.002**
Operative Time (min) by Levels of Fusion	.	.	.
Overall [Avg]	157.6 (4.2)	184.6 (7.5)	**0.001**
One [Avg]	123.0 (3.7)	138.0 (6.1)	**0.033**
Two [Avg]	171.1 (5.9)	204.1 (12.0)	**0.009**
Three or More [Avg]	212.2 (10.9)	251.8 (12.0)	**0.030**

PRESENTATION #68

Stand-Alone Cages versus Cage and Plate Constructs for Primary One- and Two-level Anterior Cervical Discectomy and Fusion: A Prospective Randomized Controlled Trial

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Introduction: Although anterior cervical discectomy and fusion (ACDF) with interbody spacer and separate plate/screw construct (PLATE) is commonly performed, some have asserted it may be associated with a higher incidence of postoperative dysphagia, increased operative time, malpositioned hardware, higher costs, and adjacent segment impingement. To address these concerns, others have opted to utilize an interbody cage with integrated screws and no plate (CAGE) with good results. This study's purpose was to compare the perioperative and radiographic outcomes between stand-alone and anterior plated 1 and 2 level ACDF.

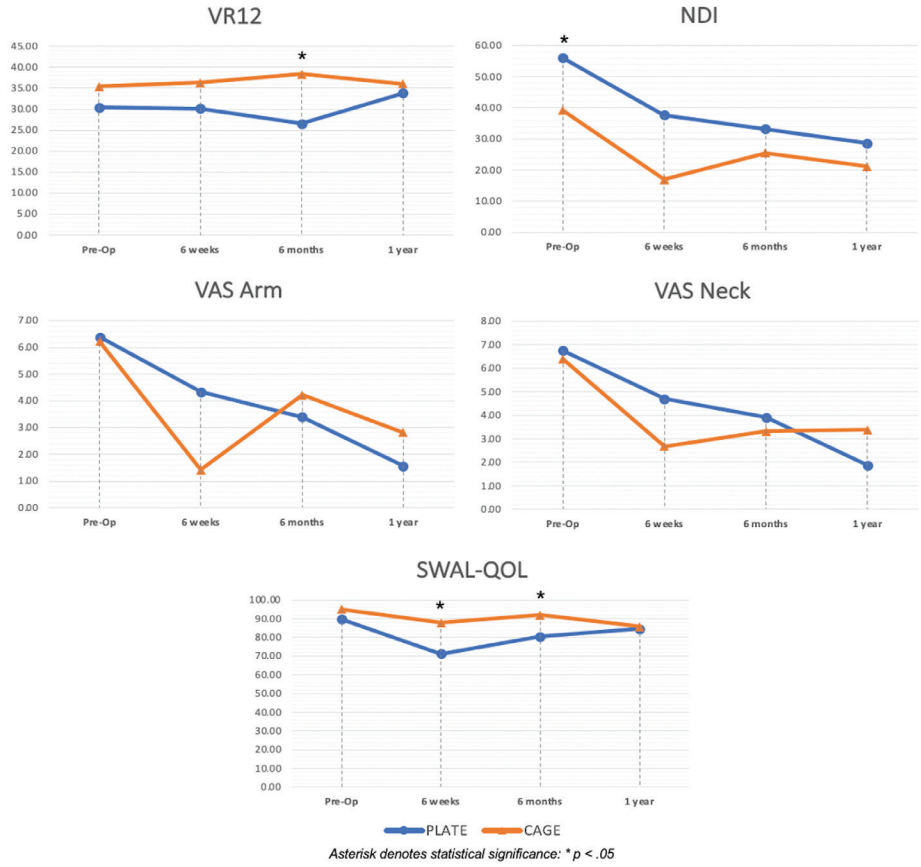
Materials and Methods: This study was a prospective, randomized, controlled trial that followed patients for a minimum of 1 year following surgical intervention. All procedures were performed by the senior surgeon between July 2017 and February 2020. Patients with 1-2 level degenerative disease were randomized into one of two treatment arms consisting of either PLATE or stand-alone CAGE reconstruction. Primary endpoints assessed included clinical improvement on patient-reported outcome metrics (PROs), construct integrity, cervical alignment, successful arthrodesis, and subsequent revision surgeries. Statistical methods included chi-square with Fisher's exact test for categorical variables and Mann-Whitney U-test or student's t-test for continuous variables. The threshold for statistical significance was set to $p < .05$.

Results: A total of 46 patients were randomized: 12 patients were treated with 1-level PLATE, 12 with 1-level CAGE, 12 with 2-level PLATE, and 10 with 2-level CAGE. For single-level ACDF, arthrodesis was observed in 90% of PLATE and 100% of CAGE patients ($p = .305$). There were no postoperative differences in PROs with the exception of worse swallow function on SWAL-QOL with PLATE at 6 weeks ($p = .050$) and 6 months ($p = .042$) (Figure 1). Pseudarthrosis requiring revision was observed in one PLATE patient. For two-level ACDF, arthrodesis was observed in 90% of PLATE and 80% of CAGE patients ($p = .531$). CAGE patients reported worse scores on NDI at 6-weeks ($p = .037$) and 6-months ($p = .017$), as well as on VAS Neck ($p = .010$), but no differences in these parameters were seen at one year. However, swallow function was worse with PLATE on SWAL-QOL at 6 weeks postoperatively ($p = .038$) (Figure 2). There were no differences in the rates of fusion, loss of disc height correction, subsidence, or sagittal parameters between the PLATE and CAGE cohorts for both one- and two-level ACDF (Tables 1 and 2).

Conclusion: There was a significantly greater incidence of transient (but not long-term) postoperative dysphagia in both the single-level and two-level PLATE cohorts. However, early postoperative outcomes were worse for two-level CAGE in certain patient-reported metrics, while radiographic assessments of cervical sagittal alignment showed few differences. These findings suggest that although anterior instrumentation may be associated with a higher likelihood of dysphagia, it may also be associated with higher short-term stability and improved patient-reported outcomes for two-level fusion until arthrodesis has been established.

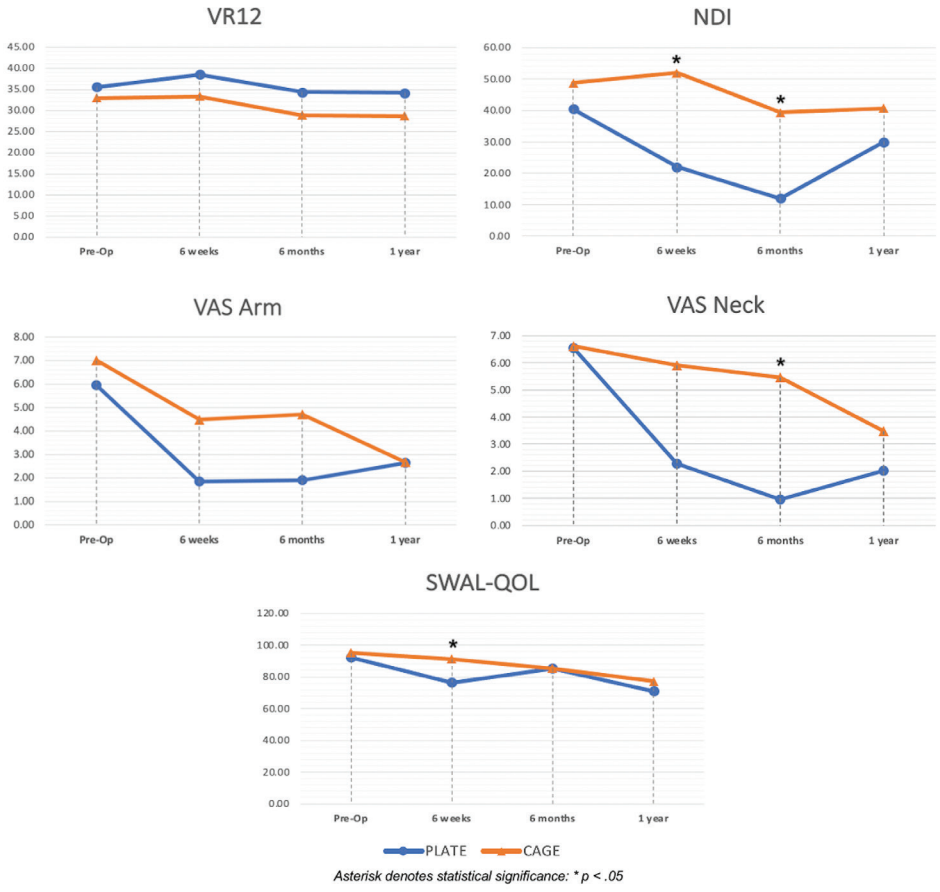
Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

PRESENTATION #68 continued



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.

PRESENTATION #68 continued



*Asterisk denotes statistical significance: * p < .05*

PRESENTATION #68 continued

	All Patients	PLATE	CAGE	*p*
SINGLE-LEVEL ACDF				
Arthrodesis	95%	90%	100%	.305
Disc Space Heights (mm)				
Operative Segment				
Anterior	-0.66 ± 1.32	-0.80 ± 1.09	-0.47 ± 1.62	.859
Middle	-0.62 ± 1.86	-0.96 ± 1.92	-0.20 ± 1.82	.450
Posterior	-1.19 ± 1.41	-1.34 ± 1.30	-1.01 ± 1.60	.859
Subsidence (mm)				
Superior Endplate	0.86 ± 0.63	0.87 ± 0.66	0.85 ± 0.63	.754
Inferior Endplate	0.70 ± 0.64	0.50 ± 0.57	0.96 ± 0.67	.189
Sagittal Cervical Alignment				
FSL	0.46 ± 3.24	-0.32 ± 2.86	1.12 ± 3.51	.262
Cervical Lordosis	0.60 ± 5.82	-0.70 ± 5.58	1.51 ± 6.10	.282
C2-C7 SVA (mm)	1.63 ± 2.69	1.08 ± 2.62	2.18 ± 2.82	.401
T1 Slope	-1.58 ± 4.60	-2.17 ± 3.70	-0.98 ± 5.66	.522
TWO-LEVEL ACDF				
Arthrodesis	85%	90%	80%	.531
Δ Disc Space Heights (mm)				
Cephalad Operative Segment				
Anterior	-0.87 ± 2.23	-0.94 ± 2.35	-0.79 ± 2.34	.715
Middle	-1.36 ± 2.09	-1.24 ± 2.24	-1.50 ± 2.13	.999
Posterior	-0.49 ± 1.85	-0.40 ± 2.46	-0.61 ± 0.97	.647
Caudal Operative Segment				
Anterior	0.30 ± 1.45	0.66 ± 1.76	-0.24 ± 0.75	.286
Middle	-1.55 ± 1.45	-1.35 ± 1.16	-1.85 ± 1.96	.831
Posterior	-0.31 ± 1.54	0.22 ± 1.39	-1.10 ± 1.59	.201
Subsidence (mm)				
Cephalad Superior Endplate	0.83 ± 0.48	0.75 ± 0.62	0.95 ± 0.09	.999
Cephalad Inferior Endplate	1.06 ± 0.69	0.85 ± 0.74	1.38 ± 0.54	.285
Caudal Superior Endplate	0.55 ± 0.48	0.32 ± 0.54	0.81 ± 0.22	.093
Caudal Inferior Endplate	0.46 ± 0.49	0.35 ± 0.43	0.59 ± 0.57	.444
Δ Sagittal Cervical Alignment				
Cephalad FSL	0.74 ± 2.74	0.40 ± 3.30	1.17 ± 1.98	.534
Caudal FSL	0.63 ± 2.37	0.49 ± 2.62	0.82 ± 2.22	.950
Cervical Lordosis	-0.83 ± 6.20	-1.31 ± 5.18	-0.16 ± 8.02	.465
C2-C7 SVA (mm)	2.13 ± 3.20	3.16 ± 4.34	1.10 ± 1.24	.465
T1 Slope	2.69 ± 4.45	2.33 ± 1.60	3.12 ± 6.78	.584

Δ, change from preoperative to postoperative assessment; FSL, Fusion Segment Lordosis; SVA, Sagittal Vertical Axis;

PRESENTATION #69

Single-level Cervical Disc Replacement Using a PEEK-on-Ceramic Implant: Results of a Multicenter FDA IDE Trial with 24-month Follow-up

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Introduction: Many early cervical total disc replacements (TDRs) produced motion through a ball-and-socket action, with metal endplates articulating with a plastic core. PEEK is used increasingly for spinal implants due to its mechanical properties and lack of artifact on imaging. A cervical TDR was designed with commercially pure titanium-coated PEEK endplates and a biconvex zirconia toughened alumina ceramic core. The purpose of this study was to compare this PEEK-on-ceramic TDR to anterior cervical discectomy and fusion (ACDF) to treat single-level cervical disc degeneration.

Materials and Methods: This was a prospective, non-randomized, multicenter Food and Drug Administration (FDA) Investigational Device Exemption (IDE) trial comparing the investigational group (Simplify® Cervical Artificial Disc) to a propensity-matched historic control group. Patients received the PEEK-on-ceramic Simplify® Cervical Artificial Disc (n=150 patients from 16 sites). The historic control group included 117 propensity-matched ACDF patients from an earlier cervical TDR IDE trial employing the same inclusion/exclusion criteria. All patients were treated for single-level symptomatic cervical disc degeneration. The primary outcome was a composite 5-point success classification at 24-month follow-up requiring: >15 point (of 100) improvement in Neck Disability Index (NDI) score; 2) maintenance/improvement in neurologic status; 3) no device failure; 4) no reoperation/revision/removal and/or supplemental fixation at the index level, and 5) no major adverse events. Outcome measures included NDI, visual analog scale (VAS) assessing neck and arm pain, neurological status, adverse events, and subsequent surgery. Radiographic assessment included flexion/extension range of motion. Evaluations were performed pre-operatively and post-operatively within 2 weeks, 6 weeks, 3, 6, 12, and 24 months. Facet joints were assessed at 24 months comparing pre- to post-operative MRI images using a published 4-point scale.

Results: The overall composite success rate was significantly greater in the TDR group vs. ACDF (93.0% vs. 73.6%; $p<0.001$). Mean NDI, neck pain, and arm pain scores improved significantly in both groups at all follow-up points. Mean NDI scores in the TDR group were significantly lower than ACDF scores at all follow-up points all $p<0.01$). Secondary surgical intervention was undertaken in 4 (2.7%) patients at the index level in the TDR group and 6 (5.1%) in the ACDF group. There were no significant differences in the rates of serious adverse events when comparing the two groups. The mean segmental range of motion of the treated level in the TDR group was 7.3o prior to surgery. This increased to 8.6 o at 3 month follow-up and continued to increase to 9.6o at 24 months ($p<0.001$). Facet joint assessment by MRI at 24-month follow-up in the TDR group showed little change from pre-operative.

Conclusion: The results of this study found that the investigational device produced outcomes similar or superior on some measures, including superiority in the composite success classification, compared with ACDF, for the treatment of single-level symptomatic cervical disc degeneration. ROM at the treated level increased from the pre-operative value and was

PRESENTATION #69 continued

maintained throughout follow-up. Safety of the PEEK-on-ceramic disc was established with no device failures in the series. These results support that the device is a viable alternative to ACDF.

PRESENTATION #70

Range of Motion on Flexion and Extension at Long-Term Follow-Up After Cervical Total Disc Arthroplasty: A Systematic Review and Meta-Analysis

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Introduction: As an alternative procedure to anterior cervical discectomy and fusion (ACDF), total disc arthroplasty (TDA) facilitates direct neural decompression and disc height restoration while also preserving cervical spine kinematics. To date, few studies have reported long-term functional outcomes following TDA. Therefore, this study sought to perform a systematic review and meta-analysis investigating how range of motion (ROM) at the operative level is maintained with long-term follow-up.

Materials and Methods: PubMed and MEDLINE were queried for all published studies pertaining to cervical TDA. The methodology for screening adhered strictly to the PRISMA guidelines. All English language prospective studies reporting ROM preoperatively, one year postoperatively, and/or at long-term follow-up of 5 or more years were included. A meta-analysis was performed using Cochran's Q and I2 to test data for statistical heterogeneity, in which case a random-effects model was used. The mean difference (MD) and associated 95% confidence intervals (CI) were reported.

Results: After an initial search yielding 2309 results, 12 studies were identified through screening that met the inclusion criteria. Eight of these studies were included for meta-analysis. Overall, 1158 patients were enrolled across the 8 studies and 944 (81.52%) were available for long-term follow-up. Of the patients who followed-up, 163 (17.27%) were implanted with PCM, 131 (13.88%) with Mobi-C, 184 (19.49%) with Secure-C, 230 (24.36%) with Prestige LP, 229 (24.26%) with Bryan, and 27 (2.86%) with ProDisc-C prostheses (Table 1). There was no difference found between operative segment ROM on flexion and extension preoperatively and at 1-year follow-up (MD = -0.91, CI: -3.07 to 1.25, p = .410; Figure 1.A). However, after excluding one study identified to contribute significantly to statistical heterogeneity via sensitivity analysis, ROM was found to significantly improve at 1-year postoperatively (MD = 1.92, CI: -2.79 to -1.04, p < .0001, Figure 1.B). There was no difference found between ROM preoperatively and at long-term follow-up (MD = 0.52, CI: -0.98 to 2.03, p = .500, Figure 1.C). However, there was a significant decrease in ROM from 1-year postoperatively to final long-term follow-up (MD = 0.77, CI: 0.24 to 1.29, p = .004).

Conclusion: Operative segment ROM on flexion and extension was found to significantly deteriorate with long-term follow-up after TDA when compared to the early postoperative period. However, ROM on flexion and extension in the long-term following TDA remained similar to baseline function. While additional studies with further longitudinal follow-up investigating how much are needed, these findings further support the notion that cervical TDA may be successful in maintaining physiological spinal kinematics over the long-term.

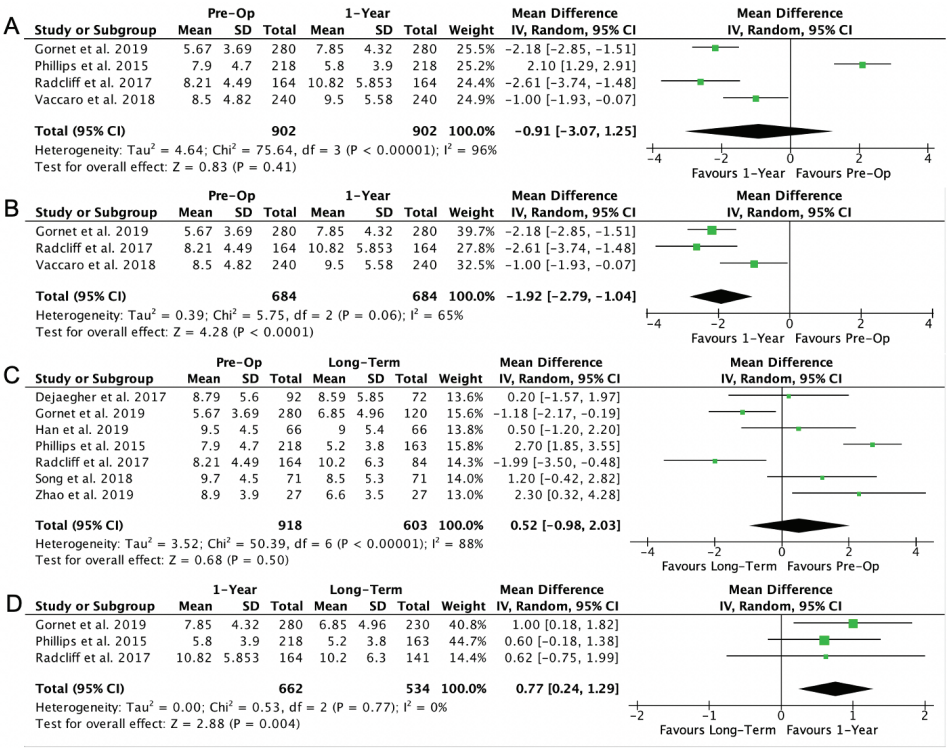
PRESENTATION #70 continued

Table 1. Range of motion data from studies included for Meta-Analysis.

Author	Device	Preoperative ROM			One-Year ROM			Long-Term ROM		
		F/E	T	LB	F/E	T	LB	F/E	T	LB
Phillips *et al.* 2015	PCM	7.9 (4.7)	0.9 (0.6)	NR	5.8 (3.9)	1.0 (0.7)	NR	5.2 (3.8)	NR	NR
Radcliff *et al.* 2017	Mobi-C	8.21 (4.49)	NR	5.04 (2.897)	10.82 (5.853)	NR	5.70 (3.218)	10.2 (6.3)	NR	5.1 (3.5)
Vaccaro *et al.* 2018	Secure-C	8.5 (4.82)	0.9 (0.62)	NR	9.5 (5.58)	1.3 (0.85)	NR	9.2	1.1	NR
Gornet *et al.* 2019	Prestige LP	5.67 (3.69)	NR	NR	7.85 (4.32)	0.97 (0.67)	6.58 (3.75)	6.85 (4.96)	NR	NR
Song *et al.* 2018	Bryan	9.7 (4.5)	NR	NR	NR	NR	NR	8.6 (5.3)	NR	NR
Dejaegher *et al.* 2017	Bryan	8.79 (5.6)	NR	NR	NR	NR	NR	8.59 (5.85)	NR	NR
Han *et al.* 2019	Bryan	9.5 (4.5)	NR	NR	NR	NR	NR	9.0 (5.4)	NR	NR
Zhao *et al.* 2019	ProDisc-C	8.9 (3.9)	NR	NR	NR	NR	NR	6.6 (3.5)	NR	NR

ROM, Range of Motion; F/E, Flexion/Extension; T, Translation; LB, Lateral Bending; NR, Not Reported

PRESENTATION #70 continued



PRESENTATION #71

Evaluation of Gait and Functional Stability in Preoperative Cervical Spondylotic Myelopathy Patients

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Introduction: Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord dysfunction in the world and can lead to significant functional deficits including proprioception and gait disturbances. Biomechanical feedback mechanisms compensating for these deficits, specifically angular momentum (AM) regulation, have remained largely unexplored. 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: 56 subjects: 32 preoperative Nurick grade 2 or 3 CSM patients and 24 controls were included. Standing balance trials were performed on a single force plate, while walking trials were conducted at self-selected pace over a 15m runway and a series of five force plates. All trials were recorded with 3D motion analysis cameras and gait modeling software was utilized to calculate stability, spatiotemporal gait parameters, and joint kinematics.

Results: Tilted ellipse area, a measure of center of pressure variance and postural stability, was significantly greater among CSM patients (847.54±764.33mm2 vs. 258.18±103.35mm2, $p<0.001$). These 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 the CSM patients tending to have slower, shorter, and wider gait compared to controls, while spending greater amount of time in double support. Compensatory AM among CSM patients was significantly increased in all three anatomic planes, where whole body AM was approximately double that of controls (0.057±0.034 vs 0.023±0.006), $p<0.001$).

Conclusion: Preoperative CSM patients showed significant alterations in spatiotemporal gait parameters and postural stability compared to controls, consistent with prior literature. Likewise, angular momentum analysis demonstrates that these patients have globally increased body excursion to maintain dynamic balance.

PRESENTATION #71 continued

Table 3. Comparison of mean spatiotemporal parameters for control population and CSM patients

Parameter	Controls	(± Standard Deviation)	CSM Patients N = 32	(± Standard Deviation)	p-value
Stride Length (m)	1.173	0.123	0.956	0.203	<0.001
Cadence (step/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 4. Comparison of whole-body angular momentum for control population and CSM patients

Angular Momentum Excursion	Controls	(± Standard Deviation)	CSM Patients N = 32	(± Standard Deviation)	p-value
Whole Body (Sag)	0.051	0.01	0.07	0.028	0.00100
Whole Body (Coronal)	0.023	0.006	0.057	0.034	<0.00001
Whole Body (Trans)	0.009	0.003	0.014	0.007	0.00015

PRESENTATION #71 continued

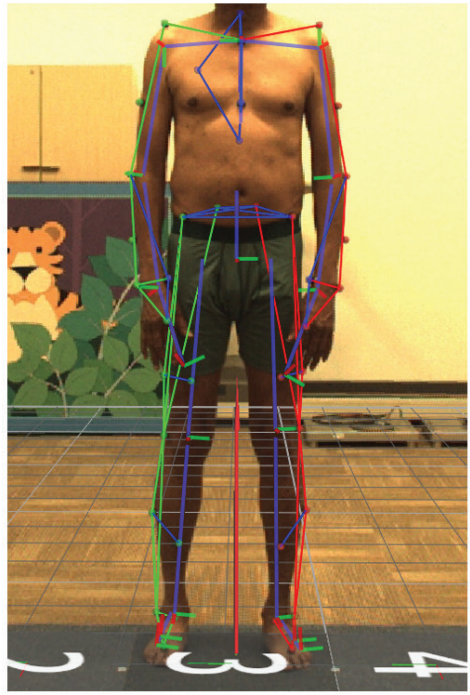

Figure 1. Subject with marker set highlighted in blue, green, and red overlay. Subject-specific model shown by coordinate frames aligned with limbs.

PRESENTATION #72

Skip laminoplasty as a novel posterior decompression technique to decrease interlaminar fusion and preserve cervical range of motion

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Introduction: Although laminoplasty is an efficient posterior decompression procedure for cervical myelopathy with favorable clinical outcomes, postoperative complications such as interlaminar fusion, which leads to the restriction of neck motion, are frequently observed. C3 laminectomy accompanied by open-door laminoplasty at other levels has been reported to result in superior neck motion without postoperative kyphosis. Therefore, we also attempted to perform laminectomies at intervening levels (C5) where laminoplasty was performed (C4 and C6) in order to prevent interlaminar fusion and preserve neck range of motion (ROM). The present study was conducted to clarify the clinical and radiographic outcomes of 'skip laminoplasty'.

Materials and Methods: A total of 101 patients who underwent skip laminoplasty or conventional laminoplasty and who were followed up for at least 2 years were retrospectively reviewed. In skip laminoplasty, laminectomy at C5 was performed for patients planned for decompression of C4-6, and laminectomy at C3/C5 was performed when decompression of C3-C6 is needed. The C4 and C6 levels were decompressed by open-door laminoplasty. In conventional laminoplasty, laminectomy at C3 was performed when decompression of C3 is needed, and the remaining levels were decompressed by open-door laminoplasty. Patient characteristics, radiographic parameters such as cervical lordosis, C2-C7 sagittal vertical axis (SVA), and cervical ROM, and patient-reported outcome measures such as neck disability index (NDI), neck pain visual analog scale (VAS), and Japanese Orthopedic Association (JOA) score were retrospectively reviewed. The results of patients who underwent skip laminoplasty were compared with those of patients who underwent conventional laminoplasty.

Results: Skip laminoplasty was performed for 23 patients (22.8%), and 78 patients (77.2%) underwent conventional laminoplasty (Table 1). Interlaminar fusion was detected in 27 (34.6%) patients who underwent conventional laminoplasty; however, no interlaminar fusion was detected in skip laminoplasty patients. Cervical ROM, C2-C7 SVA, and cervical lordosis at each follow-up point did not show significant differences between the two groups. The amount of cervical ROM reduction was greater with conventional laminoplasty; however, the difference did not reach statistical significance (-4.8±8.4 vs. -8.9±12.4, p=0.07). The NDI at the final follow-up was significantly lower in the skip laminoplasty group compared with the conventional laminoplasty group (6.2±3.0 vs. 10.6±8.0, p<0.01). Furthermore, the JOA recovery rate was significantly higher among skip laminoplasty patients compared with conventional laminoplasty patients (37.5±30.0 vs. 9.0±73.4, p<0.01) (Table 2).

Conclusion: Skip laminoplasty demonstrated a smaller decrease in cervical ROM; however, the difference was not significant. Sagittal alignment after skip laminoplasty did not significantly differ from that after conventional laminoplasty, indicating that it does not cause further postoperative kyphosis. In addition, skip laminoplasty resulted in better postoperative NDI and JOA recovery rate, which suggests that wider decompression with skip laminoplasty

PRESENTATION #72 continued

might have some benefit. Therefore, skip laminoplasty could be considered as an alternative technique to conventional laminoplasty. However, further evaluation with a larger sample size is required.

Table 1. Patient characteristics

Variables	Skip laminoplasty	Conventional laminoplasty	P value
Number	23	78	
Age (yrs)	62.2 ±10.9	64.0 ±13.1	0.55
Sex			0.55
Male	20 (87.0%)	61 (78.2%)	
Female	3 (13.0%)	17 (21.8%)	0.05
BMI(kg/m2)	27.0 ± 3.2	25.4 ± 3.5	
Smoking status			
Smoker	12 (52.2%)	33 (42.3%)	0.41
Non smoker	11 (47.8%)	45 (57.7%)	
Follow-up period (yrs)	2.1 ± 0.2	2.0 ± 0.5	0.10
Surgical level			
C3-6	17 (83.9%)	36 (36.2%)	0.02*
C4-6	6 (26.1%)	42 (53.8%)	
Laminectomy level			
None	0 (0.0%)	42 (53.8%)	
C3	0 (0.0%)	36 (36.2%)	<0.01*
C5	7 (30.4%)	0 (0.0%)	
C3,5	16 (69.6%)	0 (0.0%)	
Operation time (min)	126.0 ± 22.7	166.6 ± 52.1	<0.01*
Blood loss (ml)	160.2±186.5	80.2±92.3	0.06
Hospital stay	7.3±1.4	8.8±3.2	<0.01*

yrs, years; BMI, body mass index;
Age, follow-up period, operation time, blood loss and hospital stay were analyzed using a student's t-test
Sex, smoking status, surgical level, and laminectomy level were analyzed using a chi-square test

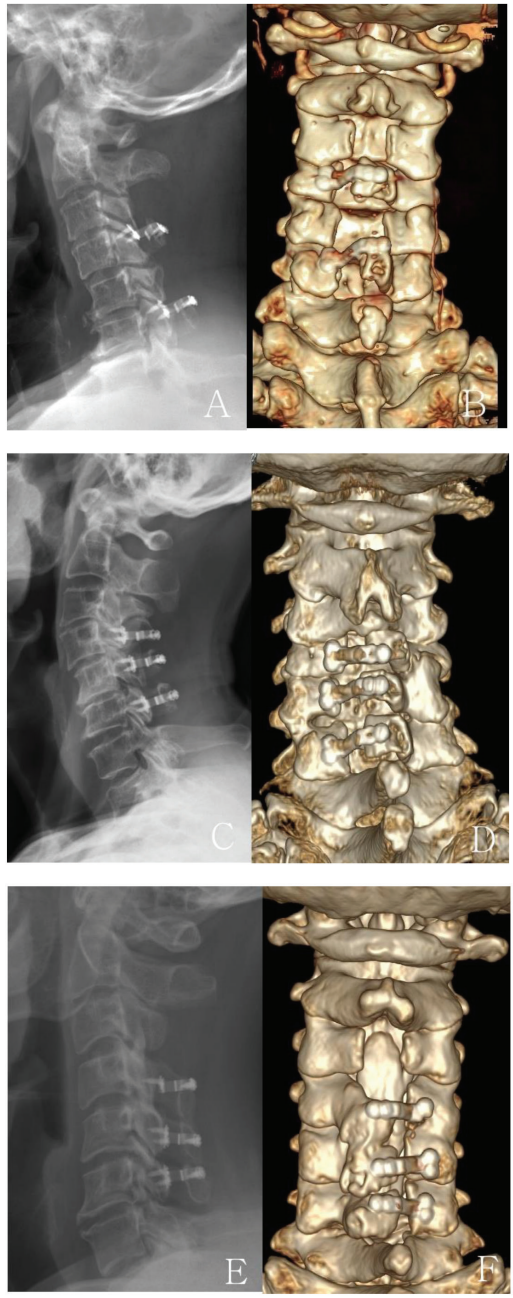
PRESENTATION #72 continued

Table 2. Radiographic results and patient reported outcome measures

Radiographic results				
Variables		Skip laminoplasty	Conventional laminoplasty	P value
Cervical ROM	Preop	27.0 ± 12.0	32.8 ± 14.3	0.08
	Final follow-up (2yrs)	22.0 ± 11.2	24.1 ± 11.8	0.45
	Difference	-4.8 ± 8.4	-8.9 ± 12.4	0.07
Decrease of cervical ROM (%)		12.9± 33.0	10.2 ± 101.4	0.84
C2-C7 SVA	Preop	32.7 ± 13.0	31.0 ± 13.7	0.61
	Final follow-up (2yrs)	34.4 ± 12.3	32.1 ± 11.9	0.43
	Difference	1.7 ± 14.6	1.1 ± 11.1	0.84
Cervical lordosis	Preop	11.6 ± 8.4	11.6 ± 9.5	0.97
	Final follow-up (2yrs)	6.6 ± 8.3	7.9 ± 9.2	0.54
	Difference	5.0 ± 7.6	3.7 ± 7.3	0.48
Interlaminar fusion level	C4-5	0 (0.0%)	4 (5.1%)	<0.01*
	C5-6	0 (0.0%)	9 (11.5%)	
	C4-5-6	0 (0.0%)	14 (18.0%)	
Patient reported outcome measures				
NDI	Preop	9.7 ± 4.3	13.1 ± 9.3	0.02*
	Final follow-up (2yrs)	6.2 ± 3.0	10.6 ± 8.0	<0.01*
	Difference	3.5 ± 3.8	2.5 ± 8.9	0.43
Neck pain VAS	Preop	2.3 ± 2.2	2.6 ± 2.2	0.64
	Final follow-up (2yrs)	2.0 ± 1.9	2.4 ± 2.4	0.47
	Difference	-0.3 ± 2.4	-0.2 ± 2.9	0.82
JOA score	Preop	12.7 ± 2.1	12.5 ± 3.3	0.78
	Final follow-up (2yrs)	14.1 ± 2.0	13.4 ± 2.9	0.24
	Difference	1.48 ± 1.0	0.9±2.6	0.10
	Recovery rate (%)	37.5 ± 30.0	9.0 ± 73.4	<0.01*

ROM, range of motion; SVA, sagittal vertical axis; NDI, neck disability index; JOA, Japanese Orthopedic Association score;
Student's t-test was used to compared the results between the two groups.
Paired t-test was used to compare the results between different time-points.

PRESENTATION #72 continued



PRESENTATION #73

Neuroimaging Biomarkers Correlate With Disease Severity In Degenerative Cervical Myelopathy

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Introduction: Natural history of degenerative cervical myelopathy (DCM) is not fully understood especially in mild populations. Clinical assessment tools are often not sensitive enough to pick up deterioration and conventional MRI can provide valuable information but has limited utility.(1) Advanced quantitative MRI (qMRI) including diffusion tensor (DTI), magnetization transfer (MT) and T2* weighted imaging (T2*WI) have been shown to provide metrics correlating with microstructure and physiology (e.g., demyelination).(2-4) These techniques were investigated to find potential biomarkers of neural injury.

Materials and Methods: 58 healthy controls and 60 patients with DCM underwent 3T MR imaging of the cervical cord using a protocol including DTI, MT and T2* weighted sequences described previously (5). Clinical assessment included modified Japanese Orthopaedic Association score (mJOA) and Graded Redefined Assessment of Strength, Sensation and Prehension (GRASSP). Image processing included template based analysis to calculate spinal cord cross sectional area (CSA), magnetization transfer ratio (MTR) , T2* weighted white to grey mater ratio (T2* WI WM/GM) and fractional anisotropy (FA) at the most compressed cervical cord level.

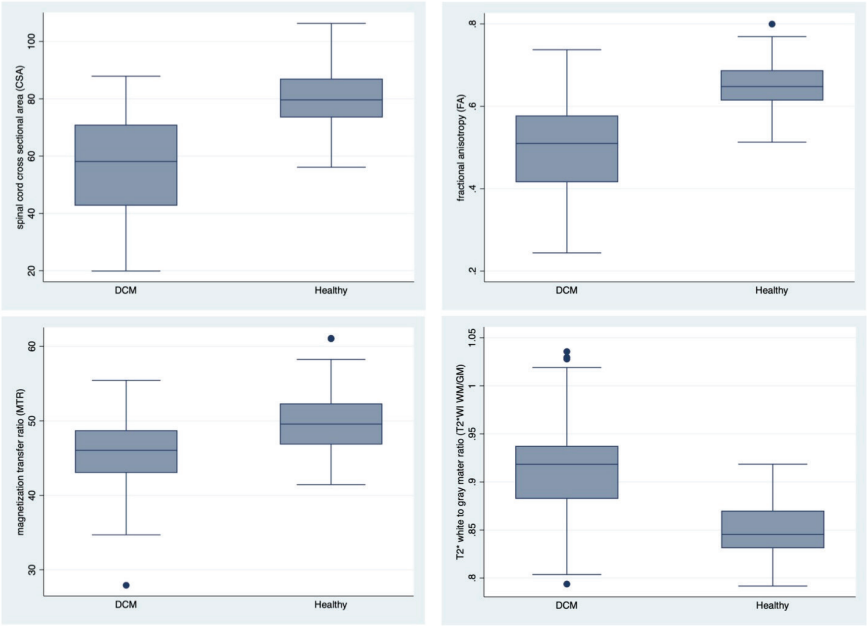
Statistical analysis included comparison of metrics between patients and controls using Student's t-test and univariate/multivariate logistic regression. Clinical correlation with functional outcome scores (mJOA) and upper extremity motor scores (GRASSP) were performed using Pearson coefficient and finally a multivariate linear regression analysis was completed with mJOA as the dependent variable.

Results: There were significant differences between DCM and healthy populations when comparing all four metrics including FA ($P<0.00001$, AUC=0.852), CSA ($P<0.0001$, AUC=0.860), MTR ($P<0.00001$, AUC=0.750) and T2*WI WM/GM ($P<0.00001$, AUC=0.848). A multivariate logistic model using all metrics showed excellent diagnostic accuracy in differentiating between healthy and DCM populations (AUC=0.942).

All metrics demonstrated good correlation with upper motor scores where CSA ($r=0.54$, $P<0.0001$) outperformed FA($r=0.41$, $P<0.00001$), MTR ($r=0.45$, $P<0.00001$) and T2*WI WM/GM ($r=-0.36$, $P=0.003$). These metrics were used in a multiple linear regression model ($R2=0.541$, $P<0.00001$) where CSA ($P<0.0001$) and T2*WI WM/GM($P=0.01$) were the strongest independent predictors of mJOA.

Conclusion: We have described a few promising biomarkers of spinal cord injury that show good correlation with clinical outcomes. Multiparametric quantitative MRI has the potential to become a valuable tool in managing patients with DCM and possibly detect microstructural changes in the spinal cord tissue before clinical symptoms can arise.

PRESENTATION #73 continued



PRESENTATION #74

Early Surgical Decompression Enhances Motor Recovery in Traumatic Cervical ASIA A Spinal Cord Injury Patients: Analysis of Prospective, Multicentre Data in 420 Cases

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Introduction: Despite growing evidence for early surgical decompression for traumatic cervical spinal cord injury(tCSCI) patients. controversy surrounds the efficacy of early surgical decompression on patients with a motor and sensory complete (ASIA A) cervical injury. With the use of prospective, multicentre dataset of tCSCI patients, we have sought to address the impact of early surgical intervention on patients with a cervical ASIA tSCI.

Materials and Methods: Patients with ASIA A cervical tCSCI were isolated from 4 prospective, multi-center datasets (NACTN, STASCIS, NASCIS 3, and SYGEN). Patients who did not get surgical decompression, lacked a baseline clinical exam, had a Glasgow coma scale of less than 13, were over the age of 70 or under the age of 16 or did not have a recorded neurological level of injury (NLI) at baseline were excluded. A scale was created tabulating muscle groups below the NLI with power of greater than 3. The difference at the one-year follow-up to baseline (<72hours) was calculated to measure the number of muscle groups gained overtime. For those missing follow-ups at one-year their 6 month results were carried forward. Significant gain was defined to include those that recovered more than two muscle groups below their NLI. Analysis of variance (ANOVA) was then done to compare significant gain over the follow-up period for patients with and without early decompressive surgery (<24hrs). A p-value of <0.05 was selected a priori for significance.

Results: We identified 420 cervical ASIA A tCSCI patients who had an average age of 33yrs. The average time from injury to surgery was 168hrs with 134 (31.9%) of patients having early surgery (<24 hrs). The mean number of muscle groups gained below the NLI was 2.69 (SD 2.3.12) for those who had early surgery compared to 2.37 (SD 3.38) for those with late surgery. Of those patients who had early surgery 39.67% had a significant improvement (greater than 2 groups gained) vs. 28.76% of those who did not have early surgery (P = 0.030 ;Table 1).

Conclusion: For the first time, we have shown a clear therapeutic benefit of early surgical decompression within 24 hrs in ASIA A tCSCI patients. For ASIA A tCSCI patients the chance of recovering two or more motor levels below the NLI is significantly increased with early surgical intervention

Table 1: Significant gain in motor function below neurological level of injury in traumatic motor and sensory complete cervical spinal cord injury patients. Significant gain defined as power of greater than 3/5 in more than two muscle group below the neurological level of injury.

Significant gain (2+ muscle groups)	Late Surgery	Early Surgery (<24hrs)
No	213 (71.24)	86 (28.76)
Yes	73 (60.33)	48 (39.67)
		P: 0.030

PRESENTATION #75

Internet Video-Based Patient Education on ACDF and CTDR: A Quantitative Analysis of Content and Quality

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Introduction: There exists wide availability of internet-based educational material for patients interested in spine surgery. YouTube in particular has presented an opportunity for patients to self-educate, but little is known about the quality and potential biases of the educational material. This study seeks to quantify and compare the quality of video materials available on YouTube for anterior cervical discectomy and fusion (ACDF) and cervical total disc replacement (CTDR).

Materials and Methods: YouTube was queried for videos related to ACDF (keywords: "ACDF" or "Anterior Cervical Fusion") and CTDR (keywords: "Cervical Disc Replacement" or "Cervical Disc Arthroplasty"). The top 40 videos from each search were obtained and duplicates were eliminated. Each set of videos was reviewed by two different reviewers and data was averaged between the two. Primary outcome of interest was the DISCERN quality index, a validated objective measure of the quality of patient educational material. Secondary outcomes included JAMA quality score, an overall content quality score, frequency of device marketing, number of views, video source, like ratio, and video power index. Statistical comparisons were made between the ACDF and CTDR data.

Results: After search completion, 57 videos were identified for ACDF and 58 identified for CTDR. For analyses based upon Video Power Index 5 ACDF and 2 CTDR videos were excluded because "likes" were disabled. The mean number of views per video was similar between groups (p=0.49). The average age of the video as determined by the number of days since upload was similar between groups (p=0.99). There was no significant difference between groups with respect to Like Ratio (p=0.47), number of views (p=1.0), or video power index (p=0.67). Among ACDF and CDR there was no significant difference in the video source frequency (p=0.321). No difference was seen in average video length (p=0.17).

The mean JAMA score for ACDF and CDR were 0.947 and 1.043, respectively (p=0.45). CTDR videos demonstrated a significantly higher DISCERN score and total content score compared with ACDF (28.026 and 23.281, p<0.001; 4.276 and 2.973, p=0.002;). Among CTDR videos, videos with an academic source had significantly higher DISCERN scores when compared with the combined scores from other sources (30.789 vs 26.679, p=0.04). Among ACDF videos, the academic videos also had significantly higher DISCERN scores compared with all other sources (27.250 vs 22.222, p=0.005). There was no significant difference between DISCERN scores in the ACDF and CDR group when looking only at the academic video sources. Compared with ACDF, CDR videos more frequently mentioned an arthroplasty device by brand name (p<0.001).

Conclusion: The overall quality of online healthcare consumer videos can be considered poor with respect to the overall JAMA, DISCERN, and total content scores. The quality of CTDR videos appears to exceed that of ACDF, despite the increased prevalence of industry-sponsorship of the educational material. Efforts should be made by surgeons to standardize online education and improve the quality of the available informational materials.

PRESENTATION #76

Risk Factors for MCID Drop-Off in Patients Undergoing Anterior Cervical Discectomy and Fusion

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Introduction: Minimum clinically important difference (MCID) has been increasingly utilized to quantify meaningful improvements in patient reported outcome measures (PROMs) following spinal procedures.[1] Some patients may achieve an MCID at an early postoperative timepoint, but these significant improvements are not always retained at long-term follow-up.

Materials and Methods: A surgical database was retrospectively reviewed for primary, elective, single- or multi-level ACDF procedures. Patient demographics, preoperative spinal pathologies, and perioperative characteristics were recorded. PROMs including visual analogue scale (VAS) for back and leg pain, Neck Disability Index (NDI), 12-Item Short Form Physical Component Summary (SF-12 PCS), Patient-Reported Outcomes Measurement Information System physical function (PROMIS PF), and Patient Health Questionnaire-9 (PHQ-9) were administered at preoperative and postoperative (6-week, 12-week, 6-month, 1-year, 2-year) timepoints. MCID achievement was assessed by comparing postoperative improvements in PROM scores from preoperative baseline to the following previously established threshold values: VAS Neck (2.6),[2] VAS Arm (4.1),[2] NDI (8.5),[2] SF-12 PCS (8.1),[2] PROMIS PF (4.5).[3] Descriptive statistics were performed for demographic and perioperative characteristics. Achievement of MCID was quantified for all PROMs at each timepoint. MCID "drop-off" was identified as patients who initially achieved an MCID, but failed at all subsequent timepoints. Relative risk of demographic and perioperative variables, as well as baseline PROM scores for MCID drop-off were identified using poisson regression with robust error variance.

Results: A total of 350 ACDF patients were included with a mean age of 49.9 years, a majority of male patients (57.1%) and a mean body mass index (BMI) of 29.3 kg/m2. Of these, 204 patients underwent single level procedures and 146 underwent multi-level ACDF. Operative means were as follows: duration = 55.5 and 81.3 min., estimated blood loss = 40.1 and 45.1 mL, and length of stay 19.2 hours and 24.2 hours for single- and multi-level procedures, respectively (Table 1). Anterior cervical plating was utilized in 52.9% of single-level procedures and 95.2% of multi-level procedures. The greatest proportions of patients achieved MCID for VAS neck at 6-months (56.4%), VAS arm at 6-months (38.3%), NDI at 6-months (67.7%), SF-12 PCS at 6-months (45.1%), and PROMIS-PF at 1-year (69.0%) (Table 2). MCID drop off rates were 26.2% for VAS neck, 26.8% for VAS arm, 17.0% for NDI, 18.6% for SF-12 PCS, and 16.3% for PROMIS PF. Significant predictors for MCID drop-off were identified as follows: Preoperative VAS neck (RR 0.8, p=0.005) and length of stay (RR 1.0, p=0.029) for VAS neck , female gender (RR 2.4, p=0.029), herniated nucleus pulposus (RR:0.5, p=0.049), and diabetes (RR:2.3, p=0.038) for SF-12 PCS, and BMI (RR:1.1, p<0.001) for PROMIS PF (Table 3).

Conclusion: The highest rates of MCID achievement were typically around 6-months following ACDF. Postoperative length of stay, female gender, diabetic status, and BMI were identified as significant risk factors for MCID drop-off for various PROMs. Understanding these risk factors can help physicians identify patients who may be at risk of regressing from earlier

PRESENTATION #76 continued

postoperative improvements.

Table 1. Perioperative Characteristics

	Single Level (n=204)	Multi-Level (n=146)
Spinal Pathology		
Herniated Nucleus Pulposus	92.2% (188)	70.6% (103)
Central Stenosis	29.4% (60)	71.4% (105)
Myeloradiculopathy	73.5% (150)	76.0% (111)
Operative Duration (minutes)	55.5 ± 21.8	81.3 ± 25.7
EBL (mean ± SD; mL)	40.1 ± 36.3	45.1 ± 29.4
LOS (mean ± SD; hours)	19.2 ± 1.2	24.2 ± 24.0
Instrumentation		
Stand-Alone Cage	47.1% (96)	4.8% (7)
Anterior Cervical Plate	52.9% (108)	95.2% (139)

EBL = Estimated Blood Loss; LOS = Postoperative Length of Stay;
SD = Standard Deviation

PRESENTATION #76 continued

Table 2. MCID Achievement

	% (n)
VAS Neck	
6-weeks	46.0% (102)
12-weeks	56.6% (116)
6-months	56.4% (102)
1-year	44.4% (44)
2-years	35.6% (16)
Drop-Off	26.2% (43)
VAS Arm	
6-weeks	38.3% (77)
12-weeks	36.4% (67)
6-months	38.3% (64)
1-year	30.6% (30)
2-years	24.4% (10)
Drop-Off	26.8% (30)
NDI	
6-weeks	43.9% (87)
12-weeks	57.7% (105)
6-months	67.7% (109)
1-year	58.5% (55)
2-years	57.1% (24)
Drop-Off	17.0% (27)
SF-12 PCS	
6-weeks	21.6% (36)
12-weeks	37.9% (75)
6-months	45.1% (50)
1-year	43.2% (35)
2-years	41.5% (21)
Drop-Off	18.6% (24)
PROMIS PF	
6-weeks	36.6% (34)
12-weeks	52.0% (39)
6-months	62.7% (42)
1-year	69.0% (40)
2-years	61.2% (30)
Drop-Off	16.3% (13)

PRESENTATION #76 continued

Table 3. Significant Risk Factors for MCID Drop-Off

	RR	SE	95% C.I.	p-value†
VAS Neck				
Preoperative VAS Neck	0.8	0.1	(0.7, 0.9)	0.005
Length of Stay	1.0	0.0	(1.0, 1.0)	0.029
VAS Arm				
[none]				
NDI				
[none]				
SF-12 PCS				
Female Gender	2.4	0.9	(1.1, 5.2)	0.029
HNP	0.5	0.2	(0.2, 0.9)	0.049
Diabetic	2.3	1.0	(1.1, 5.2)	0.038
PROMIS PF				
BMI	1.1	0.0	(1.0, 1.1)	<0.001

NDI= Neck Disability Index; PROMIS PF = Patient-Reported Outcomes Measurement Information System physical function; RR = Relative Risk; SE = Standard Error; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale; HNP = herniated nucleus pulposus
†p-value calculated using poisson regression with robust error variance

PRESENTATION #77

Incidence of Noncontiguous Cervical Injury in Patients with Thoracic Spine Fractures

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Introduction: Thoracic spine fractures (TSFs) are rarely isolated injuries, with different distributions of injuries dependent on mechanism and patient factors. Despite this observation, there are limited date on rates of concurrent injuries associated with TSFs. Specifically, the associated rates of cervical spine injuries is currently not well documented. Due to the high energy with TSFs, noncontiguous spine injuries often occur in addition to the TSF. With the addition of improved imaging capabilities and the high rates of imaging utilization in the trauma setting, it is becoming more common for spine specialists to treat cervical spine injuries in patients with TSFs. The purpose of this study is to characterize the rate and risk factors of noncontiguous cervical spine injuries in patients with TSFs so that trauma and spine surgeons are able to efficiently evaluate and treat patients presenting with TSFs.

Materials and Methods: We retrospectively reviewed the trauma database records of 242 patients presenting with a TSFs at a single institution from 2015 to 2019 with a TSF AO classification of B or C. For all patients we recorded demographics, comorbidities, and associated injuries by body region. We characterized the TSFs and cervical injuries using the AO classification system, the presenting physical exam and treatment, and follow-up visit documentation. TSFs were also categorized by level with the superior endplate of T1 to inferior endplate of T4 being classified as upper thoracic, T4/5 disc to inferior endplate of T10 being classified as middle thoracic, and T10/11 disc to inferior endplate of T12 being classified as lower thoracic.

Results: Of the 242 patients with significant TSFs, 53 were found to have a noncontiguous cervical spine injury (21.9%). Of these 53 patients, 43 required prolonged bracing, 3 needed cervical spinal fixation, and 7 died during their initial hospitalization due to the severity of their injuries. Presence of nonvertebral thoracic injury, upper extremity fracture, and head injury increased the odds of cervical injury by a factor of 2.0, 2.5, and 5.5 respectively.

The mechanism of injury for TSFs both with and without cervical spine injuries are shown in Table 1. No injury mechanism was statistically correlated with an increased risk of cervical spine injury, however mechanical fall was found to be 0.43 less likely to result in a cervical spine injury ($p = 0.03$).

Level of thoracic injury (Table 2) or presence of hyperostosis did not increase the chances of cervical spine injury, although lower thoracic injuries were 0.30 less likely to have a cervical spine injury ($p = 0.0003$).

Conclusion: The incidence of cervical spine injury in patients with AO spine B or C TSFs is common, with a rate of 21.9% in our small cohort. Concomitant thoracic, upper extremity, and head injuries in patients with TSFs should raise concern for a cervical spine injury. A high index of suspicion for these injuries is important as patients may not be able to report cervical pain due to other injuries or inability to communicate secondary to mechanical ventilation.

PRESENTATION #77 continued

Mechanism	TSF with C-spine Injury	TSF without C-spine Injury
Mechanical Fall	9	61
Fall from Height	21	55
MCC	3	7
MVC	16	44
Other	1	6
Ped vs Car	2	7
Sports	1	9
Total		**189**

Thoracic Level	TSF with C-spine Injury	TSF without C-spine Injury
Upper	23	45
Middle	33	90
Lower	15	108
Total		**243**

PRESENTATION #78

International Validation of the AO Spine Subaxial Injury Classification System: The Importance of Methodology

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Rothman Orthopaedic Institute[1] The Rothman Institute at Thomas Jefferson University[2] Jefferson University/Rothman Institute[3]

Introduction: Classification systems are instruments used to characterize injuries, communicate between providers, and guide clinical management. Ideally, classification systems are concise, comprehensive, and most importantly reliable. A poorly validated classification system serves as a biased predictor of patient outcomes confounding scientific research. Accordingly, the aim of this study was to establish the reliability of the AO Spine Subaxial Injury Classification System when applied by surgeons from around the world. Furthermore, the study highlights the importance of methodology used in validation studies, as two separate validations with disparate methodologies and results were performed for the same classification system.

Materials and Methods: In 2018, 35 injuries were independently assessed by 268 investigators on two separate occasions resulting in of 15,614 case assessments. High-resolution computerized-tomography (CT) images played at a rate of 10 frames/second without trimming, and key images, were presented in a web conference format. Aside from fracture classification, investigators were required to identify the level of injury, secondary injuries, and facet injuries (if present) as the primary versus secondary injury. The survey required completion of answer selection before proceeding to the next case, even if connectivity was lost.

In 2020, 41 injuries were independently assessed by 203 investigators on two separate occasions resulting in a total of 11,445 case assessments. In this validation, web conference format was repeated. However, CT scans were played at 2 frames/second trimmed to area of interest. Key images were larger and presented before and after CT scans. Cases with facet fracture were presented separately from morphologic injuries and were not required to be indicated as a primary versus secondary injuries. Mandatory answer selection and identification of the level of injury were removed.

Kappa statistic was calculated to assess the reliability (inter-observer agreement) and reproducibility (intra-observer reproducibility) for injury type (A, B, C and F) and subtype (A0-F4). Investigator ratings of both assessments were compared to the gold standard as defined by a panel of expert spine surgeons.

Results: The respondent demographics for the 2020 validation are presented in Table 1. The overall interobserver reliabilities comparing 2018 and 2020 validations are presented in Table 2. Intraobserver reproducibility for fracture morphology (Type A, B, and C) was 0.49 and 0.85 for 2018 and 2020, respectively. Reproducibility for fracture subtype (A1-C) and facet injury (F1-F4) together was 0.42 in 2018. Due to survey methodology, fracture subtype and facet injury

PRESENTATION #78 continued

reproducibilities were unable to be separated. In contrast, reproducibility for fracture subtype and facet injury were 0.88 and 0.76 in 2020, respectively. The percent agreement of investigator ratings of both assessments compared to the gold standard for 2018 and 2020 is presented in Table 3.

Conclusion: The AO Spine Subaxial Injury Classification System demonstrates at minimum substantial reliability for facet fracture injury and excellent reliability for fracture morphology and subtype among surgeons worldwide based on the most recent 2020 validation study. The results highlight the importance of survey methodology in classification validation. Imaging speed, video length, web conference interface, and answer recording options had significant impact on the disparate results found between validation studies.

PRESENTATION #78 continued

Table 1. Summary of Surgeon Respondent Demographics

Category	Characteristic	Respondent (%)
Geographic Region n= 203	North America	18 (8.9)
	Central and South America	34 (16.7)
	Europe	81 (40.0)
	Africa	5 (2.5)
	Asia	50 (24.6)
	Middle East	15 (7.4)
Number of Years in Practice n= 203	< 5 years	33 (16.3)
	5 - 10 years	64 (31.5)
	11 - 20 years	69 (34.0)
	> 20 years	37 (18.2)
Surgical Subspecialty n= 203	Neurosurgeon	123 (36.9)
	Orthopaedic Spine	75 (60.6)
	Other*	5 (2.5)

*Excluded from further analyses

PRESENTATION #78 continued

Table 2. Interobserver Reliability in Fracture Classification					
Subaxial Cervical Classification		2018 Validation		2020 Validation	
		Assessment 1 (k)	Assessment 2 (k)	Assessment 1 (k)	Assessment 2 (k)
Fracture Morphology	A	0.51	0.61	0.870	0.839
	B	0.32	0.40	0.804	0.740
	C	0.18	0.13	0.888	0.873
	Combined	0.40	0.45	0.860	0.873
Fracture Subtype	A0	0.26	0.38	0.893	0.880
	A1	0.38	0.51	0.768	0.668
	A2	0.37	0.48	0.841	0.836
	A3	0.39	0.49	0.774	0.723
	A4	0.41	0.35	0.767	0.734
	B2	0.10	0.03	0.726	0.684
	B3	0.52	0.66	0.908	0.835
	C	0.18	0.13	0.888	0.873
	Combined	0.32	0.35	0.835	0.800
Facet Injury	F1	0.26	0.32	0.648	0.752
	F2	0.20	0.26	0.586	0.691
	F3	0.22	0.19	0.773	0.749
	F4	0.46	0.55	0.683	0.757
	Combined	0.36	0.43	0.670	0.740

PRESENTATION #78 continued

Table 3. Percent Agreement with Gold Standard Fracture Classification

Subaxial Cervical Classification		2018 Validation		2020 Validation	
		Assessment 1 (%)	Assessment 2 (%)	Assessment 1 (%)	Assessment 2 (%)
Fracture Morphology	A	76.1	82.9	97.3	97.1
	B	41.9	42.0	90.1	87.2
	C	32.3	32.3	94.0	93.3
	Combined	54.5	54.0	95.4	94.7
Fracture Subtype	A0	40.7	49.1	94.1	93.6
	A1	65.9	76.8	88.3	84.2
	A2	80.7	89.2	95.6	94.5
	A3	74.7	87.5	90.9	92.0
	A4	31.8	28.0	83.8	82.7
	B2	7.55	7.73	80.3	78.4
	B3	72.7	79.3	94.5	90.9
	C	32.3	21.5	94.0	93.3
	Combined	40.9	40.5	91.7	90.6
Facet Injury	F1	41.9	58.6	88.2	92.1
	F2	27.4	44.1	86.3	89.4
	F3	44.8	44.9	87.2	89.8
	F4	69.5	79.3	91.4	93.0
	Combined	50.6	62.8	88.6	91.3

PRESENTATION #79

Survival Rates in Atlanto-occipital Dissociation: A Look at the Past 20 Years

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Introduction: Atlanto-occipital dissociation (AOD) has historically been considered a fatal injury. Recent small case series, however, have suggested that AOD injuries have become increasingly survivable. There has not been an adequately powered study that confirms this. The aim of this study was to assess whether the survival rate for patients with AOD increased over time.

Materials and Methods: Patients with traumatic AOD from 1996 to 2019 were retrospectively identified from our Level 1 Trauma Center database using International Classification of Diseases 9 and 10 codes. Patients were stratified into two cohorts- those diagnosed before August 15, 2015 and after. Independent sample t and Fisher's Exact tests were performed to establish the relationship between collected variables and mortality.

Results: A total of 52 patients met the inclusion criteria with a mean age of 35.3, ISS of 42.8, and admission GCS of 4.5. Thirty-two patients in total died. Mortality rate was 78% pre 2015 and 48% post-2015 respectively ($p=0.0257$). Male patients had a higher mortality rate (69.7%) than females (50%) ($p=0.164$). Ethnicity showed no difference in survival. Following regression analyses, increased ISS and decreased GCS scores were associated with a decrease in survival rates ($p<0.05$). The odds ratio of mortality for patients with a BMI>30 and GCS<8 were 4.2 ($p=0.08$) and 5.11 ($p=0.02$) respectively.

Conclusion: AOD has been documented in as many as 31% of motor vehicle fatalities. This study is the first to demonstrate that mortality rates for this devastating injury have decreased over time. Possible reasons for the improved survival rate seen in this study include: more standardized diagnostic criteria for AOD, the shift toward standard of care CT based imaging, advances in critical care, and advances in the surgical care of these patients.

PRESENTATION #80

Radiological factors associated with the severity of corticospinal tract dysfunctions for cervical spondylotic myelopathy: An analysis of the central motor conduction time and kinematic CT myelography

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Introduction: Patients with CSM often exhibit symptoms in clinical practice, particularly the elderly, whose lower extremity functions are more likely to deteriorate; however, the underlying mechanisms currently remain unclear. [1] The present study used CMCT and detailed imaging findings to identify imaging factors contributing to the severity of upper and lower limb symptoms, respectively, in CSM.

Materials and Methods: Eighty-six patients with CSM were retrospectively evaluated. The neurological status of patients was assessed using the Japanese Orthopedic Association (JOA) score. The highest total JOA score without any deficits is 17 points, and the JOA scoring system evaluates motor function (up to 4 points each) and sensory function (2 points each) in the upper and lower limbs. Plain lateral radiographs were acquired while the patient was seated in the neutral, flexion, and extension positions. C2–7 lordosis (CL) and the C2–7 range of motion (ROM) were measured using the Cobb method. C2-7 SVA and C7 slope were measured.

Cross sectional area of the spinal cord (CSA) measurements obtained at the relevant level during flexion in the neutral position and during extension were described as CSAF, CSAN, and CSAE, respectively. The amount of dynamic change in CSA (dCSA, mm2) was calculated by subtracting CSA during extension from that during flexion.

The central motor conduction time (CMCT) was calculated as follows: motor evoked potential latency-(compound muscle action potential latency + F latency-1)/2 (ms). [2] A multiple logistic regression analysis was performed to identify the various radiological parameters associated with CMCT in the upper and lower limbs. (Figure 1) In the present study, patients with CMCT-TL shorter than 8.9 ms (Q3 value) and equal to or longer than 8.9 ms with an absent waveform were classified as Groups 1 and 2, respectively. To assess radiological parameters associated with the status of Group 2, a multiple logistic regression analysis (MLRA) was performed using the stepwise parameter selection method (age and $P < 0.05$ were set as criteria for inclusion in the regression model).

Results: Demographic and univariate analysis was shown in Table 1. Age correlated with the percentage of anterior slippage (r=0.25), CL during flexion (r=0.24), C2-7 ROM neutral to flexion (r=-0.27), the total JOA score (r=-0.24), and lower limb JOA score (r=-0.26), but age was not correlated with either CMCT-UL or LL. CMCT-UL correlated with spinal cord compression during neck extension, while that in the lower limbs correlated with a larger C2-7 SVA, CL, a small C2-7 ROM, and spinal cord compression during neck flexion. Significant risk factors specific for severe lower limb dysfunction were greater anterior spondylolisthesis during neck extension (P=0.006, OR: 2.53, 95%CI: 1.13–2.07) and small C2-7 ROM in neutral to flexion (P=0.035, OR: 0.67, 95%CI: 0.52–0.88).

Conclusion: The key radiological factors associated with more severe lower than upper limb

PRESENTATION #80 continued

dysfunction were anterior spondylolisthesis during neck extension and neck stiffness during flexion. The significance of the present study is that since CSM with deteriorating neurological function has been associated with poor surgical outcomes, we advocate early interventions for patients presenting with the imaging factors associated with lower limb dysfunction.

Figure 1

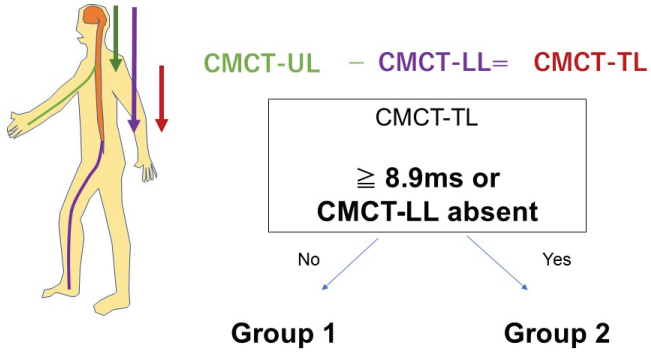

Table 1. Demographics and univariate analysis

	All patients (n=86)	Group 1 (n=61)	Group 2 (n=25)	P-value
Age	73.3 ± 8.8	72.2 ± 8.6	76.0 ± 8.9	0.03*
Sex, female/male	34/52	25/36	16/9	0.66
BMI (kg/m²)	22.9 ± 3.7	22.76 ± 3.57	23.25 ± 4.07	0.98
Duration of disease, months	22.7 ± 30.1	22.7 ± 28.1	22.6 ± 35.2	0.54
JOA score (Total)	9.33 ± 2.4	9.78 ± 2.38	8.24 ± 2.10	0.0009*
JOA score for upper limbs	2.74 ± 1.24	2.91 ± 1.21	2.32 ± 1.23	0.12
JOA score for lower limbs	2.73 ± 1.03	2.94 ± 1.00	2.22 ± 0.91	0.0034*
Electrophysiological examinations				
CMCT-UL (ms)	12.33 ± 3.28	12.56 ± 3.13	11.78 ± 3.64	0.29
CMCT-LL (ms)	18.6 ± 3.8	17.7 ± 3.3	21.6 ± 4.0	0.0002*
The responsible level according to SCEPs				0.19
C2-3	1	0	1	
C3–4	38	29	9	
C4–5	35	24	11	
C5–6	12	8	4	
X-ray				
C2-7 angle in neutral position (°)	14.41 ± 13.88	15.26 ± 13.80	12.35 ± 14.15	0.22
C2-7angle during flexion (°)	-10.02 ± 15.2	-11.54 ± 15.89	-6.30 ± 12.92	0.24
C2-7angle during extension (°)	26.04 ± 12.27	27.07 ± 11.48	23.54 ± 13.95	0.18
C2–7 ROM (°)	36.06 ± 14.27	38.61 ± 13.85	29.84 ± 13.62	0.017*
C2-7 ROM neutral to flexion	27.4 ± 12.54	30.23 ± 12.08	20.48 ± 11.03	0.0015*
C2-7 ROM neutral to extension	11.63 ± 10.21	11.81 ± 9.96	11.19 ± 11.00	0.82
C7 slope (°)	30.19 ± 10.08	29.09 ± 10.33	32.87 ± 9.09	0.11
C2–7 SVA (mm)	33.95 ± 15.26	32.49 ± 14.30	37.49 ± 17.16	0.15
Kinematic CTM				
CSA in neutral position (mm²)	43.15 ± 10.91	43.70 ± 11.38	41.80 ± 9.77	0.28
CSA during flexion (mm²)	43.34 ± 11.3	44.62 ± 11.63	40.23 ± 9.99	0.11
CSA during extension (mm²)	37.64 ± 10.98	37.53 ± 10.95	37.93 ± 11.26	0.94
dCSA (mm²)	8.73 ± 6.9	9.78 ± 7.39	6.18 ± 4.72	0.035*
dFCSA (mm²)	-0.19 ± 6.43	-0.92 ± 6.93	1.56 ± 4.81	0.073
dECSA (mm²)	5.51 ± 7.52	6.18 ± 8.08	3.87 ± 5.75	0.089
Percentage of slip during flexion	4.4 ± 11.8	1.8 ± 11.2	10.9 ± 11.0	0.0002 *
Percentage of slip during extension	-3.1 ± 10.7	-5.5 ± 10.1	2.7 ± 9.9	0. 0001*

PRESENTATION #81

Enoxaparin promotes functional recovery after spinal cord injury by antagonizing PTPR sigma

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Nagoya University[1]

Introduction: Receptor type protein tyrosine phosphatase σ (PTPR sigma) regulates axonal regeneration/sprouting and its inhibition as a molecular switch through its clustering in response to glycan ligands. Cell surface heparan sulfate oligomerlizes PTPR sigma and inactivate its enzymatic activity, leading to axonal growth promotion. Contrary, matrix-associated chondroitin sulfate monomerlizes PTPR sigma and activates it. That leads to dephosphorylation of its specific substrates such as cortactin, resulting in axonal regeneration failure after injury. However, these molecular switch model has never been challenged or utilized in clinical situation. Here, we investigated the effect of Enoxaparin, world-widely approved anticoagulant consisting of heparin oligosaccharides to spinal cord injury.

Materials and Methods: We examined whether Enoxaparin were able to compete with chondroitin sulfate for PTPR sigma. To do this, we carried out the competition assay on surface plasmon resonance (SPR). To further address the molecular interaction between Enoxaparin and PTPR sigma, isothermal calorimetry (ITC) was used. To address whether these phenomena could occur on the surface on living cells, we employed in vitro phosphatase assay. We made rat's severe spinal cord injured models which were inflicted contusion injuries on the thoracic level (Th9) using a force of 200 kdyn to evaluate the effect of enoxaparin to spinal cord injury. These models were treated with subcutaneous injection of saline and enoxaparin every day from 1day after spinal cord injury. We examined the motor function by BBB score, the sensory function by touch test and performed histological analysis of the serial section of the spinal cord stained for GAP-43 and 5-HT.

Results: SPR results showed that bound PTPR sigma to chondroitin sulfate was rapidly eluted after injection of Enoxaparin (Figure1a), suggesting that these compounds were good competitors to occupy PTPR sigma from chondroitin sulfate. ITC results showed that Enoxaparin and PTPRσ produced heat of reaction with approximately 1:6.5 binding stoichiometry (Figure1b), so we concluded that Enoxaparin can strongly interact with and induce clustering of PTPRσ. Overexpression of v-src, a proto-oncogene tyrosine kinase, greatly induced bulk protein tyrosine phosphorylation in cells, which was demonstrated by 4G10 antibody. Co-expression of PTPRσ diminished the immunoreactivity of 4G10. Treatment of cells expressing PTPRσ with Enoxaparin canceled the dephosphorylation by PTPRσ (Figure1c). The BBB score was significantly higher in Enoxaparin group than in the saline-administered control from 21stday after SCI (Figure2a). These results suggest that enoxaparin promotes motor functional recovery after spinal cord injury. The recovery of sensory function was significantly better in Enoxaparin group than in the saline-administered control from 42nd day after SCI (Figure2b). We performed histological analysis of SD rat's spinal cords treated with enoxaparin or saline at 84 days after SCI. We counted the number of GAP-43 and 5-HT positive fibers 3mm rostral and 3mm caudal from the lesion site. These positive fibers was significantly higher in both the rostral and caudal regions in enoxaparin group than in saline group (Figure 3).

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PRESENTATION #81 continued

Conclusion: We showed that Enoxaparin elute Condroitin sulfate from PTPR sigma and bind PTPR sigma, regulate activation of PTPR sigma and promote functional recovery after rat model of spinal cord injury.

Figure 1

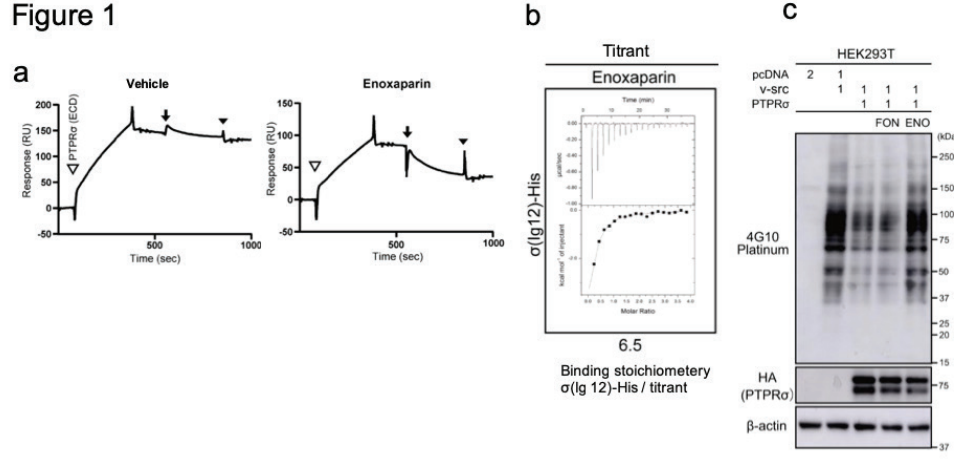
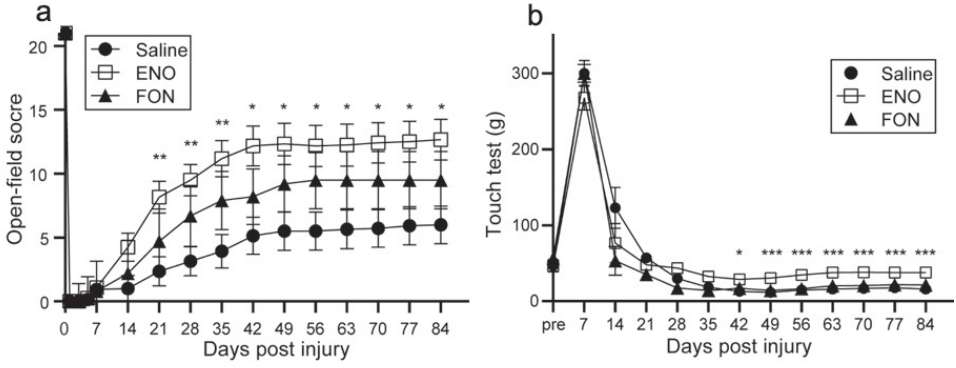
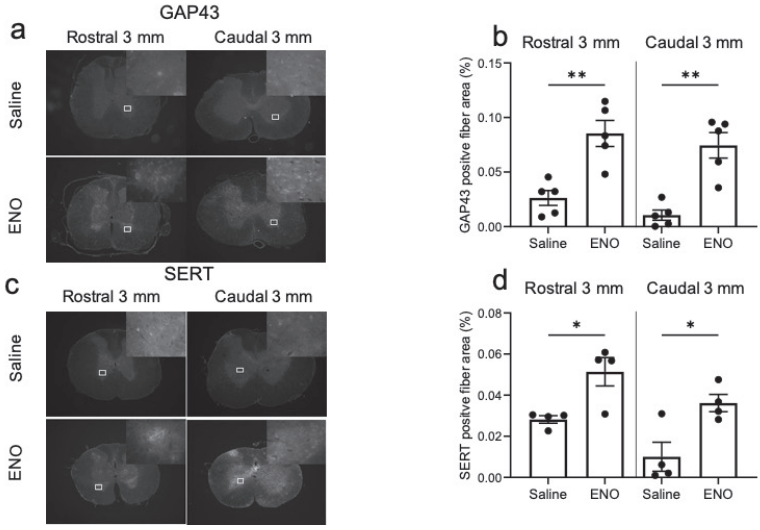


Figure 2



PRESENTATION #81 continued

Figure 3



PRESENTATION #82

Surgical outcome of cervical and thoracic extramedurally spinal tumor

Akinobu Suzuki, MD, Hidetomi Terai, MD, PhD, Shinji Takahashi, MD,PhD, Koji Tamai, MD[1], Hiroaki Nakamura, MD
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Introduction: Spinal tumor can cause myelopathy and radiculopathy, and tumor resection is indicated for symptomatic patients. It has been well studied about clinical outcome of degenerative cervical (1) and thoracic disease (2), and well reported about the surgical method or recurrence rate of spinal tumor (3). However, there are few reports focused on the pre- and post-operative clinical symptom in the patients with spinal tumor. The purpose of this study is to retrospectively analyze the clinical outcome of cervical and thoracic extramedurally spinal tumor, and to clarify the extent of improvement after resection surgery.

Materials and Methods: We included the patients who underwent excisional surgery for spinal tumor at our institution between 1993 and 2017 in this study. Asymptomatic cases and the cases with metastatic tumors, the tumor originated from bone tissue and intramedurally or cauda equina tumor were excluded. We analyzed patients' demographic data, the pathological diagnoses, and spinal level of the tumor. In terms of clinical evaluation, we evaluated the post-operative newly developed neurological symptom and pre-and post-operative Japanese Orthopaedic Association score for myelopathy (JOA score; 17 points for cervical case, and 11 points for thoracic case). The recovery rates of JOA scores were calculated by the Hirabayashi method.

Results: Totally, 86 patients (39 women and 47 men) were included in this study. Forty-one cases had tumor in cervical spine, and 45 cases in thoracic spine, and the average age was 54.9 years. Pathological diagnosis was schwannoma in 57 cases (63.3%), meningioma in 23 cases (26.7%), hemangioma/angiolipoma in 2 cases, neurofibroma in 2 cases. Two cases (2.3%) were malignant tumor (malignant peripheral nerve sheath tumor and primitive neuroectodermal tumor). Postoperatively, neurological deterioration including transient deterioration occurred in 13 cases (31.7%) of cervical group (sensory loss in 7 cases, motor loss in 3 cases, both sensory and motor loss in 3cases) and 4 cases of thoracic group (sensory loss in 3 cases, motor loss in 1 case). Five out of 7 cases with motor loss and 9 out of 13 cases with sensory loss improved in follow-up period, and finally, the rate of post-operative deterioration was as follows: sensory loss in cervical, 12.2%; motor loss in cervical, 4.9%; sensory loss in thoracic, 2.2%; and motor loss in thoracic cases, 2.2%. Most of the cases with neurological deficit were nerve sheath tumor (88.2%). In cervical cases, the pre-operative JOA score was 10.5 significantly improved to 15.2 postoperatively, and the recovery rate was 71.6%. In thoracic cases, the pre-operative JOA score was 5.5 significantly improved to 9.9 postoperatively, and the recovery rate was 86.4%.

Conclusion: In this study, we investigated the clinical outcome of cervical and thoracic extramedurally spinal tumor. The present results showed the certain incidence of post-operative neurological deterioration, and it indicates that it is more likely to occur in cases with cervical nerve sheath tumor. However, about 70% of deterioration improved in follow-up period, and the recovery rate of JOA score was relatively better compared to that reported in cervical and thoracic degenerative diseases.

PRESENTATION #83

Laminectomy Alone versus Laminectomy with Fusion for Degenerative Cervical Myelopathy – a Long-term Study of a National Cohort

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Uppsala University Hospital[1]

Introduction: To compare patient-reported 5-year clinical outcomes between laminectomy alone versus laminectomy with instrumented fusion in patients with degenerative cervical myelopathy in a population-based cohort.

Materials and Methods: All patients in the national Swedish Spine Register (Swespine) from January 2006 until March 2019, with degenerative cervical myelopathy, were assessed. Using propensity score matching based on clinical and radiological confounders, patients treated with laminectomy alone were compared with patients undergoing laminectomy with an additional instrumented fusion. The primary outcome measure was the European Myelopathy Score, a validated patient-reported outcome measure. The scale ranges from 5-18, with lower scores reflecting more severe myelopathy. Secondary outcome measures were patient-reported Neck Disability Index, European Quality of Life-5 Dimension Questionnaire, Visual Analogue Scale for neck and arm pain, complications, secondary surgeries, and mortality, along with a cost-benefit analysis.

Results: Among 967 eligible patients, 717 (74%) patients were included. Laminectomy alone was performed on 412 patients (mean age 68 years; 149 women [36%]), whereas instrumented fusion was added for 305 patients (mean age 68 years; 119 women [39%]). After imputation, there were on average 212 pairs of propensity score-matched patients with a 5-year follow-up in each group. There were no important differences in patient-reported clinical outcomes between the methods after 5 years. A higher mortality rate during the earliest postoperative years was observed in the fusion group. Due to longer hospitalization times and implant-related costs, the mean cost increase per instrumented patient was approximately $4,700 US.

Conclusion: Instrumented fusions generated higher costs and were not associated with superior long-term clinical outcomes. These findings are based on a national cohort and can thus be regarded as generalizable.

PRESENTATION #84

The impact of anterior spondylolisthesis and kyphotic alignment on dynamic changes in spinal cord compression and neurological status in cervical spondylotic myelopathy: A radiological analysis involving kinematic CT myelography and multi-modal spinal cord evoked potentials

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Orthopedic Surgery, Yamaguchi University[1]

Introduction: It is well known that the degree of cord compression in cervical spondylotic myelopathy (CSM) is associated with the position of the neck. Appropriate assessment of dynamic factors in myelopathy should make it possible to detect hidden spinal cord compression and provide useful information for choosing a surgical procedure. The mechanisms that govern dynamic changes in spinal cord compression, and the effects of such dynamic changes on the severity of myelopathy, have not yet been elucidated. This study aimed to examine how radiological parameters affect dynamic changes in the cross-sectional area of the spinal cord (CSA) in CSM patients and how they correlate with the severity of myelopathy, by evaluating multi-modal spinal cord evoked potentials (SCEPs).

Materials and Methods: Seventy-nine CSM patients were enrolled. They were examined with kinematic CT myelography (CTM), and the spinal levels responsible for their CSM were determined via SCEP examinations. The C2–7 angle, C2–7 range of motion, and percentage of slip were measured on the midsagittal view during flexion and extension, and the CSA was measured on the axial view in each neck position using kinematic CTM. The patients who exhibited the smallest CSA values during extension and flexion were classified into Groups E and F, respectively. Univariate between-group comparisons were performed using Mann-Whitney U test or chi-squared test. The radiological parameters obtained from kinematic CTM and X-ray were compared between the two groups by univariate analysis. To explore radiological parameters that are associated with the status of Group F, multiple logistic regression analysis was performed by stepwise parameter selection method ($P < 0.05$ was set as a criterion for inclusion in the regression model).

Results: Fifty-two (65.8%) and 27 (34.2%) cases were included in Groups E and F, respectively. Demographic and univariate analysis was shown in Table 1. The preoperative JOA score did not differ significantly between the groups; however, the preoperative lower-limb JOA score of Group F was significantly lower than that of Group E (2.24±0.82 vs. 2.83±1.09, P=0.016). In the multiple logistic regression analysis, a small C2–7 angle during extension (β=5 degrees, odds ratio: 0.69, 95%CI: 0.54–0.90) and the slip percentage during flexion (β=5%, odds ratio: 1.42, 95%CI: 1.09–1.85) were identified as significant predictors of belonging to Group F.

Conclusion: Exhibiting more severe spinal cord compression during neck flexion was associated with a small C2–7 angle and anterior spondylolisthesis. The neurological status of the patients in Group F was characterized by severe lower limb dysfunction because of a disturbed blood supply to the anterior column. [1]The anterior column is eventually affected in patients with common CSM, and the degree of reticulospinal tract impairment might be related to lower-limb dysfunction, but not upper-limb dysfunction [2,3](Figure 1).

PRESENTATION #84 continued

Figure 1

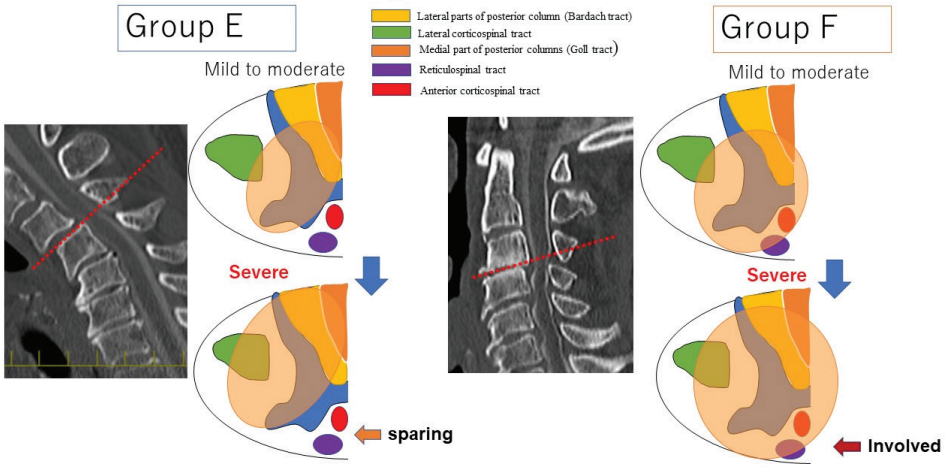

Table 1. Demographic data and univariate analyses of Group F vs. Group E

	Group F (n=27)	Group E (n=52)	P-value
Sex (male/female)	15/12	38/14	0.11
Age (years)	74.3±9.5	71.3±9.6	0.18
Duration of disease (months)	29.4±38.6	26.7±32.6	0.74
Kinematic CT myelography findings			
C2–7 angle during flexion (degrees)	-17.61±13.22	-9.89±12.35	0.012*
C2–7 angle during extension (degrees)	16.32±12.73	26.65±11.47	<0.001*
C2–7 ROM (degrees)	33.99±9.98	36.96±10.58	0.23
Slip during flexion (%)	8.6±14.0	0.8±7.2	0.0014*
Slip during extension (%)	0.6±12.4	-4.8±8.6	0.024*
CSA during flexion (mm^2)	38.67±9.69	43.95±12.43	0.058
CSA during extension (mm^2)	44.54±10.03	33.73±11.13	<0.001*
dCSA (mm^2)	5.87±4.89	10.25±7.26	0.0079*
X-ray findings			
C2–7 angle in neutral position	8.09±13.31	17.12±11.47	0.0024*
C2–7 SVA (mm)	33.61±16.07	33.76±18.34	0.97
C7 slope (degrees)	28.75±11.39	30.24±11.07	0.57
Neurological findings			
JOA score (points)	8.78±2.54	9.55±2.36	0.18
Upper-limb JOA score	2.96±1.46	2.83±1.25	0.68
Lower-limb JOA score	2.24±0.82	2.83±1.09	0.015*

E-POSTER #1

Automated detection of cervical spinal cord compression and the reliability of morphometric parameters extracted with the Spinal Cord Toolbox

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Masaryk University[1] University Hospital Brno[2]

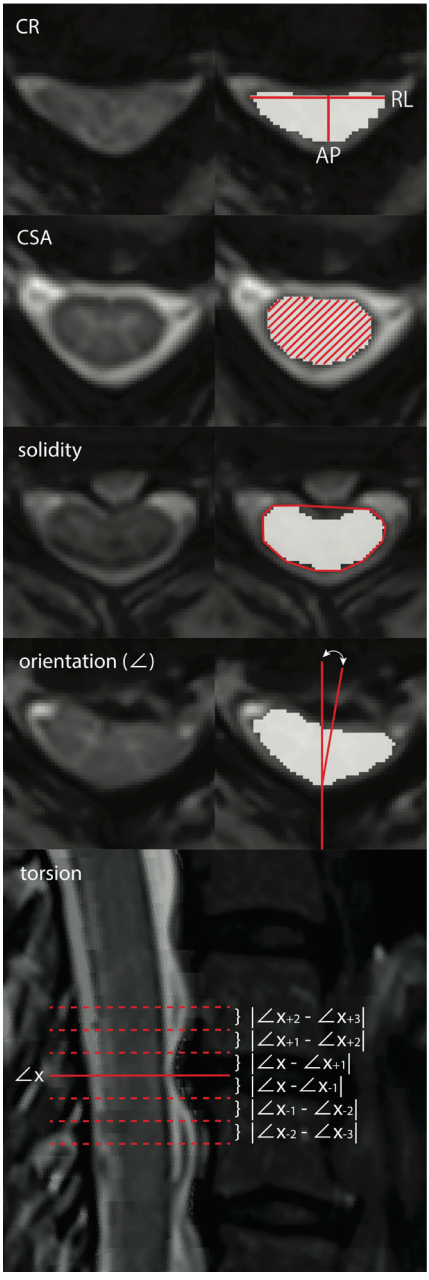
Introduction: Degenerative cervical spinal cord compression (SCC) is becoming increasingly prevalent, yet the MRI criteria that define SCC are vague, and vary between studies. This contribution addresses the automated detection of compression by means of the Spinal Cord Toolbox (SCT) and assesses the reliability of the morphometric parameters extracted with it.

Materials and Methods: Two types of MRI examination, 3T and 1.5T were performed on 66 healthy controls and 118 participants with SCC. Morphometric parameters (Figure 1) from 3T MRI obtained by SCT (cross-sectional area - CSA, solidity) and further calculated (compressive ratio - CR, torsion) were combined in multivariate logistic regression models with the binary dependent variable being the presence of compression determined by two board-certified radiologists. Intraclass correlation coefficients (ICCs) were employed to compare the reliability of parameters' from 3T and 1.5 T MRI computed by SCT with three experts' manual ratings in a subset of 35 HCs and 30 participants with SCC.

Results: The pooled model combining SCT-derived CR, CSA, solidity, torsion and one binary indicator (the C6/7 level) demonstrated outstanding compression detection (AUC = 0.947). The single best cut-off for predicted probability calculated using a multiple regression equation was 0.451, with a sensitivity of 87.3% and a specificity of 90.2%. The ICCs exhibited excellent reliability for SCT in CR (0.858) and good reliability in CSA (0.735), while the mean ICC for three expert raters was 0.722 for CR and 0.486 for CSA (Figure 2).

Conclusion: This study demonstrates successful automated compression detection based on four SCT-derived parameters. The reliability of parameters established through two MRI examinations was conclusively better for SCT compared with that of three experts' manual ratings. Automated SCT-based quantification of morphometric parameters and related SCC criteria may well come to serve as a reliable tool in the standardization of longitudinal and multicentre studies.

E-POSTER #1 continued



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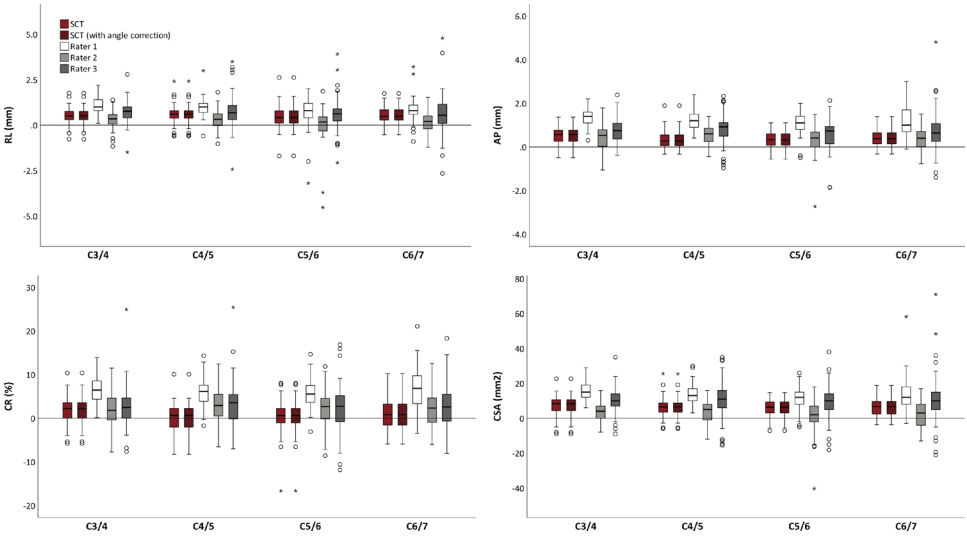
E-POSTER #1 continued



E-POSTER #2

Impact of cervical alignment for prognosis of cervical spondylotic amyotrophy – Propensity score matching analysis

Masahito Takahashi, MD, PhD[1], *Masaaki Tsuji, MD, Kazuhiko Satomi, MD, PhD, Hideto Sano, MD, PhD, Takumi Takeuchi, MD, PhD, Shoichi Ichimura, MD, PhD, Naobumi Hosogane, MD, PhD*
Orthopaedic Surgery, Kyorin University[1]

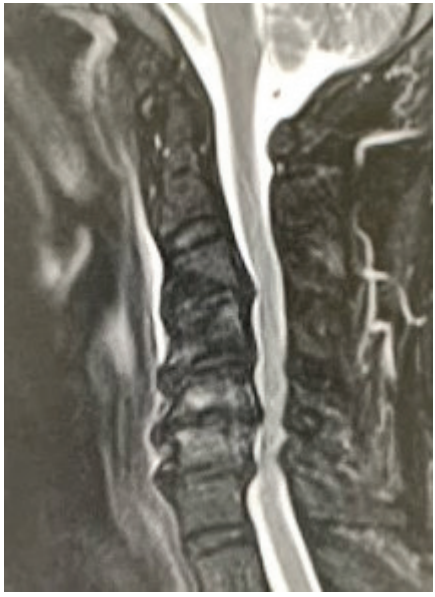
Introduction: Cervical spondylotic amyotrophy (CSA), involving dissociated motor loss in the upper extremities, is considered as the stage prior to cervical spondylotic myelopathy (CSM). In some cases of CSA, the symptom has a self-limited natural history. However, the factors associated with the natural history of recovery of CSA have not been reported in the literature. The concept of cervical alignment parameters is recognized over time, and these parameters are implied to be correlated with the health-related quality of life outcomes and pathogenesis of CSM. The purpose of this study was to investigate the impact of cervical sagittal alignment parameters on the prognosis of cervical spondylotic amyotrophy (CSA) using propensity score matching analysis.

Materials and Methods: Retrospective cohort study. Patients with proximal CSA who were followed conservatory over 6 months from the onset, had a manual muscle test (MMT) score < 3, and had confirmed denervation potentials in the deltoid and/or biceps brachii muscles on electromyography were eligible. Patients with diabetes mellitus, a rotator cuff tear, encephalopathy, or a neuromuscular disease were excluded. Age, sex, MMT score, cervical lordosis, number of stenosis levels, and existence of T2-weighted high-intensity area (T2HIA) in the spinal cord on MRI were investigated. The patients were divided into two groups, Recovery and Non-recovery group, and a propensity score matching analysis was conducted to examine the prognostic factors of proximal CSA.

Results: A total of 127 patients were diagnosed with proximal type of CSA in our department. Eligible patients were 31, 18 in Recovery group and 13 in Non-recovery group. The mean degree of cervical lordosis (CL) was significantly lower in Non-recovery group (10.2 vs. -2.3, $p < 0.01$). The mean number of levels of stenosis on MRI was 2.5 and 3.0 in Recovery group and in Non-recovery group, respectively. The number of patients having C3/4 stenosis was 7 (38.9%) in Recovery group and nine (69.2%) in Non-recovery group, with tendency to be higher incidence in Non-recovery group ($p = 0.07$). Only one patient with T2HIA on MRI was in Recovery group . Twenty-four of 31 patients were matched in a one to one ratio in the two groups. Propensity score matching by age, sex and the number of stenosis showed that CL was an independent predictor of recovery of CSA (odds ratio, 1.09; 95% confidence interval, 1.0–1.2, $p < 0.05$).

Conclusion: Cervical sagittal alignment parameters had a significant influence on the natural course of CSA, and CL might be one of the factors that predict CSA prognosis.

E-POSTER #2 continued



E-POSTER #3

What is the Ideal Cervical Spine Realignment in Operative Cervical Deformity Patients When the Thoracolumbar Spine is Not Addressed?

Lara Passfall, BS, Oscar Krol, BA, Nicholas Kummer, BS, Bhaveen Kapadia, MD, Shaleen Vira, MD, Bassel Diebo, MD, Peter Passias, MD[1]
New York Spine Institute/NYU Medical Center[1]

Introduction: There is a paucity in the literature regarding the extent of correction that should be undertaken in patients with cervical deformity (CD) who have an isolated cervical spine intervention as opposed to having a fusion construct extend to the thoracic or lumbar regions.

Materials and Methods: Included: operative CD patients >18yrs with preop (BL) and up to 2-year (2Y) HRQL/radiographic data. Patients with LIV at or below the thoracic kyphosis apex were excluded. An optimal outcome [Opt] was defined as: 1) no DJF and 2) having Virk et al. good clinical outcome at 2Y [≥2 of the following: NDI<20 or meeting MCID, mild myelopathy(mJOA ≥14), NRS-Neck≤5 or improved by ≥2 points from BL]. Univariate analyses assessed postoperative alignment for Opt pts. Opt pts were grouped based on concurrent thoracolumbar deformity at BL [CD-TL (coronal Cobb angle ≥20°, SVA≥50mm, PT≥25°, TK>60°)] or not [CD-nonTL]. Postop alignment was compared for CD-TL and CD-nonTL pts with optimal outcome.

Results: 70 CD patients with LIV above TK apex were included (58yrs, 57%F, 27.8kg/m2, levels fused: 5.7±4.2). Mean BL radiographic parameters: T1S 32.2°, C2-C7 lordosis -8.3°, TS-CL 31.4º, CL flexibility 26.9°, cSVA 40.8mm. 25 of the CD pts (35.7%) had concurrent TL deformity [CD-TL] at BL. 30 CD pts (42.9%) met optimal outcome criteria [Opt]. At 2Y, Opt patients had higher C2-C7 lordosis and C2-T3, as well as lower TS-CL (all $p<0.05$). There were no differences in BL to 2Y changes by Opt outcome (all $p>0.05$). Opt pts were more likely to improve in Ames TS-CL modifier from BL to 2Y, to improve in ≥1 SRS-Schwab modifier, and to have age-adjusted match at 2Y (all $p<0.05$). Opt pts classified as CD-TL did not differ from CD-nonTL pts in any BL to 2Y changes, in improving in alignment targets, or in DJK rates (all $p>0.05$).

Conclusion: For cervical deformity patients undergoing reconstruction with LIV above the thoracic kyphosis apex, realignment goals should emphasize optimization of TS-CL and cervical lordosis to achieve favorable functional and radiographic outcomes regardless of concurrent thoracolumbar deformity

E-POSTER #4

The Effect of Thoracic Kyphosis on Distal Junctional Kyphosis in Adult Cervical Deformity Patients

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Introduction: The effect of thoracic kyphosis (TK) on the development of distal junctional kyphosis in cervical deformity patients had remained understudied in the literature. The aim of this retrospective cohort study of single-center database was to investigate the role of thoracic kyphosis in the development of distal junctional kyphosis.

Materials and Methods: Inclusion criteria: operative CD patients (Cervical kyphosis>10°, with cSVA>4cm or CBVA>25°) and >18yrs with up to 2Y radiographic and HRQL follow-up. Significant differences in surgical, radiographic, and clinical factors and outcomes were determined. Deformity in cSVA and TS-CL was defined using the Ames criteria. Multivariate (MVA) was used to determine predictive impact of thoracic kyphosis (TK) on distal junctional kyphosis (DJK) development.

Results: 195 CD patients met inclusion criteria (58.3yrs, 46% Female, 28.3 kg/m2). Overall, 40 (21%) of these patients developed DJK. At BL patients presented with the following radiographic profile: PT (18.3), PILL (-.65), SVA C7-S1 (-6.54), cSVA C2-C7 (9.7), and TS-CL (24). Stepwise linear regression controlling for cervical deformity and global alignment at BL found both T4-T12 and T2-T12 were significant predictors of DJK development. In patients with Ames cSVA deformity at baseline, TK was not predictive, but in patients with 0 deformity it was predictive of DJK development. In patients with TS-CL deformity at baseline, controlling for age, frailty, and global alignment found TK was predictive but in patients with 0 deformity it had no significant effect. Controlling for cSVA, TS-CL, and global alignment, post-operative TK was also predictive of DJK (.97[.95-.995], p=.018). In patients with no post-op cSVA deformity, TK was predictive (.97[.94-.995], p=.021), however, could not significantly predict DJK in cases of cSVA under correction, adequate TS-CL correction, or TS-CL under correction. Controlling for BL deformity, age, frailty, and global alignment patients who were hypokyphotic had a higher chance of developing DJK (3[1.4-6.8], p=.006).

Conclusion: Baseline thoracic kyphosis was found to have a significant independent effect on DJK development in cervical deformity patients undergoing surgical correction. Even among patients who are adequately corrected in their cervical alignment, it remains imperative that thoracic kyphosis is not overlooked since it is a significant driver for development of DJK and has an adverse impact on outcomes and return to operation.

E-POSTER #5

Modified Kappa-line correlates better with neurological outcomes than modified K-line after laminoplasty for cervical myelopathy caused by ossification of the posterior longitudinal ligament

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Introduction: The K-line is used as a predictive factor in the preoperative planning for cervical myelopathy caused by ossification of the posterior longitudinal ligament (OPLL). However, recent reports have demonstrated that the focal relationship between the OPLL mass and segmental alignment also plays a significant role, and that this focal relationship cannot be evaluated using the traditional K-line. The Kappa line, which is drawn to connect the midpoints of the spinal canal at the uppermost and lowermost levels of the remaining bone levels after planned laminoplasty, has been reported to be highly correlated with neurological outcomes in selective laminoplasty, and has advantages in assessing the focal relationship between ossified mass and sagittal alignment (Figure 1). In this study, we evaluated the utility of the modified Kappa-line (mKappa-line) assessed on MRI as a predictor of neurological outcome and compared its result with the modified K-line (mK-line).

Materials and Methods: The medical records of 78 patients who underwent laminoplasty due to cervical myelopathy caused by OPLL and followed up for more than 2 years were retrospectively reviewed. Patients were divided into mK-line (+) vs. mK-line (-) groups and mKappa-line (+) vs. mKappa-line (-) groups according to whether the ossification lesion has crossed the mK-line or mKappa-line drawn in sagittal MRI images. The minimum intervals between the mK-line (mK[min])/mKappa-line (mKappa[min]) and the OPLL mass were measured. Patient characteristics, radiographic measurements, and patient-reported outcome measures (i.e., neck disability index [NDI], Japanese Orthopedic Association [JOA] scores) were compared. Pearson's correlation analysis was performed to identify the factors associated with poor neurological outcomes.

Results: The mKappa-line (-) group (n=10) had significantly higher values of the thickness of the OPLL mass and the canal occupying ratio and a significantly smaller mKappa[min] compared with the mKappa-line (+) group (n=68). Similarly, the mK-line (-) group (n=7) had a significantly smaller mK[min] compared with the mK-line (+) group (n=71). Notably, the mKappa (-) group had significantly lower values of postoperative JOA scores at 6 months and final follow-up as well the JOA recovery rate compared with the mKappa (+) group. The mK-line (-) group also had a significantly lower JOA score at the final follow-up compared to the mK-line (+) patients, but did not show a significant difference in the JOA recovery rate (Table 1). Correlation analysis showed that whereas mKappa[min] was significantly correlated with both JOA recovery rate (P=0.03)and JOA score at the final follow-up (P=0.02), mK[min] did not show such significant correlations (P=0.37 and 0.46, respectively) (Table 2).

Conclusion: Both the mK-line status and the mKappa-line status were associated with poor neurological outcomes after laminoplasty. However, only the mKappa[min] was significantly correlated with the JOA score recovery rate. These results suggest that in patients undergoing selective laminoplasty, mKappa[min] would be a more useful prognostic factor than mK[min]

E-POSTER #5 continued

by better demonstrating the relationship between segmental alignment and OPLL lesion. Therefore, the concept of mKappa-line and mKappa[min] would be helpful in choosing operative levels for selective laminoplasty that can result in better neurological recovery.

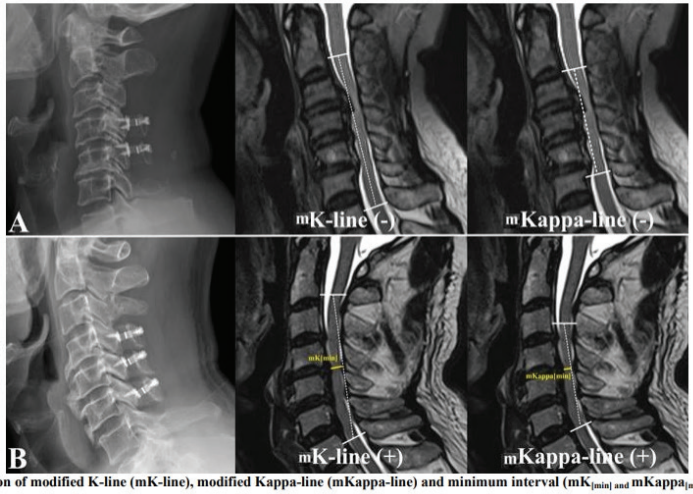

Figure 1. Definition of modified K-line (mK-line), modified Kappa-line (mKappa-line) and minimum interval ($mK_{[min]}$ and $mKappa_{[min]}$) (A) A 56-year old male patient underwent laminectomy of C3, laminoplasty of C4, C5. mK-line was drawn by placing a line the center of C2 and C7 canal. mKappa-line was drawn by connecting the mid-points of spinal canal at both uppermost and lowermost remaining bone levels after planned decompression. mK-line (-) or mKappa-line (-) was assessed when ossified mass crossed the mK-line or mKappa-line (B) A 72-year old female underwent partial laminectomy of C3 and laminoplasty of C4, C5, and C6. mK-line (+) or mKappa-line (+) was assessed when the ossification lesion did not cross the mK-line or mKappa-line.

E-POSTER #5 continued

Table 1. Patient characteristics, radiographic measurements, patient reported outcome measures

	Variables	mKappa (+)	mKappa (-)	P value	mK (+)	mK (-)	P value
Patient characteristics	Number	68	10		71	7	
	Age	65.8±10.9	64.5±13.4	0.74	65.8±11.0	64.0±13.8	0.69
	Sex						
	Male	50 (73.5%)	6 (60.0%)	0.46	52 (73.2%)	4 (57.1%)	0.40
	Female	18 (26.5%)	4 (40.0%)		19 (26.8%)	3 (42.9%)	
Radiographic measurements	Number of levels	4.2±0.8	4.3±0.5	0.69	4.2±0.8	4.0±0.6	0.48
	Cervical lordosis	11.8±7.7	11.5±5.1	0.88	12.0±7.6	9.7±5.3	0.43
	C2-C7 SVA	23.2±11.4	23.7±12.7	0.89	12.0±7.5	9.7±5.3	0.93
	OPLL thickness (mm)	4.3±1.4	6.4±1.7	<0.01*	4.5±1.5	5.5±2.0	0.11
	Canal occupying ratio (%)	46.2±15.1	64.4±16.2	<0.01*	47.4±15.8	59.9±18.3	0.06
	Minimum interval	2.2±0.9	-0.1±0.5	<0.01*	3.8±2.0	-0.5±0.9	<0.01*
	Patient reported outcome measures						
		mKappa (+)	mKappa (-)	P value	mK (+)	mK (-)	P value
NDI	Preop	13.7±6.1	17.6±8.9	0.22	14.5±6.8	12.4±3.9	0.51
	Postop 6m	8.8±7.0	10.8±8.7	0.43	8.7±6.9	12.8±9.6	0.19
	Final follow-up	6.7±5.3	10.1±10.1	0.13	6.9±6.0	10.3±8.7	0.19
JOA	Preop	13.2±3.1	11.4±3.8	0.11	13.0±3.3	12.0±2.6	0.43
	Postop 6m	14.6±2.5	11.6±4.0	0.01*	14.2±3.0	13.2±1.9	0.17
	Final follow-up	15.3±1.6	13.6±2.9	0.01*	15.3±1.7	13.4±1.9	0.01*
	Recovery rate	61.3±39.7	32.6±33.7	0.03*	60.1±39.7	32.5±36.6	0.08

mKappa, modified Kappa-line state; mK, modified K-line state; SVA, sagittal vertical axis; OPLL, ossification of the posterior longitudinal ligament; NDI, neck disability index; JOA, Japanese Orthopedic Association score

Age, number of levels, cervical lordosis, C2-C7 SVA, OPLL thickness, canal occupying ratio, minimum interval, NDI were compared using a student's t-test.

Sex was compared using a chi-square test

JOA score was compared using a Mann-Whitney U test

Table 2. Results of correlation analysis demonstrating factors associated with JOA recovery rate and JOA score at the final follow-up

Variables	JOA recovery rate		JOA score at final follow-up	
	Correlation coefficient	P value	Correlation coefficient	P value
Age	0.01	0.97	0.22	0.85
Number of levels	0.01	0.91	0.10	0.40
Cervical lordosis	0.03	0.81	-0.21	0.08
C2-C7 SVA	0.14	0.25	0.02	0.88
OPLL thickness	-0.15	0.20	-0.22	0.06
Canal occupying ratio	-0.21	0.08	-0.33	<0.01*
mK(INT)	0.11	0.37	0.09	0.46
mKappa(INT)	0.25	0.03*	0.28	0.02*

JOA, Japanese Orthopedic Association score; SVA, sagittal vertical axis; OPLL, ossification of the posterior longitudinal ligament; mK(INT), minimum interval between the modified K-line and ossification lesion; mKappa(INT), minimum interval between the modified Kappa-line and ossification lesion

Statistical analyzes were performed by using a Pearson's correlation test

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

E-POSTER #6

Anterior Cervical Discectomy and Fusion V. Cervical Disc Replacement for Cervical Spondylotic Myelopathy. An MCID Comparison

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Hospital for Special Surgery[1] Hospital flr Special Surgery[2]

Introduction: Comparative studies of patients with cervical spondylosis treated with either cervical disc replacement (CDR) anterior cervical discectomy and fusion (ACDF) are sparse in number. Previous studies have demonstrated good outcomes in patients undergoing CDR with moderate cervical spondylosis involving the disc, uncovertebral, or facet joints. The purpose of this study was to compare clinical outcomes in patients with moderate cervical spondylosis undergoing CDR versus, the gold standard, ACDF.

Materials and Methods: Patients who underwent one or two-level CDR or ACDF with moderate cervical spondylosis, quantified using a validated grading scale, were identified, and prospectively collected data was retrospectively reviewed. The following preoperative and postoperative patient reported outcomes (PRO) were prospectively collected as standard of care: Neck Disability Index (NDI), VAS-Neck, VAS-Arm, and PROMIS Physical Function (PROMIS-PF) Computer Adaptive Test Score. Cervical spondylosis was graded by assessing disk height, facet arthrosis, and uncovertebral joint degeneration (Figure 1). Each of these characteristics was given a score of 0, 1, or 2 with increasing scores correlating with more severe disease. Demographic, operative, and cervical spondylosis grades, and achievement of MCID for each PRO was analyzed and compared between the two groups.

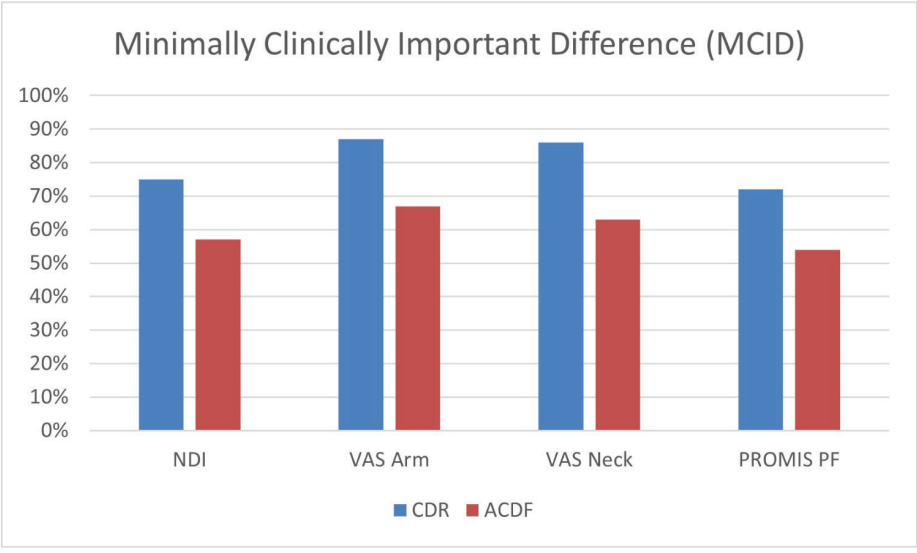
Results: A total of 66 patients were included in the present study, of which 35 (53%) were treated with CDR and 31 (47%) with ACDF. Average follow up was 15.5 months. Patients treated with ACDF were significantly older (58.7 v. 43.0 years-old, $P<0.01$). Other demographic variables were similar between the two groups. There were no significant differences in operative time, level of surgery, intraoperative complications, inpatient complications, and length of stay between the two groups. The preoperative cervical spondylotic grade was similar between the two groups (1.8 v 2.2, $P= 0.27$).

At final follow-up, patient reported outcomes improved significantly compared to preoperative values in both treatment groups. There was no significant difference in the absolute value for each patient reported outcome at final follow-up between the two groups. In the CDR group, greater than 70% of patients achieved the MCID in all four patient reported outcomes assessed; in the ACDF group, greater than 50% of patients achieved the MCID in all four patient reported outcomes assessed. There was no significant difference in the percentage of patients achieving the MCID when comparing CDR to ACDF (Figure 2).

Conclusion: The results of the present study demonstrate that patients with moderate cervical spondylosis treated with CDR reported similar postoperative patient reported outcomes to those treated with ACDF. The use of CDR in patients with spondylosis of the uncovertebral joint, facet joint, or disc space height loss may result in similar outcomes compared to ACDF treated patients, while preserving motion and avoiding the biologic demand of obtaining a fusion across the involved cervical levels.

E-POSTER #6 continued

Disc Height Grade
Grade 0: Normal disc height compared to adjacent levels
Grade 1: Less than 50% disc collapse compared to adjacent levels
Grade 2: > 50% disc collapse compare to adjacent levels
Uncovertebral Joint (UVJ) Degeneration Grade
Grade 0: UVJ normal
Grade 1: UVJ arthrosis with bone-to-bone contact
Grade 2: UVI arthrosis with osteophyte formation
Facet Arthrosis Grade
Grade 0: No arthrosis
Grade 1: Arthrosis with reduced joint space but not bone-on-bone
Grade 2: Severe arthrosis with bone-to-bone contact, irregular facet joint, osteophyte formation



E-POSTER #7

Does Recall Bias Exist in Cervical Spine Surgery Patients As Reported Through PROMIS Questionnaires?

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Introduction: Surgical outcomes are being increasingly judged on patients' perceptions of the results. Despite the improved quantitative data provided by patient-reported outcomes (PROs), they remain susceptible to confounding factors on patients' interpretations such as recall bias: the inability to accurately recall prior impairment. No studies to date have reported the accuracy of patient recall using PROMIS outcomes after cervical spine surgeries. The purpose of this study is to determine the presence and extent of recall bias in adult patients after elective cervical spine surgery.

Materials and Methods: 49 patients who had undergone either cervical decompression or cervical decompression and fusion procedures at a single tertiary academic center were identified. All patients had prospectively completed PROMIS Physical Function (PF) CAT and Pain Interference (PI) CAT prior to surgery and at 3 months, 6 months, 1 year and 2 years. Patients, at least 2 years after their index surgery, completed a recall questionnaire comprised of the PF CAT and PI CAT as though it was a time immediately before their surgery. T tests were used to compare recalled PROs with actual baseline PROs. Correlation coefficients were calculated to evaluate the agreement between recalled PROs and baseline PROs. Regression analysis was performed to determine the impact of patient characteristics or clinical factors.

Results: There were no significant differences between patient recollection of preoperative status at a minimum of 2 years postoperatively for PF and PI. There was only moderate correlation between recalled and baseline scores with regards to PF (r=0.31) (Figure 1) and PI (r=0.36) (Figure 2). No significant differences on recalled PROs were found based on age, gender, time between surgery and recalled outcomes, and duration of symptoms before surgery.

Conclusion: Our data indicate that patient recall of preoperative status after cervical surgery is accurate as measured by PROMIS PF and PI scores with only moderate correlation existing between the two. Despite the majority of patients accurately recalling their baseline state, some patients' interpretations of improvement after surgery still appear to be impacted by significant recall bias. This may have an impact on satisfaction and perceived value of cervical spine surgery particularly in these patients. Further research is necessary to identify which patients might be more prone to such a bias.

E-POSTER #7 continued

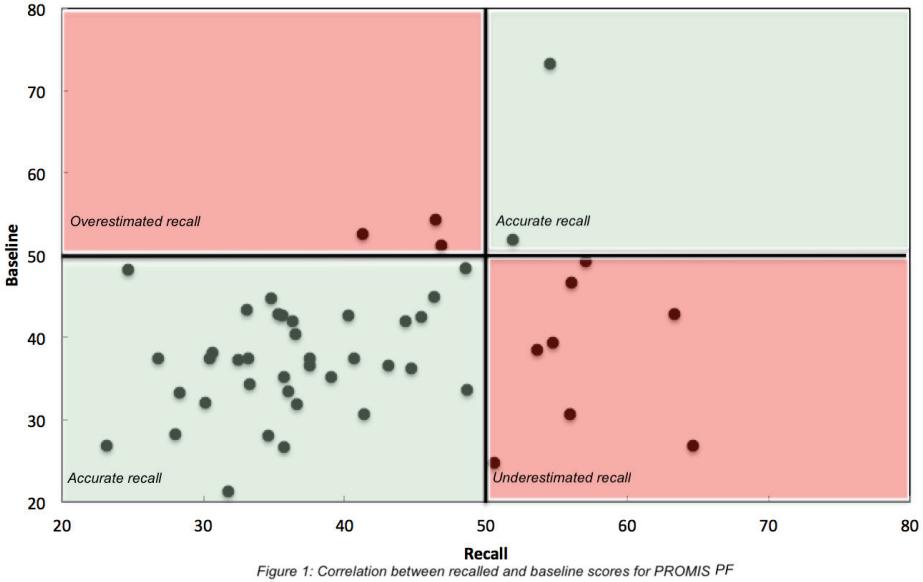

Figure 1: Correlation between recalled and baseline scores for PROMIS PF

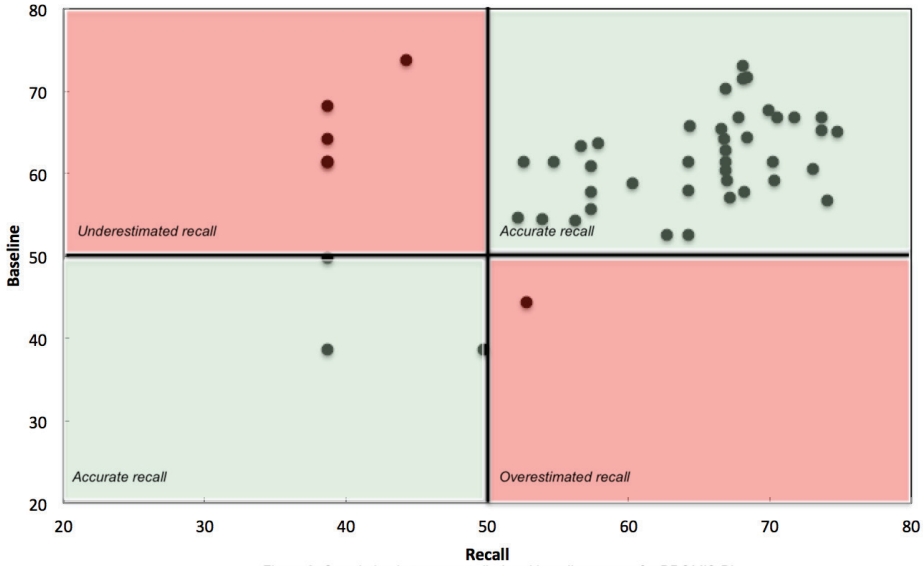

Figure 2: Correlation between recalled and baseline scores for PROMIS PI

E-POSTER #8

Rethinking the Jefferson Fracture

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Medical College of Wisconsin[1]

Introduction: Traditional thinking from a surgical perspective has typically been that a ring doesn't break in only one place and a Jefferson fracture is an axial load injury-put the patient in an orthosis and all will be fine.

The Jefferson fracture classification itself is somewhat controversial depending on the classification system used. There are basically 5 types of atlas fractures. Types I-III are the classic burst type mechanism. But there is more to Jefferson fractures than meets the eye and it will probably become a more frequent injury as automobile technology advance to fully automated vehicles. The projected differences in automotive seating configurations, postures, and inattention (sleeping, cellphone usage etc.) in these vehicles is anticipated to result in a potential increase in traumatic fractures, in particular Jefferson type IV fractures.

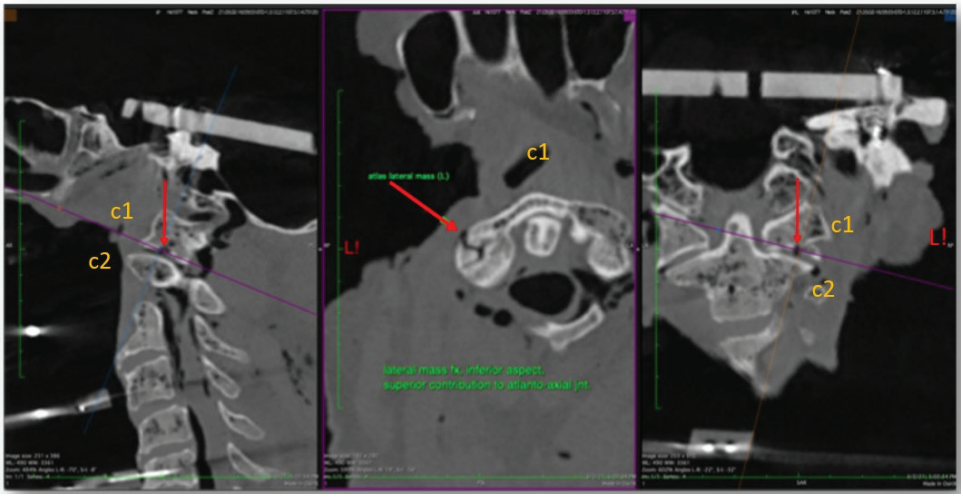
Materials and Methods: An isolated head to T1 human cadaver specimen was attached to a load cell at T1. The load cell was fixed to the top of a six-degree-of-freedom custom spinal positioning device to orient the specimen such that the occipital condyle joint is in-line with the torque axis of another custom angular displacement test device that converted the linear motion of a vertically oriented electro-hydraulic piston to a torque about the occipital condyle joint of the specimen. The head was pre-rotated in the axial plane approximately 20 degrees to the left while maintaining the coronal alignment of the lower cervical spine. Targets were secured at the head and spine (details in the body of the manuscript) and their three-dimensional positions were measured using a seven-camera optical motion capture system. Right and then left lateral bending tests were conducted. Occipital condyle joint loads were determined from the superior load cell and the stiffness difference between the left and right lateral bending was determined.

Results: The Jefferson fracture type iv (Landells III) fracture was demonstrated in our human cadaveric study with an isolated lateral mass fracture due to asymmetric axial loading with a combination of flexion, head rotation with lateral bending.

Conclusion: The classical Jefferson fracture (types, I, I, III) is a burst type mechanism from a direct blow to the vertex resulting in a symmetrical loading transmitted through the occipital condyles to the C1 lateral masses. This results in failure of the atlas ring in tension and multiple fractures typically 2-4 along the ring. Our cadaveric study demonstrated that an asymmetric axial load, rotation and lateral bending will result in a unilateral lateral mass fracture with significant contralateral ligamentous injury due to the failure in tension. These fractures may be more unstable than previously realized and MRI is recommended to assess the extent of ligamentous injury. It is anticipated that an increase in Jefferson fractures will occur in the future as autonomous vehicles become popular and vehicle seat postures change due to inattention.

E-POSTER #8 continued

C1 lateral mass(L) fx



E-POSTER #9

The Practical Reality of Accomplishing Surgery Within 24 hours for Complete Cervical Spinal Cord Injury: A Study of Clinical Practices and Safety Profile at North American Trauma Centers

Michael Balas, MD(C)[1], Michael G. Fehlings, MD, PhD, FRCSC, FACS, Jefferson Wilson, MD PhD[1], Christopher Witiw, MD, MS
University of Toronto[1]

Introduction: Substantial clinical data supports an association between superior neurological outcomes and early (within 24 hours) surgical decompression for those with a cervical spinal cord injury (SCI) [1-3]. Despite this, much discussion persists around feasibility and safety of surgery within this 24-hour timeframe, particularly for those with a complete cervical SCI. This study aims to assess the clinical practices and safety profile of surgery within 24 hours for these severely injured patients across a large sample of North American trauma centers.

Materials and Methods: Data was derived from the American College of Surgeons Trauma Quality Improvement Program (TQIP) database from 2010-2016 [4,5]. Adult patients with a complete cervical SCI (ASIA A) who underwent surgery were included. Demographic variables, injury characteristics, and treating hospital level characteristics were collected. Patients were stratified into two groups based on time to surgery with a threshold of 24 hours demarcating early versus late intervention. The risk-adjusted variability in timeliness of surgery across trauma centers was investigated using mixed-effects regression. Outlier hospitals were identified. Propensity score matching was used to balance the cohorts on all observed covariates. In-hospital adverse events including mortality, major complications, and immobility-related complications were compared between these groups.

Results: 2,862 patients from 353 North American trauma centers were included. 1,760 (61.5%) underwent surgery within 24 hours and the median time to surgery was 17.2 (IQR: 7.0 to 41.0) hours from admission. Case-mix and hospital-level characteristics explained only 6% of the variability in surgical wait-times both between-centers and within-centers. After adjusting for case-mix and hospital-level variables in the full model, the mean difference and 95% CI of each trauma center's surgical wait-time identified 18 hospitals with significantly shorter wait times (low outliers), and 6 hospitals with significantly longer wait times (high outliers) (Figure 1). After propensity score matching, no significant differences in major complications (OR=0.90; 95%CI: 0.75, 1.07), immobility related complications (OR=0.93; 95%CI: 0.78, 1.10), or mortality (OR=1.16; 95%CI: 0.89, 1.51) were identified between the two groups.

Conclusion: Surgical intervention within 24 hours occurred in less than two-thirds of patients with complete cervical SCI from this multicenter North American database. Patient and hospital-level characteristics explain little of the variability in time-to-surgery. These severely injured patients undergoing early surgery did not appear to have any increased probability of an adverse event. These findings suggest further knowledge translation efforts are needed to increase the proportion of patients in whom surgery is performed before the 24-hour threshold so that patients might reach their greatest potential for neurologic recovery.

E-POSTER #9 continued

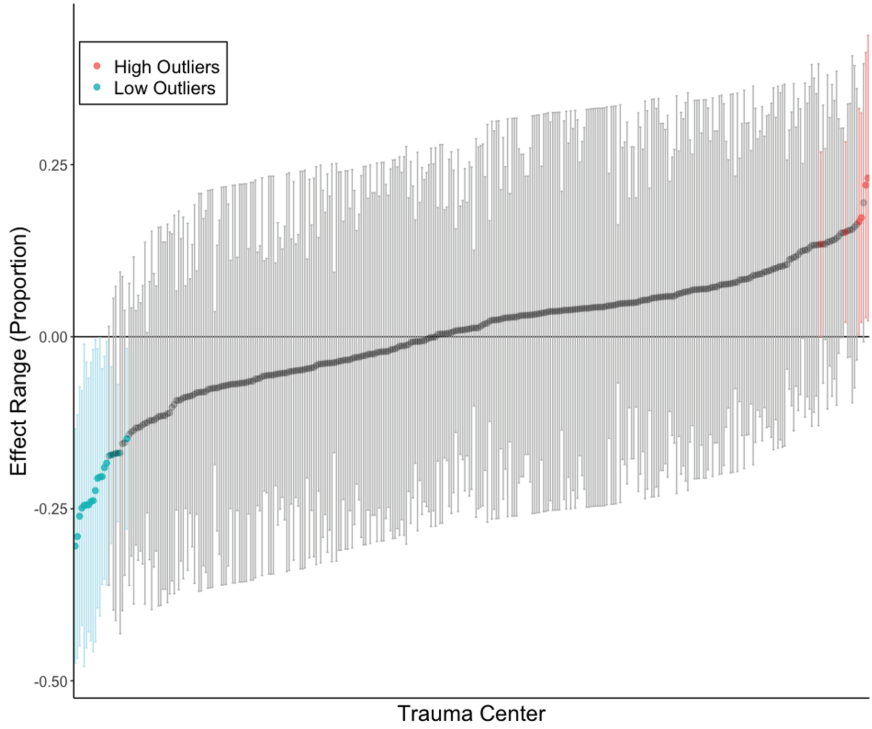


Figure 1: 'Caterpillar plot' of trauma center mean differences and 95% CIs for time to surgery, risk-adjusted for patient- and hospital-level characteristics. Hospitals that have significantly shorter times to surgery than average (upper limit of the 95% CI is below 0) are low outliers (blue), whereas those with significantly longer times to surgery than average (lower limit of 95% is above 0) are high outliers (red).

E-POSTER #10

Surgical Outcomes in Non-ambulatory Patients with Degenerative Cervical Myelopathy

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Introduction: Degenerative cervical myelopathy (DCM) represents a collection of age-related degenerative processes of the cervical spine that can result in motor, sensory and autonomic dysfunction, leading to significant reductions in quality of life.(1) Individuals with severe, non-ambulatory forms of DCM are often treated with spinal decompression although the extent of neurological improvement for this patient population is unclear. (2,3) The aim of this study was to better characterize outcomes following cervical decompression in those with severe, non-ambulatory forms of DCM. We believe the results of this study can be used to better inform the decision-making process when considering the potential benefits and risks of decompression surgery for these patients.

Materials and Methods: A retrospective analysis was done on 48 patients who underwent cervical decompression surgery at University Hospitals Cleveland Medical Center between January 2007 and December 2018. Patients greater than 18 years of age, with severe, non-ambulatory forms of DCM classified as a Nurick grade of IV or V were included in the study. Changes in Nurick and mJOA scores were used as primary outcome measures. Paired t-tests and Wilcoxon-signed rank tests were used to compare Nurick and mJOA scores before and after surgery. Patient demographics, operative details, and post-surgical complications were analyzed using descriptive statistics.

Results: Patients experienced significant improvements in both outcomes following cervical decompression surgery. The mean Nurick grade improved from 4.10 +/- 0.31 to 2.21 +/- 0.82 ($p < 0.001$, paired t-test; 95% CI -2.08 to -1.71), while the mean mJOA score improved from 10.58 +/- 1.51 to 13.60 +/- 1.58 ($p < 0.001$, paired t-test; 95% CI 2.59 to 3.45). The average follow-up duration was 2.50 +/- 1.83 years. Following surgery, 44 of the 48 patients gained the ability to ambulate without the aid of a walking frame or someone else's assistance.

Conclusion: Our study demonstrated that patients with severe forms of DCM experienced significant improvement in neurological function following cervical decompression surgery. These improvements indicate that cervical decompression surgery is effective in this patient population and has the potential to improve neurological status.

E-POSTER #10 continued

Characteristic	Means or Frequencies
Age (yr)	64.41 ± 12.15
Sex (N=48)	
Male	30 (62.5%)
Female	18 (37.5%)
Race (N=46)	
Caucasian	36 (78.3%)
African American or Black	10 (21.7%)
No. of Levels Compressed	2.94 ± 1.10
Surgical Approach	
Anterior	19 (39.6%)
Posterior	29 (60.4%)

Table 1. Patient Characteristics

Values for mean presented as mean ± standard deviation

E-POSTER #10 continued

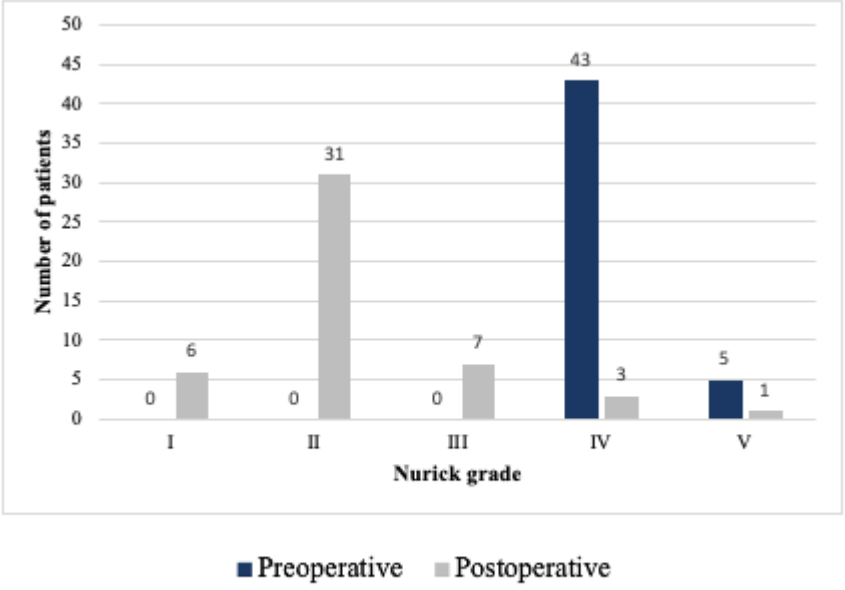

Figure 1. Distribution of Nurick grades before and after surgery

E-POSTER #10 continued

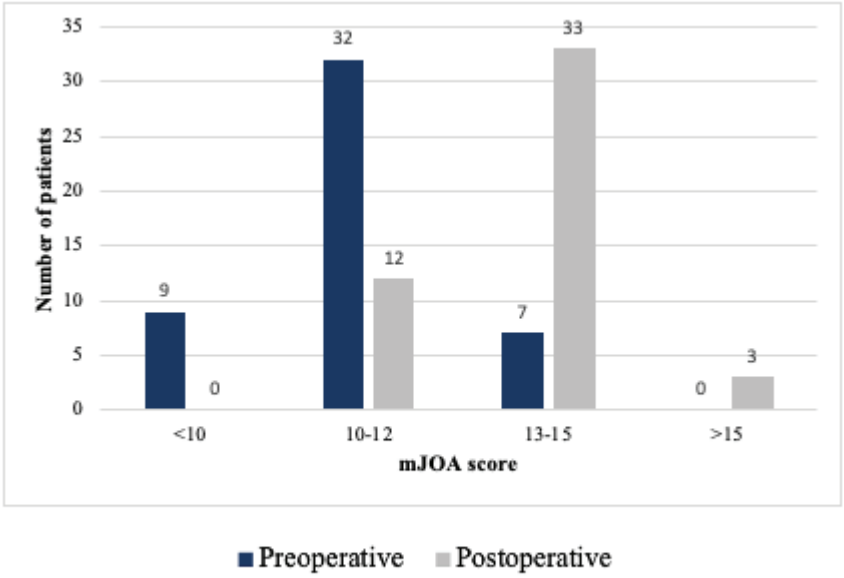

Figure 2. Distribution of mJOA scores before and after surgery

E-POSTER #11

Choose Wisely--ACDF and Cervical Disc Arthroplasty in the Outpatient Setting

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Introduction: Anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA) have become attractive targets for outpatient surgery. Understanding the safety profile of these procedures remains important as they transition to an outpatient environment. Therefore, we assessed the prevalence of rapid responses (RRTs) and major complications in the inpatient setting following one or two level ACDFs and CDAs at a high-volume institution over a two year period. We also evaluated for patient and procedural risk factors that place patients at greater risk for an RRT or a postoperative complication.

Materials and Methods: This was an IRB-approved, retrospective cohort study of adult patients who underwent single- or two-level ACDF or CDA at one hospital between 2018 and 2019. Patient demographics, procedural data, and comorbidities were collected. The hospital's database was queried for RRTs during the patient's immediate postoperative hospital stay as well as for acute complications occurring in the immediate postoperative period. Complications were defined as events that were life threatening, required an intervention, or led to a delay in hospital dismissal. One thousand and forty patients were included. There were 888 ACDFs (491 1-level, 397 2-level) and 152 CDAs (119 1-level, 33 2-level).

Results: There were 36 patients (3.5%) with an RRT; 24% occurred >24hr after surgery. There were 24 patients (2.3%) who experienced one or more acute complications; 71% occurred >6hr after surgery. Severe dysphagia was the most common complication (11/24; 45.8%). There were 3 postoperative hematomas that required surgical evacuation (3/24; 12.5%) and one instance of acute respiratory failure requiring emergent reintubation (1/24; 4.2%). Patients who had an RRT postoperatively had significantly higher odds of developing a complication (OR 14, $p < 0.01$) and had a significantly longer hospital stay (54 hrs vs. 30 hrs; $p<0.001$). Patients who developed a complication were significantly older (61 yrs vs. 54 yrs, $p=0.014$); were more commonly former smokers ($p=0.007$); had a higher prevalence of COPD (46% vs 16%, $p<0.001$); had a higher prevalence of asthma (25% vs. 9%, $p=0.024$); and had a higher percentage of ASA 3 classification ($p=0.010$). Revision surgeries were more commonly performed in patients with an RRT (36% vs 18%; $p=0.015$) and in patients with a postoperative complication (38% vs 18%; $p=0.028$) compared to the general cohort. Moreover, the length of surgery was longer in patients who developed a complication (113 min vs. 87 min; $p<0.001$). All patients who developed dysphagia had surgery involving C4-5 or more proximal.

Conclusion: RRTs and complications are uncommon following 1 or 2 level ACDFs or CDAs but portend a longer hospital stay and increased morbidity. Careful patient selection remains important in determining what patients may safely undergo outpatient ACDF or CDA. Revision surgeries place patients at higher risk for RRTs and complications. Additionally, older patients, patients with COPD or asthma, patients who are active or former smokers, or patients who have an ASA classification of 3 or greater are at increased risk of postoperative complications.

E-POSTER #12

Meeting Preoperative Expectations Predicts Patient Satisfaction following Anterior Cervical Discectomy and Fusion

Elliot Cha, MS, Conor Lynch, MS, Shruthi Mohan, BS, Cara Geoghegan, BS, Caroline Jadczak, BS, Kern Singh, MD[1]
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Introduction: Patient reported outcome measures are widely used to assess the results of spine surgery. A number of previous studies have examined factors that determine patient satisfaction following anterior cervical discectomy and fusion (ACDF).[1-2] However, the influence of preoperative expectations on postoperative satisfaction following ACDF has not been thoroughly explored.[3-4] Our study aims to assess the predictive value of preoperative expectations on patient satisfaction following ACDF.

Materials and Methods: A surgical registry was retrospectively reviewed for primary, single or multi-level ACDF procedures. Patients were excluded if surgery was indicated due to trauma, infection, or malignancy, or if preoperative expectation surveys were not available. Demographic characteristics and operative variables were collected for all included patients and descriptive statistics were performed. Patients' expectations regarding surgical outcomes in neck and arm pain were assessed at the preoperative timepoint using the questions "What do you expect your [arm/neck] pain to be following surgery?". Current levels of neck and arm pain were assessed using the Visual Analogue Scale (VAS) at preoperative and 6-week, 12-week, 6-month, and 1-year postoperative timepoints. Patients' satisfaction with their current level of neck and arm pain was individually assessed on a scale of 1-10 at each postoperative timepoint. Actual pain improvement was calculated as (postoperative pain scores - preoperative scores). Whether expectations were met was evaluated by comparison of expectation scores to actual postoperative VAS scores at each postoperative timepoint. Evaluation of expectation pain scores and actual pain scores as predictors of patient satisfaction was performed using linear regression at each postoperative timepoint.

Results: 34 patients undergoing primary ACDF procedures had a mean age of 48.7 years, majority were male (52.9%), 47.1% were obese, and 11.8% were smokers. Most patients underwent single level procedures (61.8%). Mean operative time was 61.9 min., mean estimated blood loss was 28.1 mL, and mean length of stay was 10.9 hours. The majority of patients met their preoperative pain score expectations at all timepoints except for neck pain at 6-weeks (47.1%, Table 1). By 1-year postoperatively, 85.3% and 82.4% of patients had met their expectations for postoperative neck and arm pain, respectively. Postoperative improvement in pain was a significant predictor of satisfaction only for neck pain at 6-months ($p=0.001$) and arm pain at 12-weeks ($p=0.014$) and 6-months ($p=0.001$, Table 2). Meeting preoperative expectations for neck and arm pain acted as a significant predictor of satisfaction at all postoperative timepoints (all $p<0.05$), except for neck pain at 6-weeks ($p=.327$, Table 3).

Conclusion: Most patients achieved their preoperative expectations for neck and arm pain by 1-year following ACDF surgery. While overall improvement in neck and arm pain only predicted postoperative satisfaction at a few timepoints, meeting preoperative expectations for postoperative pain significantly predicted patient satisfaction at all timepoints except 6-weeks for neck pain. This indicates that patients' preoperative expectations may actually

E-POSTER #12 continued

be a more important indicator for postoperative success than their raw improvement in pain scores. This information will be important for physicians to consider when counseling patients preoperatively and assessing outcomes postoperatively.

Table 1. Degree to which Expectations were Met

	Expectations Met	Expectation - Actual Mean ± SD
Neck Pain		
6-weeks	47.1% (16)	-1.8 ± 2.8
12-weeks	76.5% (26)	-0.9 ± 2.2
6-months	64.7% (22)	-1.4 ± 2.8
1-year	85.3% (29)	-2.2 ± 2.8
Arm Pain		
6-weeks	61.8% (21)	-1.6 ± 2.6
12-weeks	82.3% (28)	-0.8 ± 2.0
6-months	73.5% (25)	-1.8 ± 2.5
1-year	82.4% (28)	-2.3 ± 2.5

SD = standard deviation

Table 2. Postoperative Pain Improvement as a Predictor of Satisfaction

	Satisfaction Mean ± SD	R^2	*p-value
Neck Pain			
6-weeks	6.5 ± 3.4	0.066	0.178
12-weeks	7.6 ± 3.1	0.144	0.120
6-months	7.6 ± 3.2	**0.457**	**0.001**
1-year	6.9 ± 4.1	0.213	0.180
Arm Pain			
6-weeks	6.9 ± 3.8	0.097	0.099
12-weeks	8 ± 3.5	**0.324**	**0.014**
6-months	8.0 ± 2.7	**0.481**	**0.001**
1-year	6.9 ± 4.1	0.263	0.129

*p-values calculated using linear regression

Boldface indicates significance; SD = Standard Deviation

E-POSTER #12 continued

Table 3. Meeting Expectations as a Predictor of Postoperative Satisfaction

	Satisfaction Mean ± SD	R^2	*p-value
Neck Pain			
6-weeks	6.5 ± 3.4	0.030	0.327
12-weeks	7.6 ± 3.1	**0.579**	**<0.001**
6-months	7.6 ± 3.2	**0.396**	**0.002**
1-year	6.9 ± 4.1	**0.477**	**0.027**
Arm Pain			
6-weeks	6.9 ± 3.8	0.029	0.335
12-weeks	8 ± 3.5	**0.426**	**0.003**
6-months	8.0 ± 2.7	**0.608**	**<0.001**
1-year	6.9 ± 4.1	**0.430**	**0.039**

*p-values calculated using linear regression
Boldface indicates significance; SD = standard deviation

E-POSTER #13

Preoperative Sleep Difficulty Predicts Clinically Significant Improvement Following ACDF

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Rush University Medical Center[1]

Introduction: A number of previous studies have reported varying results regarding the impact of preoperative Patient Health Questionnaire-9 (PHQ-9) scores on outcomes following anterior cervical discectomy and fusion (ACDF).[1-3] However, the significance of individual items within the PHQ-9 survey as predictors of postoperative outcomes has not been explored. Our study aims to study the relationship between responses to individual PHQ-9 survey items and achievement of minimum clinically important difference (MCID) following ACDF.

Materials and Methods: A prospectively maintained surgical database was retrospectively reviewed for primary, single-level ACDF procedures performed from April 2016 to November 2018 for degenerative spinal pathology. Patients without preoperative PHQ-9 scores or whose procedures were performed for malignant, infectious, or traumatic indications were excluded. Patient demographics, preoperative spinal pathology, and perioperative characteristics were recorded. Patient reported outcome measures (PROMs) were administered at preoperative and 6-week, 12-week, 6-month, 1-year, and 2-year postoperative timepoints. PROMs included PHQ-9, Visual Analogue Scale (VAS) neck and arm, Neck Disability Index (NDI), 12-Item Short Form Physical Composite Score (SF-12 PCS), and Patient-Reported Outcomes Measurement Information System physical function (PROMIS PF). Descriptive statistics were performed for demographics, preoperative spinal pathology, perioperative variables, and PROM scores. Rates of MCID achievement were determined by comparing postoperative PROM improvement from baseline to the following previously established values: VAS neck (2.6), VAS arm (4.1), NDI (8.5), SF-12 PCS (8.1), PROMIS PF (4.5). Logistic regression analysis was used to assess responses to each individual question of the preoperative PHQ-9 survey as predictors of MCID achievement in each other PROM.

Results: A total of 66 ACDF patients met inclusion criteria. The cohorts mean age was 47.2 years and a majority were male (57.6%) and non-obese (BMI <30 kg/m2; 53.0%) (Table 1). Herniated nucleus pulposus was the most common preoperative spinal diagnosis (95.6%). Mean operative duration was 50.3 minutes, mean estimated blood loss was 27.5 mL, and most patients were discharged on postoperative day 0 (81.8%). Mean postoperative PROM scores were improved from preoperative baseline at all timepoints and a majority of patients achieved MCID for all measures except SF-12 PCS. PHQ-9 question 3 significantly predicted MCID achievement for VAS neck (p=0.045), VAS arm (p=0.049), and SF-12 PCS (p=0.037). No other PHQ-9 items nor overall PHQ-9 scores significantly predicted MCID achievement (Table 2 and 3).

Conclusion: Question 3 of the PHQ-9 survey regarding "trouble falling asleep, staying asleep, or sleeping too much" significantly predicted meaningful improvement in neck pain, arm pain, and physical function following ACDF, although overall PHQ-9 scores did not. Patients experiencing significant sleep-related difficulties may be especially likely to benefit from ACDF surgery.

E-POSTER #13 continued

Table 1. Patient Demographics

	Total (n=66)
Age (mean ± SD)	47.2 ± 10.1
Gender	
Female	42.4% (28)
Male	57.6% (38)
Body Mass Index (BMI)	
<30 kg/m^2	53.0% (35)
≥30 kg/m^2	47.0% (31)
Smoking Status	
Non-Smoker	84.9% (56)
Smoker	15.2% (10)
Diabetes	
Non-Diabetic	86.4% (57)
Diabetic	13.6% (9)
ASA Classification	1.9 ± 0.6
CCI Score	1.4 ± 2.0
Ethnicity	
White	71.2% (47)
African American	12.1% (8)
Hispanic	10.6% (7)
Asian	3.0% (2)
Insurance	
Medicare/Medicaid	1.5% (1)
Workers' Compensation	27.3% (18)
Private	71.2% (47)

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD = Standard Deviation

E-POSTER #13 continued

Table 2. PHQ-9 Items as Predictors of Pain and Disability MCID achievement

	OR	95% CI	*p-value
VAS Neck MCID			
Question 1	1.2	(0.7, 2.2)	0.550
Question 2	1.2	(0.6, 2.3)	0.667
Question 3	**2.0**	**(1.0, 3.9)**	**0.045**
Question 4	1.2	(0.6, 2.3)	0.594
Question 5	0.8	(0.4, 1.6)	0.489
Question 6	0.9	(0.4, 1.8)	0.741
Question 7	0.9	(0.5, 1.7)	0.758
Question 8	0.6	(0.3, 1.4)	0.271
Question 9†	-	-	-
Question 10	1.1	(0.5, 2.2)	0.843
Overall PHQ-9 Score	1.0	(0.9, 1.1)	0.971
VAS Arm MCID			
Question 1	1.2	(0.7, 2.1)	0.434
Question 2	1.0	(0.6, 1.7)	0.949
Question 3	**1.7**	**(1.0, 2.9)**	**0.049**
Question 4	1.0	(0.6, 1.7)	0.975
Question 5	0.6	(0.3, 1.2)	0.180
Question 6	0.7	(0.3, 1.3)	0.240
Question 7	0.9	(0.5, 1.6)	0.699
Question 8	0.8	(0.4, 1.7)	0.560
Question 9†	-	-	-
Question 10	0.8	(0.4, 1.4)	0.396
Overall PHQ-9 Score	1.0	(0.9, 1.1)	0.683
NDI MCID			
Question 1	1.9	(0.9, 3.7)	0.060
Question 2	1.3	(0.7, 2.5)	0.415
Question 3	1.6	(0.9, 2.8)	0.110
Question 4	1.6	(0.8, 3.0)	0.153
Question 5	1.2	(0.6, 2.3)	0.694
Question 6	1.5	(0.6, 3.4)	0.348
Question 7	1.4	(0.7, 2.9)	0.322
Question 8	1.1	(0.5, 2.5)	0.825
Question 9†	-	-	-
Question 10	2.0	(0.8, 4.6)	0.117
Overall PHQ-9 Score	1.1	(0.9, 1.2)	0.291

*p-values calculated using logistic regression to assess each question as a predictor of MCID achievement

†Unable to assess question 9 due to the limited number of patients with affirmative responses

Boldface indicates statistical significance

E-POSTER #13 continued

Table 3. PHQ-9 Items as Predictors of Physical Function MCID Achievement

	OR	95% CI	*p-value
SF-12 PCS MCID			
Question 1	1.6	(0.9, 2.7)	0.092
Question 2	1.2	(0.7, 2.0)	0.624
Question 3	**1.7**	**(1.0, 2.9)**	**0.037**
Question 4	1.5	(0.8, 2.6)	0.167
Question 5	1.4	(0.7, 2.5)	0.355
Question 6	1.2	(0.6, 2.3)	0.632
Question 7	1.2	(0.7, 2.2)	0.460
Question 8	1.6	(0.7, 3.5)	0.253
Question 9†	-	-	-
Question 10	1.4	(0.7, 2.7)	0.309
Overall PHQ-9 Score	1.1	(0.9, 1.2)	0.205
PROMIS PF MCID			
Question 1	1.6	(0.9, 2.9)	0.137
Question 2	1.1	(0.6, 2.1)	0.724
Question 3	1.1	(0.6, 1.9)	0.828
Question 4	1.3	(0.7, 2.4)	0.456
Question 5	0.8	(0.4, 1.5)	0.503
Question 6	0.9	(0.5, 1.9)	0.870
Question 7	1.3	(0.7, 2.6)	0.388
Question 8	1.3	(0.5, 3.0)	0.576
Question 9†	-	-	-
Question 10	1.3	(0.6, 2.7)	0.473
Overall PHQ-9 Score	1.1	(0.9, 1.2)	0.263

*p-values calculated using logistic regression to assess each question as a predictor of MCID achievement

†Unable to assess question 9 due to the limited number of patients with affirmative responses

Boldface indicates statistical significance

E-POSTER #14

Use of Multimodal Analgesic Protocol for Management of Postoperative Pain Following Cervical Laminoplasty: Clinical Case Series

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Introduction: Cervical laminoplasty procedures have been demonstrated as a strong option for the treatment of cervical spinal stenosis and myelopathy.[1] However, severe postoperative pain and lengthy inpatient stays have been reported in association with this procedure. [2-3] Our study aims to report a clinical case series of patients undergoing posterior cervical laminoplasty procedures with the use of an enhanced multimodal analgesic (MMA) protocol.

Materials and Methods: Prospectively recorded data was reviewed for consecutive patients that underwent posterior cervical laminoplasty with C2 dome laminectomy procedures with the use of an enhanced MMA protocol from 2013 to 2020 (Appendix A). Patients that received postoperative patient-controlled analgesia (PCA) were excluded. Patient demographics including age, gender, body mass index (BMI), smoking status, diabetes status, American Society of Anesthesiologists (ASA) physical classification, Charlson Comorbidity Index (CCI), and insurance/payment received were collected. Perioperative characteristics were recorded and stratified by the number of spinal levels decompressed to report preoperative spinal pathology, and operative duration, estimated blood loss (EBL), postoperative length of stay, postoperative day (POD) of discharge. Postoperative complications were recorded and summarized along with inpatient pain scores and narcotic consumption up to POD 1, using the numerical rating scale and oral morphine equivalents, respectively. Patient reported outcome measures (PROMs) were administered at preoperative and 6-week, 12-week, 6-month, and 1-year timepoints and included VAS neck, VAS arm, Neck Disability Index (NDI), and Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS PF).

Results: A total of 27 patients were included with a mean age of 59.0 years. The cohort was 81.5% male, 44.4% were obese (BMI ≥30 kg/m2), 11.1% were smokers, and 3.7% were diabetic. Most patients had an ASA classification of 2 (63.0%), a mean CCI score was 2.9, and a majority of patients carried private insurance (88.9%). Laminoplasty procedures were performed at 4 levels in 16 patients, 5 levels in 10 patients, and 6 levels in one patient. Most patients had both central stenosis (92.6%) and myeloradiculopathy (88.9%) and one patient had a diagnosis of herniated nucleus pulposus. Mean operative time was 105 minutes, mean EBL was 27 mL, and most patients were discharged on POD1 (59.3%) (Table 1). One patient experienced fever of unknown origin and one patient required reintubation and experienced altered mental status (Table 2). Mean inpatient pain scores were 4.3 on POD0 and 4.6 on POD1. Mean preoperative and 1-year PROM scores were as follows: VAS neck (4.6, 1.8), VAS arm (4.9, 3.1), NDI (35.9, 17.6), PROMIS PF (38.0, 46.6).

Conclusion: This clinical case series demonstrates that cervical laminoplasty procedures are feasible using an enhanced MMA protocol in place of more traditional opioid-based postoperative analgesia. Patients in this cohort were discharged in a timely manner, had well-controlled postoperative pain, and demonstrated favorable long-term outcomes.

E-POSTER #14 continued

Appendix A: Multimodal Analgesic Regimen

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. Tramadol 50mg
2. Cyclobenzaprine 10mg orally for spasms
3. 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

Inpatient Medications:

1. Tramadol 50mg
2. Oxycodone 5mg
   a. 5mg as needed for pain (VAS 4-6)
   b. 10mg as needed for pain (VAS 7-10)
3. Cyclobenzaprine 10mg
4. Pregabalin 75mg
5. Acetaminophen 650mg q6h
6. Cold compress applied to surgical site

E-POSTER #14 continued

Table 1. Perioperative Characteristics

	4-Levels (n=16)	5-Levels (n=10)	6-Levels (n=1)
Spinal Pathology			
Central Stenosis	87.5% (14)	100% (10)	100% (1)
Myeloradiculopathy	81.3% (13)	100% (10)	100% (1)
Herniated Nucleus Pulposus	5.6% (1)	0% (0)	0% (0)
Operative Levels			
C3-6	93.7% (15)	0.0% (0)	0.0% (0)
C3-7	0.0% (0)	100.0% (10)	0.0% (0)
C4-C7	6.3% (1)	0.0% (0)	0.0% (0)
C3-T1	0.0% (0)	0.0% (0)	100.0% (1)
Operative Time (Mean ± SD; min)	106.7 ± 28.4	102.1 ± 17.6	107
Estimated Blood Loss (Mean ± SD; mL)	78.1 ± 43.7	80.0 ± 36.9	100
Length of Stay (Mean ± SD; hours)	49.6 ± 34.8	30.4 ± 16.0	53.9
Day of Discharge			
POD0	6.3% (1)	10.0% (1)	0% (0)
POD1	50.0% (8)	80.0% (8)	0% (0)
POD2	12.5% (2)	0.0% (0)	100% (1)
POD3	18.8% (3)	10.0% (1)	0% (0)
POD4	0% (0)	0% (0)	0% (0)
POD5	12.5% (2)	0.0% (0)	0.0% (0)
Inpatient Pain Score			
POD0	4.0 ± 2.8	5.2 ± 0.6	4.0
POD1	4.8 ± 2.1	4.0 ± 0.7	4.7
Inpatient Narcotic Consumption (OME)			
POD0	46.7 ± 25.4	50.0 ± 21.5	90.0
POD1	46.3 ± 24.4	40.0 ± 19.1	67.6

OME = Oral Morphine Equivalents; POD = Postoperative Day

E-POSTER #14 continued

Table 2. Postoperative Complications

Complication	Total (n=27)
Reintubation	3.7% (1)*
Urinary Retention	0.0% (0)
Urinary Tract Infection	0.0% (0)
Acute Renal Failure	0.0% (0)
Postoperative Anemia	0.0% (0)
Altered Mental Status	3.7% (1)*
VTE	0.0% (0)
Pulmonary Embolism	0.0% (0)
Pneumothorax	0.0% (0)
Atelectasis	0.0% (0)
Pleural Effusion	0.0% (0)
Arrhythmia	0.0% (0)
Ileus	0.0% (0)
Nausea / Vomiting	0.0% (0)
Fever of Unknown Origin	3.7% (1)
Total Complications	7.4% (2)

VTE = venous thromboembolism
*complication applies to the same patient

E-POSTER #15

Cervical Myelopathy With Severe Neck Pain: Is Anterior Or Posterior Approach Better?

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Introduction: It is unclear if multilevel anterior cervical discectomy and fusion (ACDF) or posterior cervical laminectomy and fusion (PCF) is superior for patients with cervical myelopathy (CSM) and high preoperative neck pain.

Materials and Methods: We studied patients undergoing surgery for CSM in the prospective QOD CSM module who received a sub-axial fusion of 3 or 4 segments with VAS-neck pain of 7 or greater at baseline. Twelve-month outcomes were compared for those undergoing ACDF versus PCF.

Results: We compared 73 patients (58.4%) undergoing ACDF and 52 patients (41.6%) undergoing PCF.

Preoperatively, ACDF were younger (57.8±9.5 vs. 64.8±10.3 years;p<0.001) and more often presented with arm weakness (37.0% vs.15.4%;p=0.008) and radicular pain (64.4% vs. 42.3%;p=0.01). ACDF were more often employed or employed and on leave (49.3% vs. 21.2%;p=0.001). ACDF had worse NDI at baseline (52.7±15.1 vs. 47.0±16.6;p=0.047) but similar neck pain (p>0.05). Otherwise, groups were well matched for remaining baseline patient-reported outcomes and covariates. Both groups demonstrated improvements in all outcomes at 12 months (p<0.05). In multivariable analyses, ACDF was associated with greater NDI improvement (ß=-14.7; 95%CI[-2.8— -26.7];p=0.02), EQ-5D improvement (ß=0.17; 95%CI[0.02-0.32];p=0.03), mJOA improvement (ß=2.4; 95%CI[0.5-4.4];p=0.02), and higher NASS Satisfaction (OR=5.1;95%CI[1.4-18.0];p=0.01). There was no significant difference in the ability of either procedure to improve neck pain or arm pain in adjusted analyses (p>0.05). There were no differences in 3-month readmission and 12-month reoperation rate, return to work or baseline activities (p>0.05).

Conclusion: Compared to PCF, multilevel ACDF was associated with superior disability, quality of life, functional status, and satisfaction 12 months following 3- or 4-segment surgery for CSM in patients with severe neck pain. Approach was not associated with postoperative neck pain or arm pain. Both multilevel ACDF and PCF were associated with significant 12-month improvements in neck pain, arm pain, disability, quality of life (QoL), and functional status.

E-POSTER #15 continued

Table 1. Characteristics of patients	ACDF (n = 73)	PCF (n = 52)	*p* value
Age (years), mean ± SD	57.8 ± 9.5	64.8 ± 10.3	<0.001**
Female, n (%)	38 (52.1)	22 (42.3)	0.28
BMI, mean ± SD	29.9 ± 6.5	29.9 ± 5.7	0.98
Smoker, n (%)	16 (21.9)	9 (17.3)	0.53
Comorbidities, n (%)			
Diabetes Mellitus	19 (26.0)	12 (23.1)	0.71
Coronary Artery Disease	11 (15.1)	4 (7.7)	0.21
Anxiety	18 (24.7)	14 (26.9)	0.77
Depression	19 (26.0)	19 (36.5)	0.21
Caucasian Race, n (%)	56 (76.7)	32 (61.5)	0.07
4 or more years of college level education, n (%)	15 (20.5)	13 (25.0)	0.56
Employed or employed and on leave, n (%)	36 (49.3)	11 (21.2)	0.001**
Presenting Symptoms, n (%)			
Arm Weakness	27 (37.0)	8 (15.4)	0.008**
Arm Pain	47 (64.4)	22 (42.3)	0.01**
Arm Numbness	55 (75.3)	33 (63.5)	0.15
Neck Pain	60 (82.2)	38 (73.1)	0.22
Motor Deficit, n (%)	47 (64.4)	34 (65.4)	0.91
Independently Ambulatory, n (%)	65 (89.0)	41 (78.8)	0.12
Symptom Duration, n (%)			0.08
< 12 months	29 (39.7)	29 (55.8)	
>12 months	44 (60.3)	23 (44.2)	
ASA grade, n (%)			0.84
1 or 2	31 (42.5)	23 (44.2)	
3 or 4	42 (67.5)	29 (55.8)	
Levels fused, mean ± SD	3.2 ± 0.4	3.5 ± 0.5	0.83
Fusions crossing the cervicothoracic junction, n (%)	--	4 (7.7)	--
mJOA, baseline, mean ± SD	11.6 ± 2.5	11.0 ± 3.1	0.27
VAS Neck Pain, baseline, mean ± SD	8.4 ± 1.1	8.1 ± 1.0	0.11
VAS Arm Pain, baseline, mean ± SD	6.9 ± 2.7	6.7 ± 3.0	0.62
NDI, baseline, mean ± SD	52.7 ± 15.1	47.0 ± 16.6	0.047**
EQ-VAS, baseline, mean ± SD	54.6 ± 19.5	52.3 ± 22.5	0.54
EQ-5D, baseline, mean ± SD	0.46 ± 0.19	0.45 ± 0.19	0.81

**** denotes a significant difference with p-value < 0.05.**

E-POSTER #15 continued

Table 2. Perioperative outcomes	ACDF (n = 73)	PCF (n = 52)	*p* value
Estimated Blood Loss (ml), mean ± SD	89.5 ± 101.4	189.4 ± 313.7	0.01**
Length of Hospitalization (days), mean ± SD	2.1 ± 1.7	4.6 ± 4.8	<0.001**
Discharge Disposition			<0.001**
Home or Home Health Care, n (%)	68 (93.2)	32 (61.5)	

**** denotes a significant difference with p-value < 0.05.**

E-POSTER #15 continued

Table 3. Univariate comparison of clinical outcomes	ACDF (n = 73)	PCF (n = 52)	*Unadjusted p* value
mJOA, 12 months, mean ± SD	14.0 ± 3.0	12.2 ± 3.9	0.01**
mJOA, 12-month change, mean ± SD	+2.4 ± 3.6	+0.8 ± 3.6	0.04**
VAS Neck Pain, 12 months, mean ± SD	3.8 ± 3.1	4.7 ± 3.3	0.18
VAS Neck Pain, 12-month change, mean ± SD	-4.6 ± 3.2	-3.3 ± 3.4	0.06
VAS Arm Pain, 12 months, mean ± SD	2.6 ± 2.9	4.1 ± 3.3	0.03**
VAS Arm Pain, 12-month change, mean ± SD	-4.1 ± 3.6	-2.0 ± 4.3	0.01**
NDI, 12 months, mean ± SD	26.9 ± 20.9	33.6 ± 23.2	0.15
NDI, 12 month-change, mean ± SD	-26.4 ± 22.2	-12.7 ± 24.0	0.006**
EQ-VAS, 12 months, mean ± SD	67.2 ± 22.4	62.6 ± 26.4	0.38
EQ-VAS, 12-month change, mean ± SD	+10.5 ± 24.8	+13.1 ± 32.4	0.67
EQ-5D, 12 months, mean ± SD	0.70 ± 0.21	0.62 ± 0.23	0.09
EQ-5D, 12-month change, mean ± SD	+0.24 ± 0.20	+0.13 ± 0.28	0.03**
NASS Satisfaction, 12 months, mean ± SD			0.19[1]
1	22 (66.7)	14 (50.0)	
2	7 (21.2)	7 (25.0)	
3	1 (3.0)	0 (0)	
4	3 (9.1)	7 (25.0)	

**** denotes a significant difference with p-value < 0.05. [1] Comparing NASS 1 and 2 versus 3 and 4**

E-POSTER #16

Three-dimensional reduction method with a modified C2 isthmus screw in irreducible atlantoaxial dislocation: a technical note

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Introduction: Cervical spinal cord compression caused by irreversible atlantoaxial dislocation (IAAD) often leads to paralysis, even threaten the life of patients. The anatomical reduction is the key to relieve spinal cord compression. But the reduction would be failed if only anteroposterior reduction was paid attention without the correction of vertical and angulated dislocation. So, the three-dimensional reduction plays a vital role in surgical reduction. However, at present, the most commonly used combination of C1 pedicle screw (PS) or lateral mass screw (LMS) and C2 PS or isthmus screw in the posterior approach often fails to achieve satisfactory reduction at one time. The difficulty during surgical reduction of IAAD is usually caused by short anteroposterior and vertical distance between heads of C1 and C2 screws, which lack enough space for reduction operation. The objective of this study is to describe a three-dimensional reduction method with a modified C2 isthmus screw and to illustrate its advantage and effectiveness for IAAD. No studies to date have reported the details and outcomes on this technique.

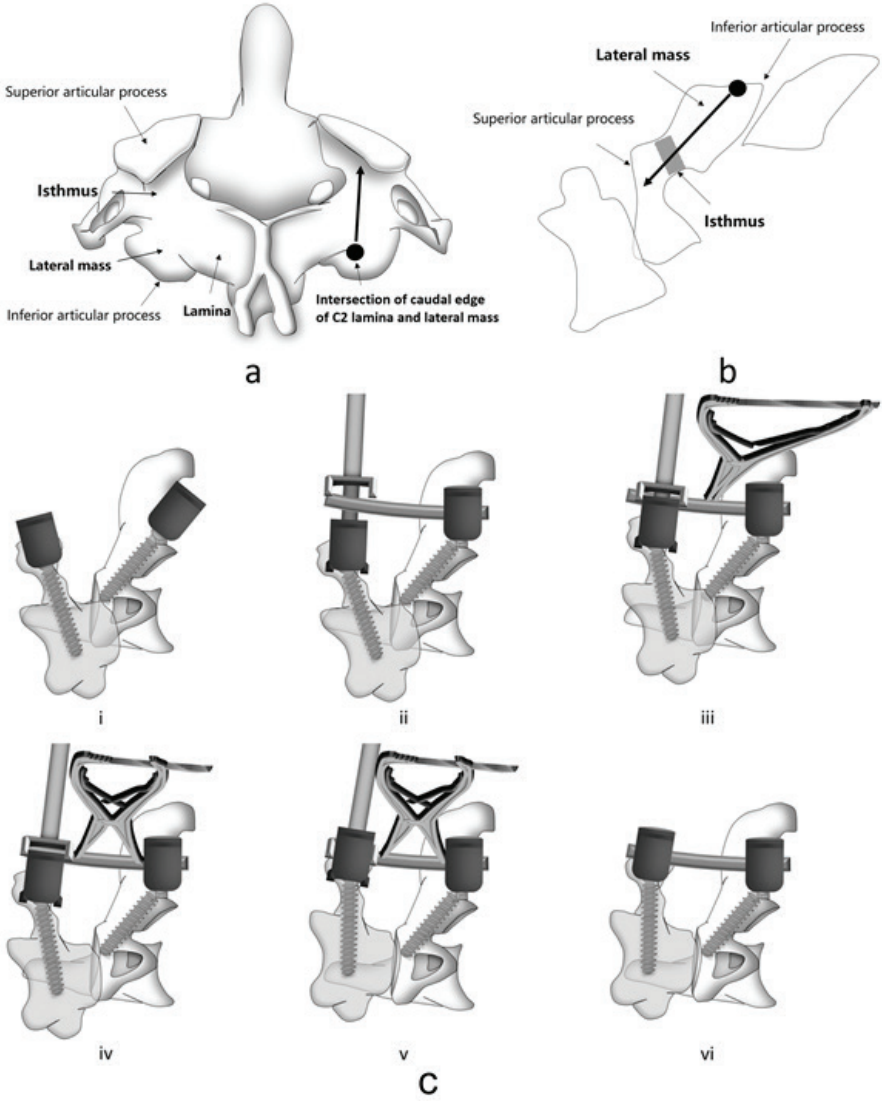
Materials and Methods: Clinical data of twelve patients with IAAD were retrospectively analyzed. All the patients underwent skull traction under the electrocardiograph monitoring before the surgery. All the patients underwent reduction and fixation with modified C2 isthmus screw combined with C1 pedicle screw (PS) or lateral mass screw (LMS), fusion with autologous bone graft. The insertion point was lateral to the intersection of caudal edge of C2 lamina and lateral mass, with a trajectory towards C2 isthmus, via lateral mass (Fig. 1a). The anterior wall of C2 lamina and superior articular surface of C2 should not be injured or perforated (Fig. 1b). Through the pulling and distracting operation, the reduction of anteroposterior and vertical dislocation was achieved at the same time, and angulated dislocation and cross-sectional rotation was completed simultaneously to finish three-dimensional reduction (Fig. 1c). Radiographic evaluation included anteroposterior and direct distance between different insertion points (Fig. 2), the occipitoaxial angle (O-C2A), clivus-canal angle (CCA) and cervicomedullary angle (CMA). Clinical outcomes evaluation included the Japanese Orthopaedic Association (JOA) score, Visual analog scale (VAS) and Neck Disability Index (NDI).

Results: The mean duration of follow-up was 62.2 months (range from 12 months to 95 months). All the patients achieved and maintained effective three-dimensional reduction during the follow-up (Fig. 3). The anteroposterior and direct distance was significantly higher in modified C2 isthmus screw than C2 PS whether combined with C1 PS or LMS ($P<0.05$). The degree of O-C2A, CCA and CMA, JOA score, NDI, and VAS were significantly improved after the surgery ($P<0.05$). There were no cases of neurological injury, vertebral artery injury and hardware failures.

Conclusion: Three-dimensional reduction method with a modified C2 isthmus screw is effective and safe in managing IAAD. It can increase the anteroposterior and vertical distance between the heads of C1 and C2 screws, which is benefit for the three-dimensional reduction operation of AAD shown as anteroposterior, vertical, and angulated dislocation in the sagittal

E-POSTER #16 continued

plane, especially for irreducible cases.



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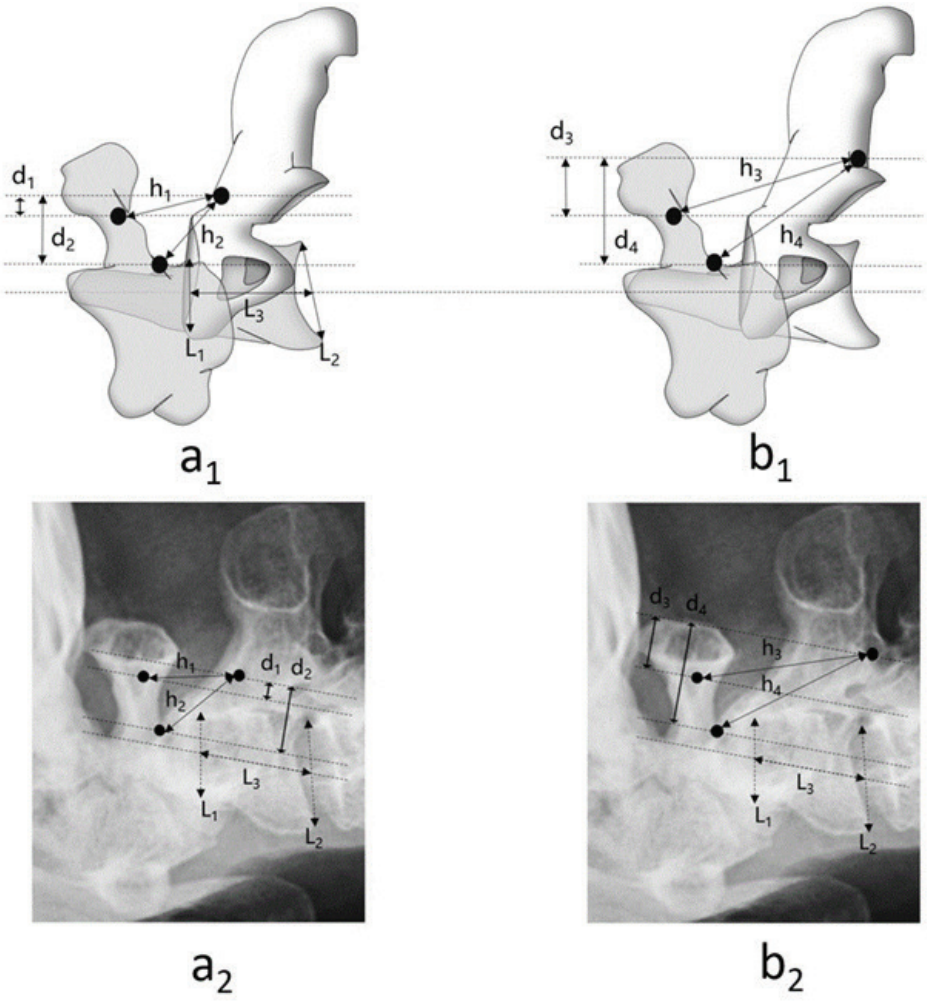

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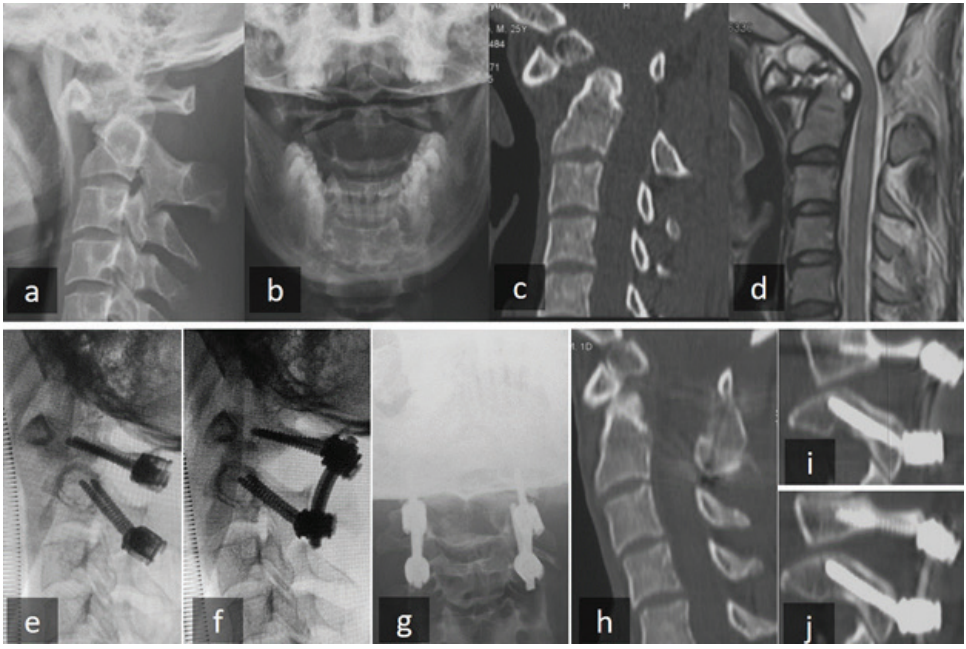

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E-POSTER #17

Measurement of cervical range of motion by Comprehensive Musculoskeletal Analysis System: Repeatability and reliability analysis

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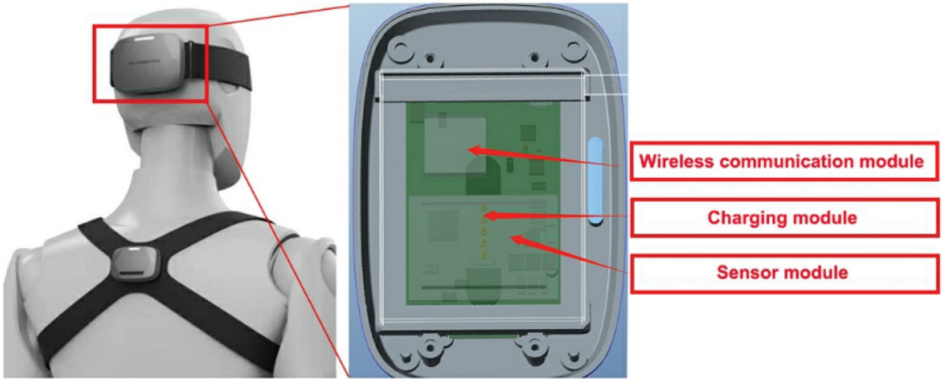
Introduction: To propose a new method of measuring the cervical range of motion (ROM) by Comprehensive Musculoskeletal Analysis System (CMAS), and investigate the repeatability and reliability.

Materials and Methods: he patients with neck or shoulder pain in the spine surgery clinic of our hospital were included. The ROM of the cervical spine was measured by CMAS and the dynamic image of DSA. 50 patients were measured with CMAS (Group A). There were 28 males and 22 females, aged from 20 to 68 years, with an average of 45.1 ±13.8 years old. 15 patients were also measured with dynamic x-ray (DSA, digital subtraction angiography) images (Group B). There were 8 males and 7 females, aged from 21 to 68 years, with an average age of 46.1 years old. The measurement results of the two groups were compared and correlation analyzed. Intra-observer and inter-observer consistency of Group A were analyzed. The two methods' reliability was analyzed using Standard error of measurement (SEM) and minimum detectable change (MDC).

Results: There was no significant difference in demographic dates between the two groups ($P > 0.05$). And there was no significant difference between the two methods in different gender and age groups ($P > 0.05$). Intra-observer consistency analysis of Group A showed high degree, ICC = 0.947, 95% CI (0.763, 0.980), $P < 0.01$. Inter-observer consistency analysis also showed high degree, ICC = 0.899, 95% CI (0.799, 0.947), $P < 0.01$. For Group A, SEM and MDC were 3.0 ° and 6.9 ° respectively, and SEM and MDC were 1.8 ° and 4.1 ° respectively for Group B. Correlation analysis showed that the two methods had significant correlation ($P < 0.01$), and the correlation coefficient was 0.758. Bland Altman's analysis showed that the average difference between the two methods was 0.29 °. The BlandAltman plots demonstrated that most of the data were within the 95% consistency limit.

Conclusion: The measurement of cervical ROM with CMAS has good repeatability and reliability and is an effective method for measuring cervical ROM.



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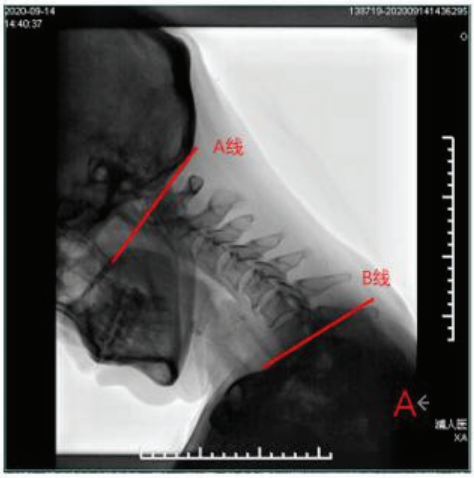

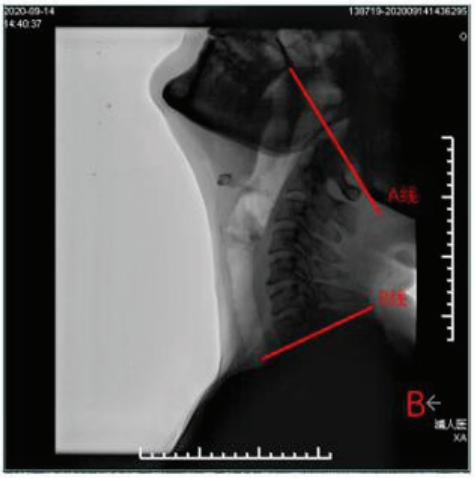

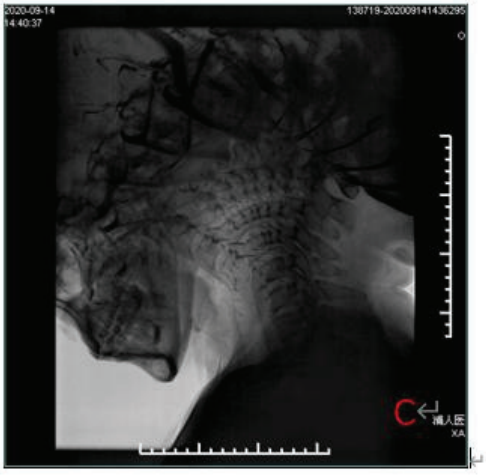

E-POSTER #18

Periprosthetic bone loss after artificial cervical disc replacement: a radiographic study

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Introduction: To investigate the incidence of periprosthetic bone loss (PBL) after artificial cervical disc replacement (ACDR), and analyze the imaging characteristics of PBL during the follow-up period.

Materials and Methods: 67 patients treated by ACDR from January 2009 to August 2016 were retrospectively reviewed. There were 38 males and 29 females with an average age of 41.4 ± 6.1 years. The mean follow-up time was 88.6 ± 14.5 months. There were 41 patients with cervical spondylotic myelopathy, 21 patients with cervical spondylotic radiculopathy and 5 patients with cervical radiculomyelopathy. The incidence, classification, imaging characteristics of PBL and operation related complications were analyzed.

Results: The incidence of PBL increased with the increase of follow-up time. Incidence of PBL was 5.98%, 7.46%, 11.94%, 26.87% and 37.31% at 6 months, 1 year, 2 years, 4 years postoperatively and the last follow-up, respectively. At the last follow-up, PBL was observed at C3/4 in 3 cases, C4/5 in 7 cases, C5/6 in 11 cases and C6/7 in 4 cases. There were 12 cases of grade 1, 9 cases of grade 2 and 4 cases of grade 3 PBL. At the last follow-up, there were no significant differences in cervical ROM, segment ROM, T1S and Cobb angle between the two groups ($P > 0.05$). SVA in group A (PBL group) was significantly higher than that in group B (no PBL group) ($P = 0.02$). In the PBL group, the sagittal diameter and height of the upper vertebral body were significantly smaller than those of the lower vertebral body ($P = 0.02, 0.01$). There was no significant difference in hoarseness, dysphagia and spontaneous fusion between the two groups. The incidence of axial pain in group A was significantly higher than that in group B ($P = 0.02$).

Conclusion: PBL is commonly observed after ACDR. Most of the PBL is grade 1-2, and PBL in the upper vertebral body usually more serious. The incidence of axial pain is higher in patients with PBL.

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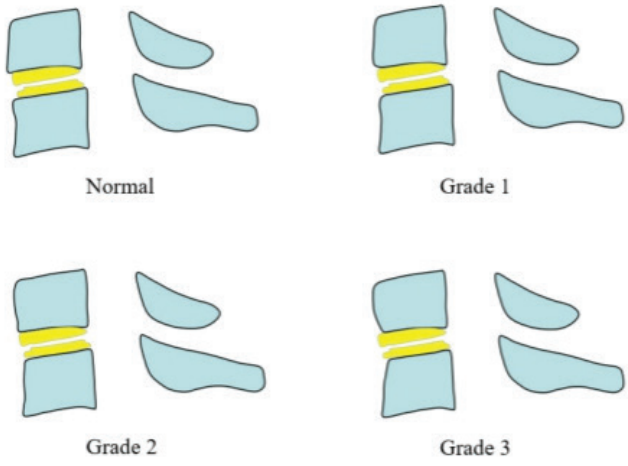

Figure 1 Classifcation and grading system for bone loss after cervical arthroplasty

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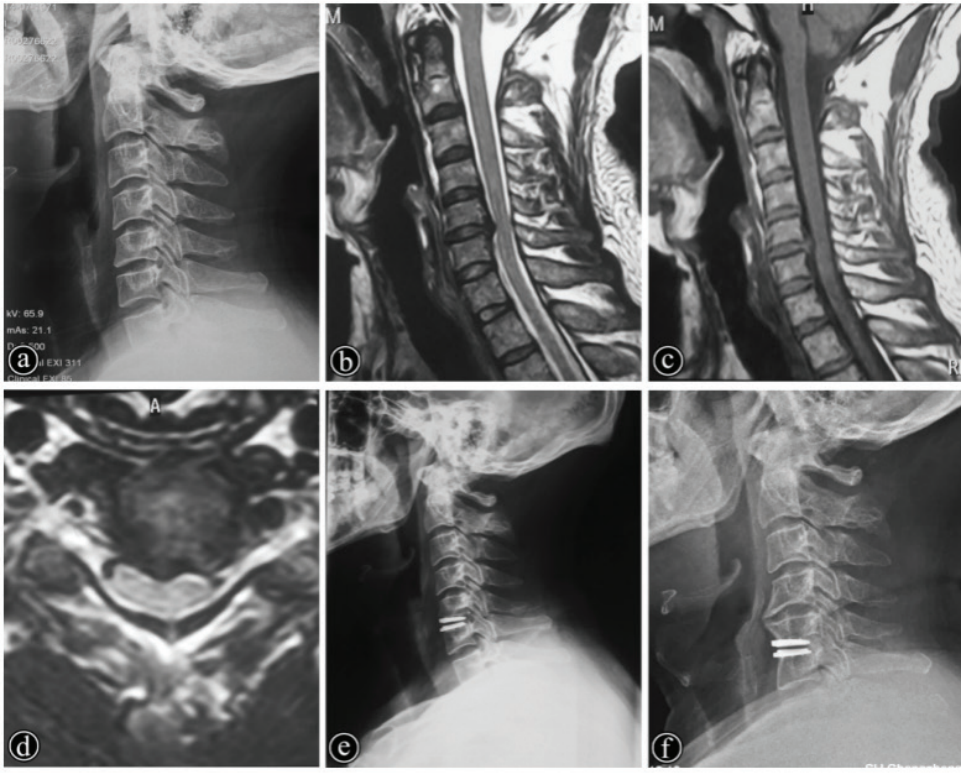

Figure 5 A 41 year old male patient with cervical spondylotic myelopathy **a** Preoperative cervical lateral X-ray **b,c,d** Preoperative MRI showed C5/6 disc herniation, spinal cord compression **e** postoperative cervical lateral X-ray **f** 7-year follow-up, cervical lateral X-ray showed grade 3 PBL.

E-POSTER #18 continued

Table 1. Demographic data comparison between the two groups

	Group A (n= 25)	Group B (n=42)	t/χ^2	P
Sex (M/F)	15/10	24/18	0.05	0.82
Age (years)	40.6±5.8	41.9±6.2	0.81	0.42
Pre-operation duration (month)	13.4±6.3	11.0±7.1	1.39	0.17
Diagnosis			0.47	0.79
CSM	14	27		
CSR	9	12		
CSM and CSR	2	3		
Surgical level			0.03	1.00
C3/4	3	5		
C4/5	7	11		
C5/6	11	19		
C6/7	4	7		
Follow up (month)	90.5±16.7	87.4±13.2	0.84	0.40

Table 2. Radiographic parameters comparison between the two groups

	Group A (n= 25)	Group B (n=42)	t	P
Cervical ROM	42.0±7.3	44.2±6.4	1.29	0.20
Surgical level ROM	5.3±1.9	5.0±1.6	0.88	0.38
Sagittal parameters				
T1S	24.1±5.2	25.1±5.3	0.78	0.44
Cobb angle	13.6±2.9	14.3±3.3	0.81	0.42
SVA	24.1±9.6	19.4±6.6	2.34	0.02

Table 3. Radiographic parameters comparison of the upper and lower adjacent vertebral bodies

	Upper adjacent vertebral bodies	Lower adjacent vertebral bodies	t	P
Sagittal diameter of endplate	18.4±0.8	18.6±0.9	2.5	0.02
vertebral height	14.4±0.9	14.5±0.9	2.8	0.01

Paired t test was used.

Table 4. Complications comparison between the two groups

	Group A (n= 25)	Group B (n=42)	P value
Hoarseness	3	5	1.00
Dysphagia	1	2	1.00
Axial pain	5	1	0.02
Spontaneous fusion	1	2	1.00

Fisher's exact test was used.

E-POSTER #19

Risk factors of subaxial intervertebral disorder after occipitocervical or atlantoaxial fusions in rheumatoid arthritis

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Introduction: Progressive cervical spine instability in the patient with rheumatoid arthritis (RA) has the potential to result in pain, disability, myelopathy, neurologic deficit and even sudden death. Atlantoaxial subluxation (AAS) is the most common manifestation followed by subaxial subluxation (SAS) and vertical subluxation (VA) into the foramen magnum. Although surgical intervention such as occipitocervical fusion (O-C fusion) or posterior atlantoaxial fusion (C1-2 fusion) has proved to be successful for stabilization of AAS and VA, incidence and development of disc degeneration lead to SAS has often observed following initial arthrodesis. The purpose of the present study was to identify the patients at risk of SAS who have undergone O-C2 or C1-2 fusion.

Materials and Methods: Twenty-eight patients who had undergone surgery since 2006 were retrospectively reviewed. There were 18 women and 1 man with a mean age of 63.6 years. The mean follow-up period after surgery was 4.4 years. Seventeen patients underwent O-C2 fusion and eleven patients underwent C1-2 fusion for AAS. There was no patient who had SAS before surgery. The patients were divided into O-C2 or C1-2 fusion groups to evaluate for RA duration, blood test data, radiographic parameters, and use of Disease Modifying Anti-Rheumatic Drugs (DMARDs). The radiographic parameters investigated were atlantodental interval (ADI), Redlund-Johnell value, occipitoaxial angle (O-C2 angle), atlantoaxial angle (C1-2 angle) and subaxial alignment (C2-C7 angle) before surgery, immediately after surgery and at the final examination.

Results: The duration of the disease was 22.8±7.5 years in the O-C2 fusion group and 20.8±10.2 years in the C1-2 fusion group. There was no difference in preoperative blood test data between the two groups. Biological DMARDs (bDMARDs) were used in three cases in each of the O-C2 and C1-2 fusion groups; cases without bDMARDs were treated with conventional synthetic DMARDs (csDMARDs). Four cases of SAS occurred in the O-C2 group and none in the C1-2 group. No reduction in the incidence of SAS was observed with preoperative use of bDMARDs. The C2-7 angle decreased immediately after surgery in both groups, and showed a gradual decrease during the course of the study in the O-C2 fusion group, but not in the C1-2 fusion group.

Conclusion: SAS occurred only in O-C2 group. This was attributed to the fact that the mobility between O-C1 was left intact, resulting in less mechanical load on the caudal cervical spine. In addition, several previous reports have suggested that the loss of cervical lordosis leads to the development of SAS, and a similar trend was observed in the series investigated in this study. In addition, the number of cases in which bDMARDs have been introduced has been increasing in recent years, but we could not confirm any suppression of the occurrence or progression of subaxial subluxation in cases in which bDMARDs were used preoperatively in this study. In general, many cases of SAS occur after AAS or VS, and we believe that adequate control of RA before AAS or VS occurs is important not only for conservative treatment but also for surgical treatment.

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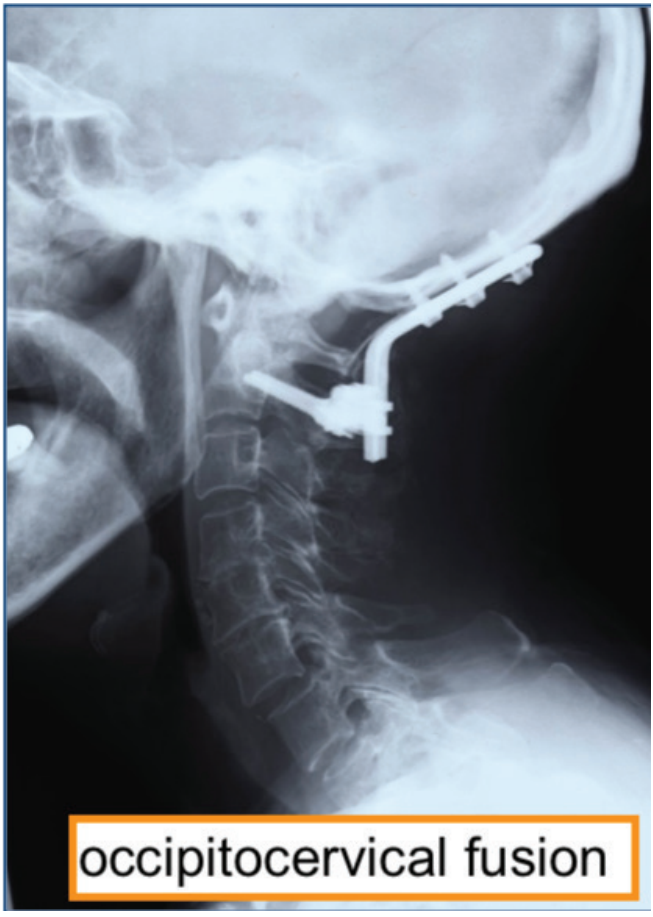

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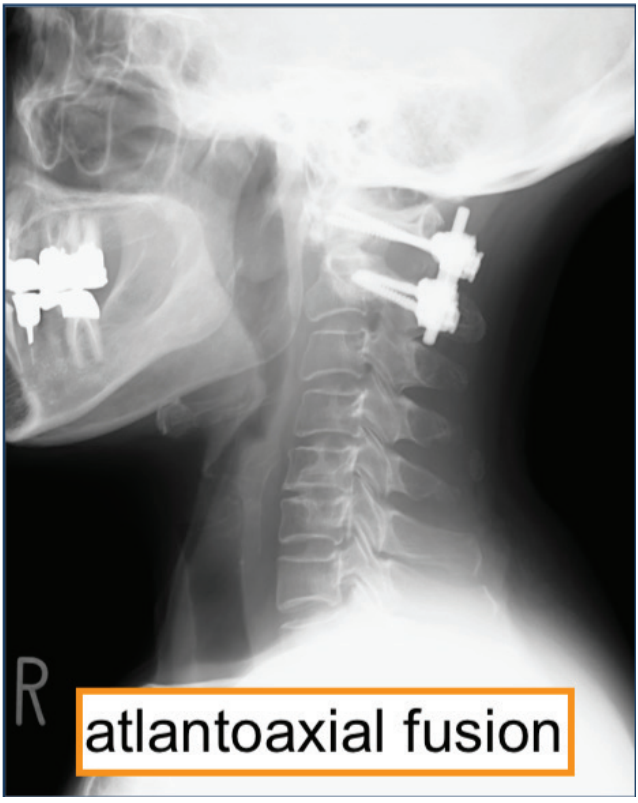

E-POSTER #20

Metal-On-Metal versus Metal-On-Plastic Artificial Discs in Two-Level Anterior Cervical Disc Replacement: A Meta-Analysis with Follow-Up of 5 Years or More

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Introduction: Despite positive clinical outcomes, accelerated rates of ASD in ACDF, especially in two-level surgery, has led spinal surgeons to increasingly use ACDR as an alternative. However, long-term success rates are still being investigated, and may be limited by the material properties of the device utilized. The use of metal-on-metal (MoM) bearings in total joint arthroplasty, for example, has been shown to significantly decrease volumetric wear rates, but subsequent complications associated with metallosis have prompted a shift towards utilizing metal-on-plastic (MoP) or ceramic implants instead. Although highlighted in joint arthroplasty studies, long-term outcomes between differing biomaterial composites in ACDR have not been thoroughly investigated. The purpose of this study was to evaluate the patient-reported clinical outcomes, overall reoperation rates, complications, and rates of ASD of MoM versus MoP artificial discs in two-level ACDR for the treatment of cervical DDD.

Materials and Methods: A systematic search of three electronic databases (PubMed, CINAHL Plus, and SCOPUS) was conducted utilizing terms related to two-level ACDR. All studies included had a sample size of >10 patients, minimum 5-year follow-up, and reported data on ASD. Cadaver studies, non-English manuscripts, articles with less than 5-year follow-up and studies in which only single-level ACDR was investigated were excluded. A total of 7 studies were included in this analysis. Studies were analyzed for demographic data, clinical outcome scores (NDI, VAS-neck, and VAS-arm), overall reoperation rates, complications, and rates of ASD. A random-effects model of meta-analysis was used for groups that were determined to be heterogenous and a fixed-effects model was utilized for groups that were not. An overlap of 95% confidence intervals suggests no statistically significant difference at the $p<0.05$ level.

Results: Seven studies were included with data on 980 patients (442 MoM, 538 MoP). The study population was 52.84% female, with a mean age of 48.01 years, and a mean follow-up of 85.66 months. The mean improvement in NDI was 34.42 (95% CI, 32.49-36.36) and 29.72 (95% CI, 27.15-32.29) for the MoM and MoP groups, respectively. The mean improvement in VAS-neck was 11.20 (95% CI, 10.69-11.70) and 8.78 (95% CI, 7.81-9.74) for the MoM and MoP groups, respectively. The mean improvement in VAS-arm was 10.73 (95% CI, 9.83-11.63) and 8.49 (95% CI, 7.59-9.39) for the MoM and MoP groups, respectively. 3.85% (95% CI, 2.40-6.10) of patients who underwent ACDR with a MoM implant required reoperation compared to 5.33% (95% CI, 3.68-7.65) of patients with a MoP implant. Heterotopic ossification and dysphagia were the most common complications in both groups. The MoM cohort showed a higher incidence of HO (72.62% vs. 21.07%), but a lower incidence of dysphagia (0.96% vs 16.31%) compared to the MoP cohort. The MoM cohort had a larger proportion of patients with ASD who underwent subsequent surgery at an adjacent level (7.89% MoM versus 1.91% MoP).

Conclusion: Our present meta-analysis suggests that the use of MoM artificial discs in two-level ACDR results in superior clinical outcome score improvement, but higher rates of ASD requiring secondary surgery compared to MoP discs after a follow-up period of 5 years or more.

E-POSTER #20 continued

Table 1. Characteristics of included studies

Study	Year	Device Type	Study Type	Sample Size	Mean F/u, mo	Mean age, y	Male/Female (%)	Level of Evidence
Gornet *et al*[7]	2019	MoM	Prospective RCT	209	120	47.1	44/56	II
Gao *et al*[11]	2018	MoM	Retrospective	24	66	54.7	62.5/37.5	III
Lanman *et al*[13]	2017	MoM	Prospective RCT	209	84	47.1	44/56	II
Yang *et al*[12]	2018	MoP	Prospective RCT	48	81	51.3	57.9/42.1	II
Radcliff *et al*[9]	2017	MoP	Prospective RCT	225	84	45.3	50.2/49.8	II
Jackson *et al*[14] *	2016	MoP	Prospective RCT	234	60	-	50.2/49.8	II
Lei *et al*[10]	2016	MoP	Retrospective	31	105	42.6	48.4/57.1	III

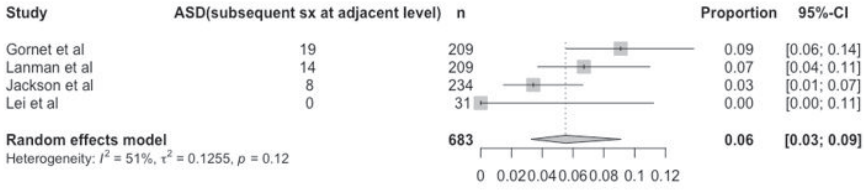
RCT= Randomized control trial; F/u= Follow-up; MoM= metal-on-metal; MoP= metal-on-plastic

*Jackson *et al* reported an age range for their patient cohort (18-69 years)

Table 2. Reoperation, Total Complications and ASD Proportions of MoM and MoP Cohorts

	MoM Proportion (%)	MoM 95% CI	MoP Proportion (%)	MoP 95% CI
Reoperation	3.85	(2.40-6.10)	5.33	(3.68-7.65)
Total Complications	5.43	(3.67-7.97)	1.68	(0.27-9.78)
ASD (CASP)	7.89	(5.67-10.90)	1.91	(0.96-3.78)

MoM= metal-on-metal; MoP= metal-on-plastic; ASD= adjacent segment disease; CASP= clinical adjacent segment pathology



E-POSTER #21

Myelopathic versus radiculopathic patients undergoing cervical spine surgery: Patient factors impacting baseline motor evoked potentials (MEPs)

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Introduction: When preoperative responses of intraoperative neuromonitoring (IONM) cannot be obtained, the value of IONM is marginalized as any intraoperative clinical decisions made do not have adequate baseline comparisons. While there is a known association with baseline MEPs and anesthetic regimen as well as preoperative motor strength, less is known regarding associations with other patient factors. The purpose of this study was to determine the association of past medical history, demographic, and patient-reported symptom variables with attainability of baseline MEPs for patients with myelopathy or radiculopathy.

Materials and Methods: Demographic data, past medical history, and patient reported outcome measures were retrospectively obtained. Patient reported outcome measures included mental (MCS-12) and physical (PCS-12) health components of the SF-12, NDI, VAS Neck and VAS Arm pain scores, and mJOA. All surveys and data were collected preoperatively. Patients were separated into two cohorts based on the primary diagnosis of radiculopathy or myelopathy. Within each cohort, analyses were conducted to assess associations between demographics, past medical history, PROMs and baseline monitorability of MEPs using t-tests, Mann-Whitney U, and chi-square tests, as appropriate. Univariable and multivariable logistic regression models estimated the odds of having at least one unmonitorable MEP baseline.

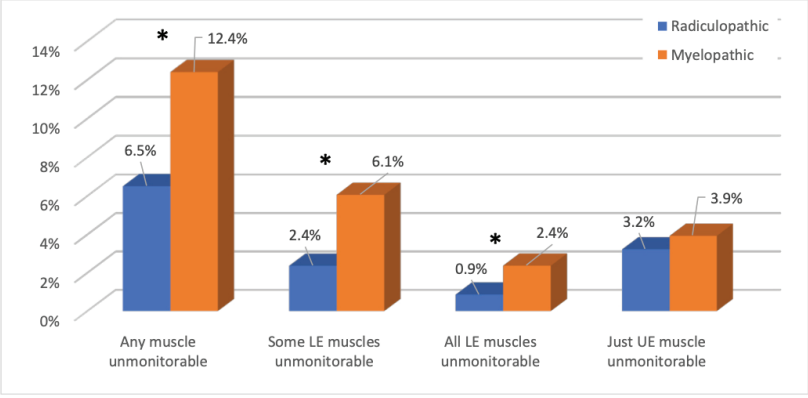
Results: A total of 2,532 patients were included for analysis. Multivariable logistic regression showed that peripheral vascular disease (OR 2.830 [1.274, 6.057], p=0.009), type II diabetes (OR 1.658 [1.55, 2.358], p=0.005), and high blood pressure (OR 1.406 [1.016, 1.947] p=0.040) were the only comorbidities independently associated with increased odds of unmonitorable baseline MEPs from one or more muscles. A primary diagnosis of myelopathy, age, and sex were the only patient factors significantly associated with unmonitorable baseline MEPs. A history of thyroid disorder was inversely related to having unmonitorable MEPs at baseline. For both diagnostic cohorts, unmonitorable baseline MEPs from the lower extremities were significantly associated with lower (worse) preoperative scores on the MJOA lower extremity motor function questions (radiculopathy cohort: 4.0 [3.0, 7.0] versus 7.0 [5.0, 7.0], p=0.004; myelopathy cohort: 4.0 [4.0, 7.0] versus 6.0 [4.0, 7.0] p<0.001). There was no other significant association between unmonitorable MEPs and other PROMs within the radiculopathic cohort. For the myelopathic cohort, unmonitorable MEPs were associated with significantly better VAS Neck pain, MCS-12, and NDI scores. Overall, myelopathic patients, were significantly more likely to have unmonitorable MEPs from any muscle (12.4% versus 6.5%, p<0.001), and from one or more lower extremity muscles (6.1% versus 2.4%, p<0.003) or all lower extremity muscles (2.4% versus 0.9%, p<0.001) in particular. For myelopathic patients with no reported lower extremity dysfunction and with no history of high blood pressure or type II diabetes, at least some

E-POSTER #21 continued

lower extremity MEPs were monitorable, and thus cord function was monitorable in >99% of patients.

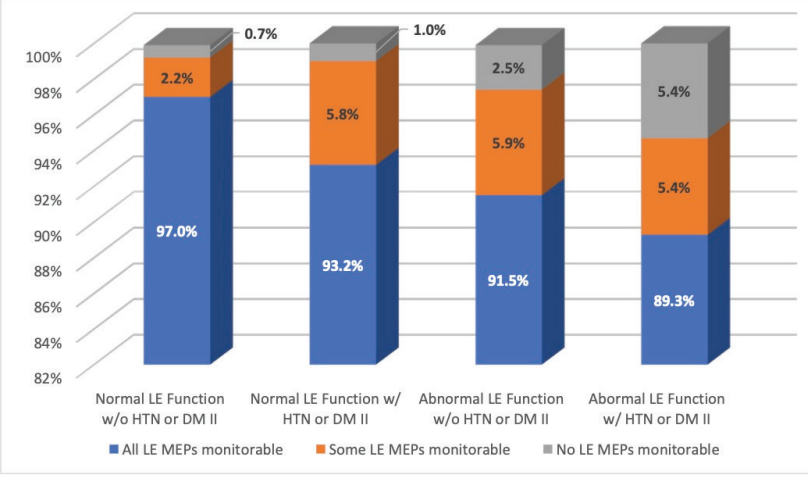
Conclusion: Unmonitorable baseline MEPs without significant weakness should be a relatively uncommon event, even in myelopathic patients. Myelopathic patients are more likely to have unmonitorable baseline MEPs due to the associated cord pathophysiology, but history of high blood pressure, vascular disease, or type II diabetes also further increases the odds of having unmonitorable baseline MEPs.

Figure 1. Baseline monitorability of MEPs in myelopathic (n=1,602) versus radiculopathic (n=930) patients. Patients undergoing surgery for myelopathy were significantly more likely to have at least one muscle unmonitorable compared to patients undergoing surgery for radiculopathy (OR 2.04 [1.52, 2.78]; $p<0.001$). Myelopathic patients were more likely to have some (OR 3.14 [1.46, 6.78]; $p<0.003$) or all (OR 2.92 [1.82, 4.67]; $p<0.001$) lower extremity (LE) muscles unmonitorable compared to patients with radiculopathy. There was no difference between the two groups in the rate of patients who presented only with unmonitorable MEPs of the upper extremity (UE).



E-POSTER #21 continued

Figure 2. Pattern of monitorable lower extremity (LE) MEPs for myelopathic patients. Comparison of patients who reported normal LE function on mJOA lower extremity questionnaire (score of 6-7) versus patients who reported some LE dysfunction (score of 0-5) broken down further into patients without a history of diabetes type II (DM II) or high blood pressure (HTN) versus patients with a history of DM II or HTN. The proportion of patients with all monitorable, some monitorable or no monitorable LE MEPs varied significantly across the four patient cohorts (p=0.004).



E-POSTER #22

Advanced Compressive Extension Injuries are Often Mistaken for Bilateral Jumped Facets

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Introduction: Advanced compressive extension (CE) injuries of the subaxial cervical spine were initially described in an article by Allen et al as failure of the posterior ring of the vertebral arch in association with compression of the subaxial cervical spine with extension of the neck. This mechanism can lead to fracture of the posterior arch, either unilaterally or bilaterally with or without subluxation of the body of the injured vertebrae. Bilateral jumped facets (BJF) in contrast occur in distractive flexion, i.e. the cervical spine is in a flexed position and the subaxial spine is distracted. For a patient with a compressive extension injury, if subluxation is present in the form of anterolisthesis, it can be difficult to distinguish this injury as compared to a patient with bilateral jumped facets even though there is a completely different mechanism to the injury. The key difference in fracture morphology, namely a lamina fracture, may lead to a difference in neurologic outcome between the two types of injury. The current study hypothesizes that the initial neurologic function between the two injuries is significantly different and defines an easily measurable radiographic parameter to help identify the difference on initial sagittal CT scan.

Materials and Methods: IRB Approval was obtained to look for patients with advanced compressive extension injuries and bilateral jumped facet injuries. Demographic data, ASA, ASIA, and complications were collected from the patients' charts. CT scans were reviewed to assess injury pattern, anterolisthesis, and spinal canal diameter. Injuries were classified according to the Allen classification. The means of each variable were analyzed using descriptive statistics and compared between the two groups using student t tests.

Results: The CE injury group had an average age of 55 years, was 81% male. The BJF group had an average age of 42 years, 67% male. Anterolisthesis was similar between the CE and BJF groups (7.1mm vs 7.4mm, p=0.06). 17% of patients in the CE group presented as an ASIA grade A, as compared to 60% of patients in the BJF group who presented as an ASIA A grade, which is significantly different ($p<0.001$). The canal diameter at the injured level was significantly different between the CE and the BJF groups (21.1mm vs 9.7mm, $p<0.001$). Thirty percent of patients in the advanced CE group had complications, none of which included postoperative spinal malalignment, nonunion or hardware-related complications, or worsening of neurologic exam and three deaths occurred in the postoperative hospitalization period (7 to 15 days). Six percent of patients in the BJF group had complications all related with segmental instability and need for further operative stabilization.

Conclusion: CE injuries of the subaxial cervical spine present with a widened canal diameter at the level of the injury as compared to bilateral jumped facets and have significantly better ASIA grade on presentation as compared to patients with bilateral jumped facets. The canal diameter, interpreted as the space available for the spinal cord, increased with compressive extension injuries, likely explaining these findings.

E-POSTER #23

Cervical Deformity Score: A Composite Alignment Tool to Optimize Outcomes while Mitigating Complications for CSRS

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Introduction: Cervical alignment and Cervical deformity surgery are complex topics. Recently, a score inspired by work on thoracolumbar alignment was developed for cervical alignment (Cervical Deformity Score, CDS). While this score was designed to predict early mechanical failures, its association with patient reported outcomes (PROM) remains unclear. The purpose of this study was to investigate the association between PROM, complications, and a newly described Cervical Deformity Score.

Materials and Methods: Cervical Deformity (CD) patients with a minimum of 1-year radiographic and clinical follow-up were investigated. Post-operative CDS was constructed using offset from age-adjusted values: SVA [(age -55)*2+25], T1 Slope [(age -55)/4 + 28.7], and TS minus CL [cst: between 26.5 and 14.5°]. Points were assigned based on the offset from alignment targets and the CDS was the sum of the three individual scores. Association with patient reported outcomes was investigated using Pearson's correlations. Comparison of CDS between patients with and without complication within 1-year was conducted. Logistical regression controlling for demographic and comorbidities was conducted to identify if CDS was an independent predictor of complications.

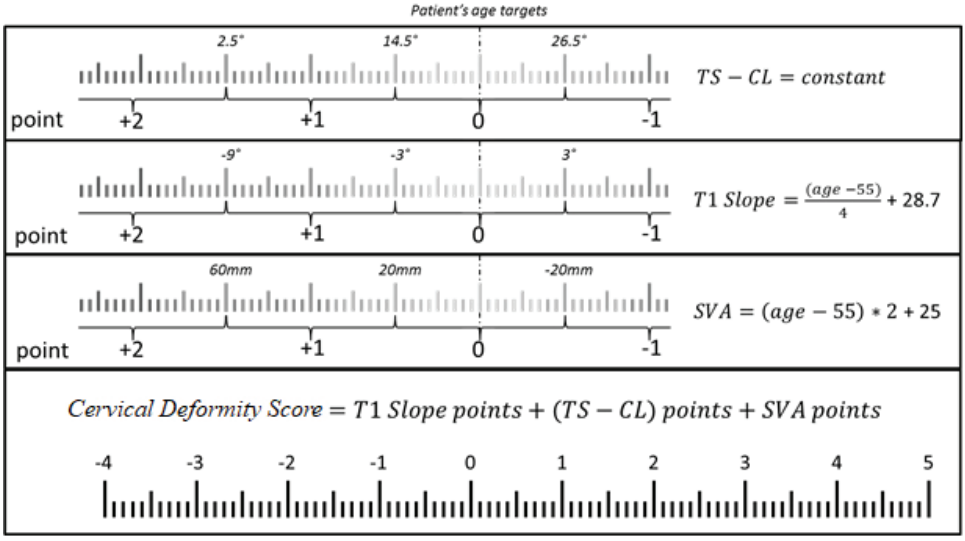
Results: 102 patients met inclusion criteria (61.7yo±10, 66.7% F); 37.6% of them had a history of previous cervical surgery (16.7% previous ACDF, 11.7% previous posterior fusion). Pre-operatively, they had elevated disability (NDI: 47.1±18.1), pain (NSR Neck: 6.6±2.5), myelopathy (mJOA: 13.6±2.7) and lower general health (EQ5D: 0.74±0.07). They also presented with an overall cervical kyphotic alignment (C2-C7: -6.3°±20.9), a moderate cervical anterior alignment (cSVA: 39mm±20; TS-CL: 37.9°±19.4) and a posterior global thoracolumbar alignment (SVA: -3mm±68). The median number of levels fused was 7 [4 9], with 49% treated with a posterior approach and 30.4% with a combined approach. 83.2% received an osteotomy, 44.6% posterior osteotomy, 16.8% grade 6 or 7. The mean Op Time was 368min±208, median EBL was 525cc [200 1025], and LOS was 5days [4 8].

At 1-year, patients improved significantly in terms of disability (NDI: 36.2±20.7, 60.8% reached MCID), pain (NSR: 4.1±2.9) and general health (EQ5D: 0.79±0.08) (all $p<0.001$). The cervical alignment significantly changed (C2-C7: 7.8±14.5m ; cSVA: 34mm±15 ; TS-CL: 28.9°±12.6 all $p<0.002$), with a 1- year CDS of 1.68±2.46 (prctl [0 3.25]). There was a significant association between increased CDS and increased disability ($r=0.273$), pain ($r=0.336$) and lower general health ($r=-0.283$). Patients with a lower disability level (NDI<20) had a significantly lower CDS (0.71±2.3 vs 2.16±2.4 $p<0.004$). Patients without any complications before 1- year had a lower CDS (0.78±2.33 vs 2.18±2.40 $p=0.005$), as did patients without major complications (1.36±2.27 vs 2.50±.78 $p=0.037$). Deeper analysis revealed significant differences in terms of CDS for patients experiencing cardiopulmonary, instrumentation and radiographic complications

E-POSTER #23 continued

(p<0.05). Multivariate analysis, controlling for age and comorbidities, showed 1-year CDS to be a significant predictor of complication (p=0.002, OR=1.409).

Conclusion: With better outcomes and lower complication rates, maintaining a proportionate alignment post-operatively can result in superior outcomes following CD surgery.



		N	Mean	StD	25th	50th	75th	p-value
Any Complication?	**No**	37	0.78	2.33	-1.0	0.0	3.0	0.0051
	Yes	65	2.18	2.4	1.0	2.0	4.0	
Major Complications?	**No**	74	1.36	2.27	0.0	2.0	3.0	0.0368
	Yes	28	2.5	2.78	0.3	2.5	4.0	
Post-op NDI > 20?	**No**	34	0.71	2.34	-1.3	1.0	2.3	0.0043
	Yes	68	2.16	2.39	0.0	2.0	4.0	

E-POSTER #24

The effects of individual's sex on the management and outcomes of individuals with acute traumatic spinal cord injury: The results of a series of propensity-score matched cohort studies

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Introduction: While few pre-clinical studies documented potential neuroprotective effects of estrogen and progesterone, there is no conclusive evidence on sex-related differences in outcomes after traumatic spinal cord injury (SCI). This study examined the potential effects of sex on injury epidemiology, management and outcomes after traumatic C1-L2 SCI using prospectively accrued data from a large Canadian database.

Materials and Methods: A series of propensity-score matched cohort studies was performed comparing the subgroups of females in premenopause (age< 40 years), females in perimenopause (41≥age≥50) and females in postmenopause (age>50), with the subgroups of males distributed similar age categories. In each subgroup analyses, females were matched on a 1:1 ratio to males using the propensity score matching on age at SCI onset, Charlson Comorbidity Index, and level and severity of SCI. Data for the studies were selected from the Rick Hansen Spinal Cord Injury Registry (RHSCIR) from April/2014 to September/2019 in Canada. Females were compared with males regarding injury epidemiology (i.e. mechanism of SCI, ethnicity, Glasgow coma score [GCS], Injury Severity Score [ISS]), management (i.e. direct transfer to a spine center, need for mechanical ventilation, use of skeletal traction, administration of Methylprednisone, surgical versus conservative treatment, time from injury to surgical decompression), and outcomes after SCI (i.e. length of stay [LOS] in the acute care and rehabilitation facilities, ASIA motor and sensory subscores, Functional Independence Measure subscores, discharge destination, and frequency of spasticity at discharge).

Results: Of the 7,196 cases included in the RHSCIR, 1,245 females and 4,334 males fulfilled the inclusion/exclusion for this study and were considered during the propensity-score matching process.

Among individuals younger than 40 years, females (n=320) more often were white (p=0. 0268) and had SCI due to falls or transportation-related accidents (p=0.0014) than males (n=320), but both subgroups were comparable regarding GCS and ISS. Both subgroups under 40 had comparable management except for females had more often surgical treatment (p=0.0326). There were no significant differences between females and males under 40 regarding outcomes.

Among individuals between 40 and 50 years of age, females (n=133) were comparable to males (n=133) regarding the other baseline data, management, and outcomes.

Among individuals older than 50 years, females (n=531) had more often fall-related SCIs than males (n=531). Females had shorter LOS in the rehabilitation facilities than males (p=0.0205). However, there were no significant differences between the subgroup of females and the subgroup of males regarding the other baseline data, management, and outcomes.

Conclusion: The results this series of propensity-score matched cohort studies suggest that sex was not a key determinant of the vast majority of clinical, neurological and functional

E-POSTER #24 continued

outcomes following traumatic C1-L2 SCI, when data analyses were controlled for major potential confounders. Of note, females older than 50 years had shorter LOS in rehabilitation facilities than their male counterparts in the same age group. Those results support the notion that male and female adults of any age subgroup should be included in future clinical trials on novel therapies for management of acute traumatic SCI, enabling recruitment and allowing broader generalizability of their results.

E-POSTER #25

Reduction in Postoperative Risk: One Surgeon's Evolution of Anterior Cervical Discectomy and Fusion

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Introduction: Risk for poorer outcomes following anterior cervical discectomy and fusion (ACDF) have previously been associated with non-modifiable factors.[1,2] One factor that is seldom considered is the progression of a surgeon's familiarity and proficiency with the procedure. Our study aims to determine the impact that a surgeon's surgical proficiency has on postoperative outcomes and complications following ACDF.

Materials and Methods: A surgical database was retrospectively reviewed to identify eligible cervical spine procedures from 2006 to 2018. Inclusion criteria was set as the first 115 and last 115 primary, elective, single level ACDF procedures performed either at the C5-6 or C6-7 level. To control for variations in comorbidities between populations, a propensity score match was performed prior to analysis. Demographic information, perioperative characteristics, and the immediate and longitudinal postoperative outcomes were recorded. Immediate postoperative outcomes were recorded as mean inpatient pain scores (Numerical Rating Scale; NRS), mean opioid consumption (measured as oral morphine equivalent; OME), and any medical complications. Longitudinal outcomes were recorded as 6-month pseudoarthrosis rates and 1-year arthrodesis rates. Demographic, perioperative, immediate and longitudinal postoperative outcomes were compared for differences among the 2 populations using either Chi-square analysis or a two-tailed t-test. Surgeon's experience as defined by years experience and number of cases was evaluated for associations with operative and postoperative outcomes using both multivariate regression and multivariate multiple regression.

Results: After inclusion and exclusion criteria were applied, 230 patients were identified as eligible, first 115 cases and most recent 115 cases. The study cohort had a mean age of 45.5 years, an average BMI of 28.9 kg/m2 and was 59.1% male. Case cohorts differed by BMI, CCI score, and insurance used (all $p<0.05$). No differences in medical comorbidities were demonstrated. Cases performed earlier in the surgeon's career were significantly longer, had higher EBL, longer LOS, and a larger proportion of patients discharged on a later postoperative date (all $p<0.001$). Surgical cases performed later in the surgeon's career had a higher proportion of patients with a myeloradiculopathy and central spinal stenosis (both $p=0.001$) (Table 1). Arthrodesis rates at 1-year did not differ between groups. NRS did not demonstrate significant differences between groups throughout the inpatient stay. Narcotic consumption was greater for earlier surgical cases on POD1 ($p<0.001$) (Table 2). Multivariate analysis demonstrated years of practice significantly influenced operative time, EBL, LOS, and date of discharge (all $p<0.001$). A similar finding was demonstrated for a number of cases performed (all $p<0.001$) (Table 3). Regression analysis evaluating both years experience and number of cases together demonstrated significant effects on operative time, EBL, LOS, and date of discharge (all $p<0.001$).

Conclusion: As a single surgeon's proficiency with single level ACDF increased, better operative characteristics and immediate postoperative outcomes were demonstrated. Both the

E-POSTER #25 continued

number of cases performed and years of experience were significant, modifiable mitigators of improved quality of ACDF procedures.

Table 1. Perioperative Characteristics

Characteristic	Total (n=230)	First 115 Cases	Last 115 Cases	*p-value
Spinal Pathology				
Degenerative Disc Disease	2.2% (5)	1.7% (2)	2.6% (3)	0.651
Central Stenosis	21.7% (50)	12.2% (14)	31.3% (36)	**0.001**
Herniated Nucleus Pulposus	93.5% (215)	95.7% (110)	91.3% (105)	0.422
Neuropathy				**0.001**
None	11.7% (27)	22.6% (26)	0.9% (1)	
Radiculopathy	26.1% (60)	40.0% (46)	12.2% (14)	
Myelopathy	1.7% (4)	2.6% (3)	0.9% (1)	
Myeloradiculopathy	60.4% (139)	34.8% (40)	86.1% (99)	
Operative Time (Mean ± SD; min)	59.5 ± 34.7	68.4 ± 45.9	50.4 ± 12.0	**<0.001**
Estimated Blood Loss (Mean ± SD; mL)	48.3 ± 49.5	67.5 ± 63.7	28.9 ± 9.7	**<0.001**
Length of Stay (Mean ± SD; hours)	20.6 ± 13.1	30.4 ± 8.9	10.7 ± 8.5	**<0.001**
Day of Discharge				**<0.001**
POD 0	40.0% (92)	0.0% (0)	80.0% (92)	
POD 1	54.8% (126)	89.6% (103)	20.0% (23)	
POD 2	4.8% (11)	9.6% (11)	0.0% (0)	
POD 3	0.4% (1)	0.9% (1)	0.0% (0)	

POD = postoperative day; SD = standard deviation
Boldface indicates significance

E-POSTER #25 continued

Table 2. Postoperative Outcomes

Outcome	First 115 Cases	Last 115 Cases	*p-value
1-year Arthrodesis Rate	91.2% (104)	95.4% (83)	0.249
Inpatient Pain (NRS)			
POD 0	4.8 ±1.5 (108)	4.5 ± 2.1 (106)	0.433
POD 1	3.8 ± 1.6 (110)	3.7 ± 1.3 (21)	0.721
POD 2	3.4 ± 1.9 (20)	3.0 ± 0.0 (1)	-
POD 3	2.2 ± 0.0 (1)	-	-
Inpatient Narcotics (OME)			
POD 0	47.7 ± 40.6 (111)	38.3 ±30.9 (114)	0.051
POD 1	29.3 ± 27.8 (115)	5.7 ± 13.6 (115)	**<0.001**
POD 2	37.5 ± 35.3 (11)	-	-
POD 3	0.0 (1)	-	-

VAS = Visual Analogue Scale; OME = oral morphine equivalent
*p-values calculated using two-tailed t-test (continuous) or chi-square (categorical)
Boldface indicates statistical significance

Table 3. Multivariate Analysis

	Years of Practice			Number of Cases			
	Coeff	95% C.I.	*p-value	Coeff	95% C.I.	*p-value	†p-value
Operative Time	-7.56	[-9.2, -5.9]	**<0.001**	-0.106	[-0.13, -0.08]	**<0.001**	**<0.001**
EBL	-18.8	[-23.6, -13.3]	**<0.001**	-0.291	[-0.36, -0.21]	**<0.001**	**<0.001**
LOS	-7.29	[-8.6, -5.9]	**<0.001**	-0.119	[-0.14, -0.10]	**<0.001**	**<0.001**
Discharge Date	-0.35	[-0.41, -0.29]	**<0.001**	-0.005	[-0.006, -0.005]	**<0.001**	**<0.001**
POD 0 Pain	0.00	[-0.23, 0.23]	0.996	-0.002	[-0.004, 0.003]	0.907	0.922
POD 0 OME	-2.04	[-6.6, 2.5]	0.379	-0.033	[-0.10, 0.03]	0.340	0.629
Complications	-0.28	[-0.07, 0.02]	0.249	-0.005	[-0.001, 0.001]	0.108	0.099

EBL = estimated blood loss; LOS = length of stay; OME = oral morphine equivalent
*p-values calculated using multivariate analysis
†p-value calculated using multivariate multiple regression analysis
Boldface indicates statistical significance

E-POSTER #26

Does Persistent Opioid Use Predict Healthcare Resource Utilization after Cervical Spine Surgery?

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Introduction: Persistent opioid use in patients undergoing elective spine surgery is known to be associated with various poor outcome measures. However, there is a lack of literature assessing the how patients with persistent opioid use other healthcare resources after surgery. The purpose of this study is to compare healthcare resource utilization between patients with and without persistent opioid use following elective cervical spine surgery.

Materials and Methods: Patients undergoing elective spine surgery between November 1, 2013 and September 30, 2018 at a single, tertiary academic center were prospectively followed for 12 months after surgery. Patients were split into two groups, those with and without persistent opioid use (defined as new opioid prescriptions after 180 days postoperatively). Differences in healthcare resource utilization in the first 365 days after surgery were collected and compared between the two groups. Healthcare resource metrics included cervical imaging studies, emergency department visits, urgent care visits, postoperative opioid prescriptions, epidural or other spinal injections, and pain management referrals at 90-, 180-, and 365-days postoperatively. Overall healthcare utilization was divided into three groups – low, moderate, high – based on tertiles.

Results: 139 patients were included in the final cohort. Twenty-nine patients had persistent opioid use at 180 days postoperatively. Patients with and without persistent opioid use had similar patient and surgical profiles – sex, age, body mass index (BMI), American Society of Anesthesiology (ASA) class, type of procedure, and the number of levels fused ($p>0.05$) (Table A). Notably, patients with persistent opioid use were found to have higher Charlson comorbidity indexes ($p=0.036$) (Table A). Healthcare utilization measures were similar between the two groups – including overall utilization (Table B), cervical x-ray studies, cervical CT studies, cervical MRI studies, emergency department visits, and urgent care visits at 90-, 180-, and 365- days postoperatively.

Conclusion: Patients with persistent opioid use following elective cervical spine surgery are not more likely to utilize more healthcare resources in the first 365 days following surgery. These patients have similar rates of imaging studies, emergency department visits, and urgent care visits. These patients were, however, more likely to pursue interventional pain procedures (e.g. epidural or other spinal injections) suggesting patient need for continued pain relief despite surgical intervention.

E-POSTER #26 continued

Table A. Demographics, patient-, and surgical- variables

	No Persistent Opioid Use [n = 110]	Persistent Opioid Use [n = 29]	P
Sex			
Male	58.2%	62.1%	0.707
Female	41.8%	37.9%	
Age	54.6 ± 15.4	56.2 ± 15.0	0.609
Body Mass Index (BMI)	28.9 ± 5.7	29.2 ± 6.3	0.791
Charlson Comorbidity Index	2.0 ± 1.9	2.9 ± 2.6	*0.036*
ASA Class	2.2 ± 0.5	2.2 ± 0.6	0.965
Procedure			
ACDF	91.8%	79.3%	0.131
PCF	2.7%	17.2%	0.056
Other	5.5%	3.5%	0.834
Number of Levels Fused	1.5 ± 0.9	2.1 ± 1.6	0.057

Table B. Overall healthcare utilization (by tertile)

	No Persistent Opioid Use [n = 110]	Persistent Opioid Use [n = 29]	P
Overall Healthcare Utilization			
Low (1st tertile)	38 (34.5%)	7 (24.1%)	0.287
Moderate (2nd tertile)	37 (33.6%)	10 (34.5%)	0.932
High (3rd tertile)	35 (31.8%)	12 (31.4%)	0.380

E-POSTER #26 continued

Table C. Healthcare utilization measures

	No Persistent Opioid Use [n = 110]	Persistent Opioid Use [n = 29]	P
Cervical X-Rays			
90 days	1.9 ± 1.0	2.2 ± 0.8	0.207
180 days	2.6 ± 1.3	2.9 ± 1.1	0.319
365 days	3.5 ± 1.6	4.0 ± 1.5	0.148
Cervical Computed Tomography (CT)			
90 days	0.0 ± 0.2	0.0 ± 0.2	0.962
180 days	0.1 ± 0.3	0.1 ± 0.4	0.754
365 days	0.2 ± 0.6	0.3 ± 0.5	0.684
Cervical Magnetic Resonance Image (MRI)			
90 days	0.1 ± 0.3	0.1 ± 0.3	0.960
180 days	0.1 ± 0.3	0.2 ± 0.4	0.191
365 days	0.2 ± 0.5	0.3 ± 0.5	0.436
Emergency Department Visits			
90 days	0.1 ± 0.2	0.2 ± 0.5	0.244
180 days	0.1 ± 0.3	0.3 ± 0.8	0.259
365 days	0.2 ± 0.7	0.5 ± 1.2	0.245
Urgent Care Visits			
90 days	0.1 ± 0.3	0.1 ± 0.4	0.344
180 days	0.1 ± 0.4	0.2 ± 0.5	0.526
365 days	0.2 ± 0.6	0.3 ± 0.8	0.641
Opioid Prescriptions			
90 days	1.5 ± 1.8	2.8 ± 2.8	*0.020*
180 days	1.6 ± 2.1	4.2 ± 4.5	*0.005*
365 days	1.6 ± 2.1	7.3 ± 6.0	*<0.001*
Epidural/Other Spinal Injections			
90 days	0.0 ± 0.1	0.0 ± 0.2	0.311
180 days	0.0 ± 0.2	0.2 ± 0.5	*0.017*
365 days	0.1 ± 0.4	0.5 ± 0.9	*0.002*

E-POSTER #27

In vivo molecular signatures of cervical spinal cord pathology in degenerative compression

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Introduction: Degenerative cervical myelopathy (DCM) is a severe consequence of degenerative cervical spinal cord (CSC) compression. The non-myelopathic stage of compression (NMDC) is highly prevalent and often progresses to disabling DCM. This study aims to disclose markers of progressive neurochemical alterations in NMDC and DCM by utilizing an approach based on state-of-the-art proton magnetic resonance spectroscopy (1H-MRS).

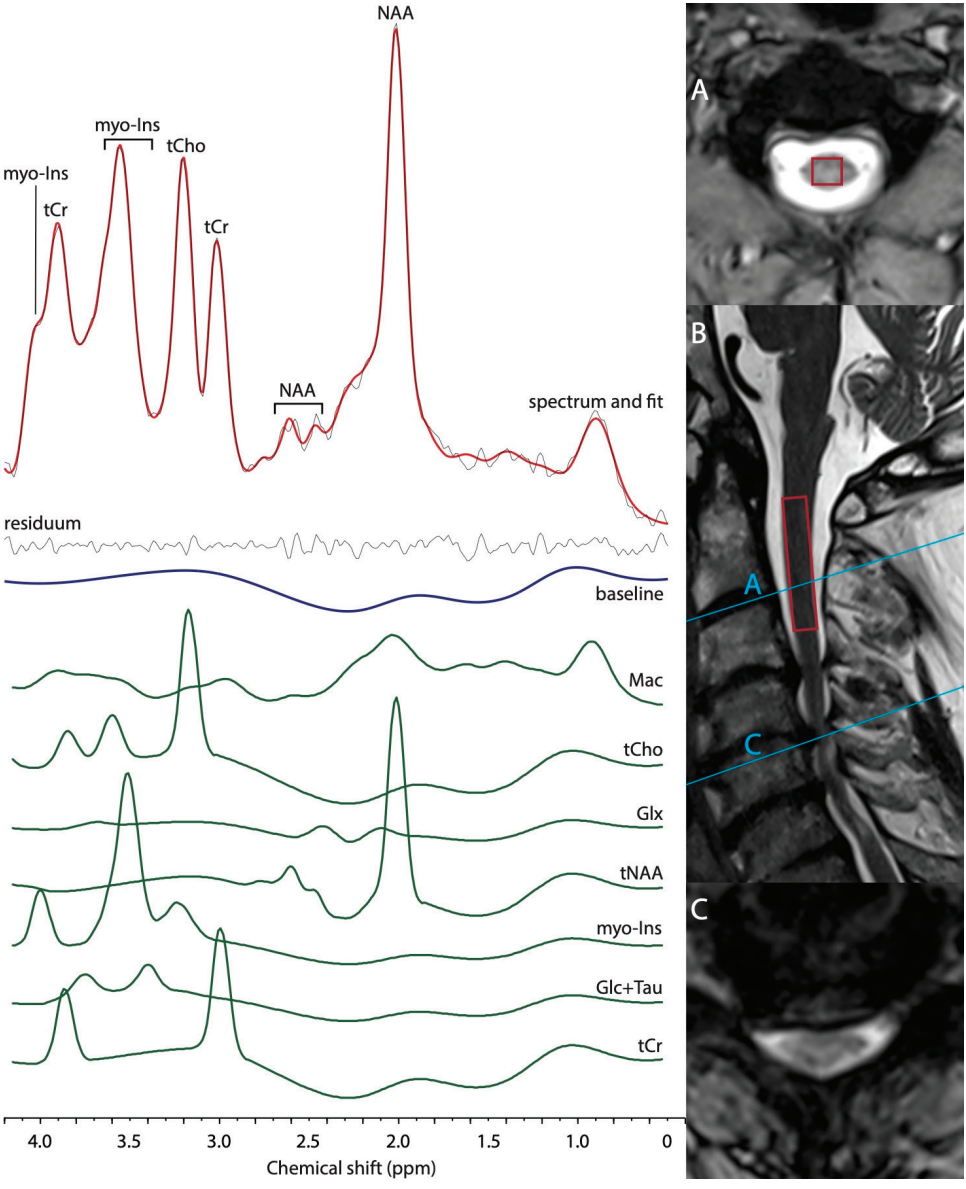
Materials and Methods:

Proton-MRS data were prospectively acquired with short-echo cardiac-triggered semi-LASER from 73 participants with CSC compression (51% women, 55.5 ± 10.6 y.o.) and 47 healthy controls (HC, 57% women, 53.3 ± 9.3 y.o.) on a clinical 3T scanner. Compression-affected participants were clinically categorized as NMDC and DCM, radiologically as suffering from mild (MC) or severe (SC) compression. T2-weighted images were employed to center the MRS voxel at C2 level. The CSC segment to be used for volumetry was determined by craniocaudal voxel diameter. Neurochemicals quantified from the spectra and CSC volumes were compared between HC×NMDC×DCM and HC×MC×SC, with general linear models adjusted for age and height effects (pFWE <0.05) and related to stenosis severity, electrophysiology, and myelopathy symptoms (p <0.05).

Results: Alteration in the ratio of total creatine (tCr) to total N-acetylaspartate (tNAA) appeared in NMDC (+11%) and was more pronounced in DCM (+26%) and SC (+21%). Myo-inositol/tNAA, glutamate+glutamine/tNAA and volumes showed change only in DCM (+20%, +73%, and –14%) and SC (+12%, +46%, and –8%, respectively) relative to HC. Both tCr/tNAA and myo-inositol/tNAA correlated with compression severity and volume (–0.376

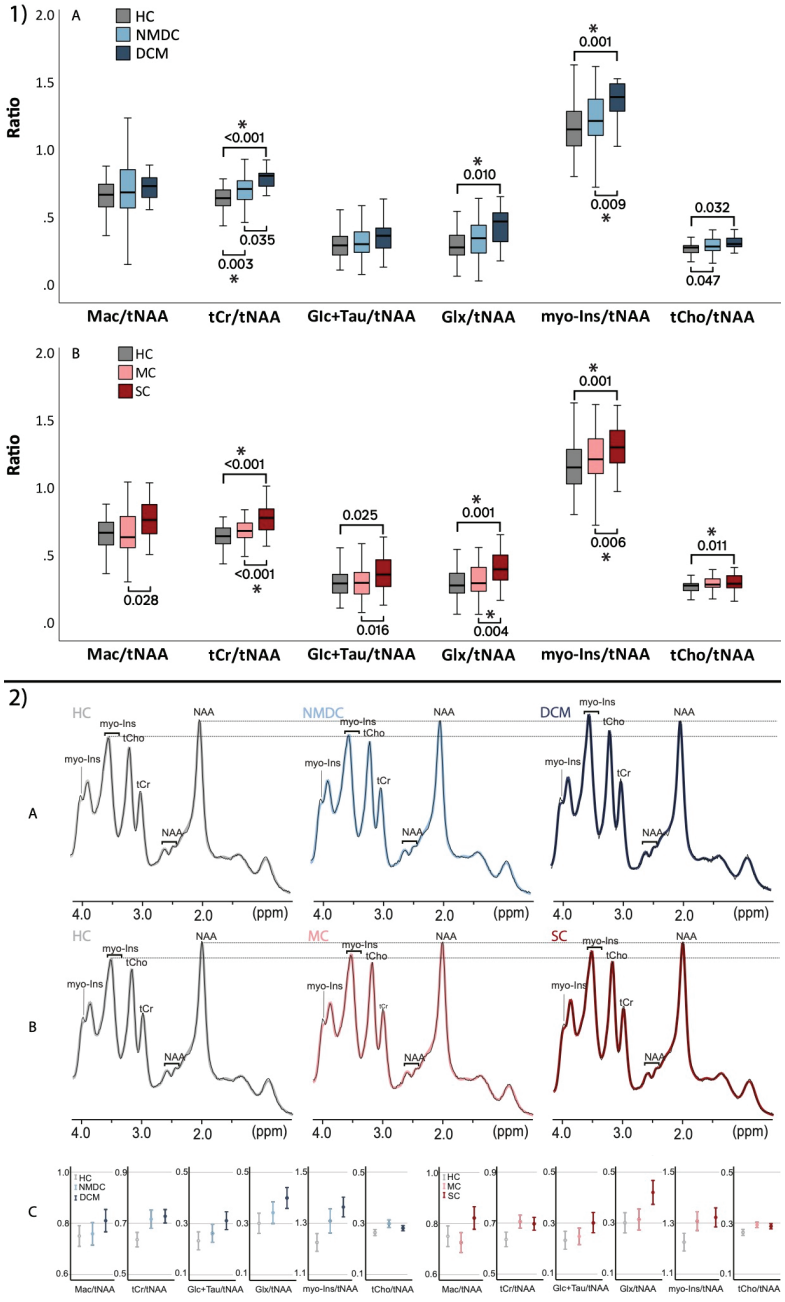
Conclusion: Short-echo 1H-MRS provided neurochemical signatures of CSC impairment that reflected compression severity and clinical significance. While neurochemical changes were detected at a non-myelopathic stage, volumetry reflected only clinically manifest myelopathy.

E-POSTER #27 continued



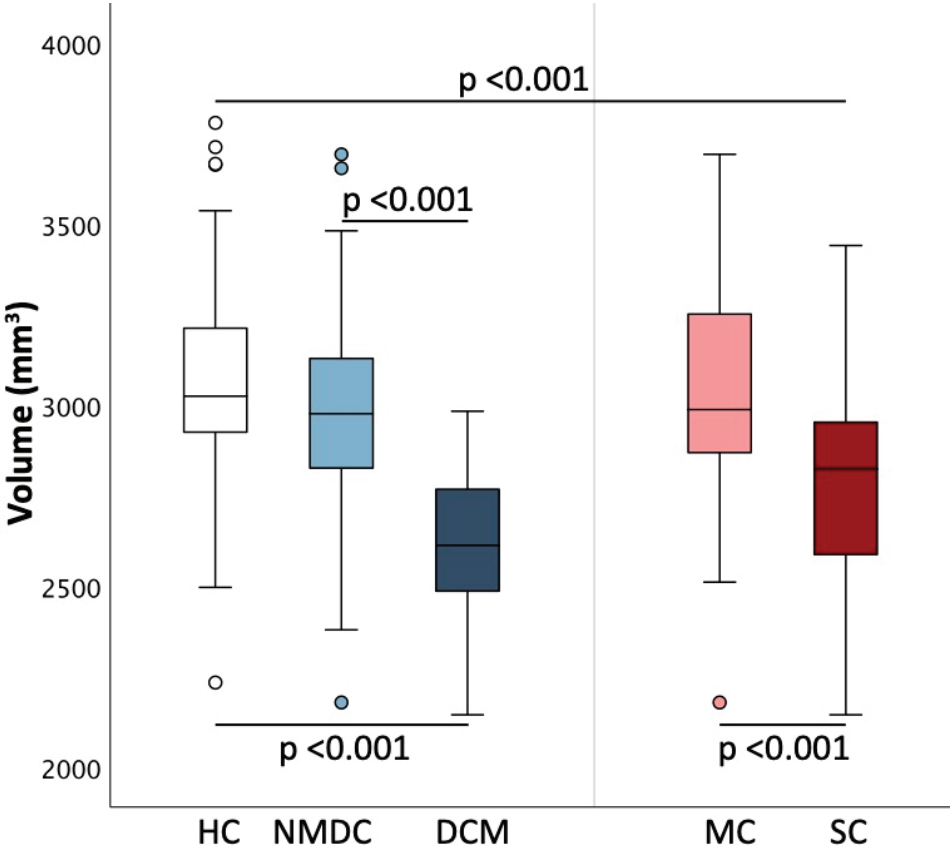
Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

E-POSTER #27 continued



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.

E-POSTER #27 continued



E-POSTER #28

Re-emergence of Depressive Symptoms and Associated Risk Factors in Cervical Spine Patients

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Introduction: Treatment of cervical spine pathology has been associated with improvement of mental health outcomes;[1-3] however, for some, mental health may worsen. Few have investigated worsening of depressive symptoms following cervical spine procedures such as anterior cervical discectomy and fusion (ACDF) or cervical disc arthroplasty (CDA). Our study aims to evaluate risk factors associated with worsening depressive symptoms following ACDF or CDA.

Materials and Methods: A surgical database was retrospectively reviewed for primary, elective, single or multilevel ACDF or CDA procedures. Demographics and perioperative information was collected, and descriptive statistics performed. Short Form 12-Item and Veterans RAND Mental Component Summary (SF-12 and VR-12 MCS), Patient Health Questionnaire-9 (PHQ-9), Visual Analogue Scale (VAS) for neck and arm, and Neck Disability Index (NDI) were collected preoperatively and at 6-weeks, 12-weeks, 6-months, and 1-year postoperatively. Improvement of all outcome measures from preoperative values was evaluated using paired Student's t-test. Achievement of minimum clinically important difference (MCID) was evaluated by comparing the difference in preoperative and postoperative scores with the following pre-established values: 4.7 (SF-12 MCS),[4] 8.1 (VR-12 MCS),[5] and 3.0 (PHQ-9).[5] Worsening of depressive symptoms, MCID "drop-off", was defined as patients who demonstrated achievement of an MCID at an earlier postoperative timepoint and subsequently failed to achieve an MCID at a later timepoint. Bivariate poisson regression with robust error variance was performed to determine relative risk of demographic and perioperative characteristics with mental health MCID "drop-off".

Results: An initial 872 patients were identified as eligible for the study with 362 included in the final study cohort. Mean age was 49.0 years and 58.6% were male with a mean body mass index of 29.1 kg/m2. Preoperatively 47.2% of patients had a high level of neck pain, 43.2% with high arm pain, 12.9% with a poor PHQ-9 score and 43.9% with a poor SF-12 MCS score. Majority of patients experienced myeloradicular symptoms (81.2%) and had a spinal pathology of herniated nucleus pulposus (85.4%). Majority of procedures were performed at the single level (61.4%) with 80.4% of procedures being ACDF and 19.6% being CDA. Mean operative time was 61.9 minutes with an average estimated blood loss of 40.3mL. The study cohort had a mean length of stay of 18.7 hours. Both SF-12 MCS and PHQ-9 demonstrated significant improvements from preoperative levels at all postoperative timepoints (all $p<0.01$). VAS neck, VAS arm, and NDI demonstrated significant improvement at all timepoints (all $p<0.001$). Risk factors associated with a MCID "drop-off" for both SF-12 and VR-12 MCS included a worse preoperative SF-12 PCS (all $p<0.05$; Table 1 & 2), workers' compensation ($p=0.012$; Table 1) only for SF-12 PCS, and active smoker status for PHQ-9 ($p=0.049$; Table 3).

Conclusion: Cervical spine patients demonstrated significant improvements in mental health, pain, disability, and physical function following cervical procedures. Worse preoperative

E-POSTER #28 continued

depressive symptoms and workers' compensation were risk factors for re-emergence of postoperative depression. These results may indicate that patients presenting with worse depression may be more susceptible to loss of initial improvements in mental health outcomes.

E-POSTER #28 continued

Table 1. Bivariate Analysis for SF-12 MCS MCID Drop-Off

Characteristic	Dropped MCID (%)	RR	95% C.I.	p-value†
Overall	22.2%	-	-	-
Age				
18-50 years	68.9%	Reference		
>50 years	31.1%	0.6	(0.3 - 1.3)	0.199
Gender				
Female	37.8%	Reference		
Male	62.2%	1.3	(0.6 - 2.6)	0.436
Body mass index (BMI)				
<30 kg/m^2	60.0%	Reference		
≥30 kg/m^2	40.0%	1.1	(0.5 - 2.2)	0.777
Smoking status				
Non-smoker	82.2%	Reference		
Smoker	17.8%	1.5	(0.6 - 3.7)	0.382
Diabetes				
Non-Diabetic	88.9%	Reference		
Diabetic	11.1%	1.3	(0.4 - 3.8)	0.648
Ageless CCI				
<1	41.0%	Reference		
≥1	59.0%	0.7	(0.3 - 1.5)	0.421
ASA				
<2	97.6%	Reference		
≥2	2.4%	0.2	(0.03 - 1.9)	0.171
Insurance				
Non-WC	**64.4%**	**Reference**		
WC	**35.6%**	**1.9**	**(1.1 - 3.2)**	**0.012**
VAS Neck				
<7	51.4%	Reference		
≥7	48.6%	0.9	(0.4 - 2.0)	0.846
VAS Arm				
<7	58.8%	Reference		
≥7	41.2%	0.8	(0.4 - 1.8)	0.607
SF-12 MCS*				
Not Depressed >45.6	**48.9%**	**Reference**		
Depressed ≤45.6	**51.1%**	**2.5**	**(1.5 - 4.2)**	**<0.001**
PHQ-9				
Minimal to Moderate (<15)	95.8%	Reference		
Moderately severe to Severe (≥15)	4.2%	0.2	(0.02 - 1.4)	0.139

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; RR = Relative Risk; VAS = Visual Analog Scale
Boldface indicates statistical significance
*Threshold value defined by Vilagut et al.
†p-value calculated using Poisson's regression with robust error variance

E-POSTER #28 continued

Table 2. Bivariate Analysis for VR-12 MCS MCID Drop-Off

Characteristic	Dropped MCID (%)	RR	95% C.I.	p-value†
Overall	16.3%	-	-	-
Age				
18-50 years	64.0%	Reference		
>50 years	36.0%	0.8	(0.4 - 1.9)	0.721
Gender				
Female	32.0%	Reference		
Male	68.0%	1.4	(0.6 - 3.1)	0.388
Body mass index (BMI)				
<30 kg/m^2	60.0%	Reference		
≥30 kg/m^2	40.0%	1.2	(0.5 - 2.4)	0.705
Smoking status				
Non-smoker	84.0%	Reference		
Smoker	16.0%	1.5	(0.6 - 3.9)	0.383
Diabetes				
Non-Diabetic	84.0%	Reference		
Diabetic	16.0%	1.9	(0.7 - 4.8)	0.175
Ageless CCI				
<1	45.5%	Reference		
≥1	54.5%	1.3	(0.6 - 2.8)	0.507
ASA				
<2	87.0%	Reference		
≥2	13.0%	1.5	(0.5 - 4.5)	0.428
Insurance				
Non-WC	76.0%	Reference		
WC	24.0%	0.9	(0.4 - 2.3)	0.965
VAS Neck				
<7	52.2%	Reference		
≥7	47.8%	0.9	(0.4 - 1.9)	0.821
VAS Arm				
<7	47.8%	Reference		
≥7	52.2%	1.4	(0.6 - 2.8)	0.482
SF-12 MCS*				
Not Depressed >45.6	**28.0%**	**Reference**		
Depressed ≤45.6	**72.0%**	**3.5**	**(1.6 - 8.1)**	**0.002**
PHQ-9				
Minimal to Moderate (<15)	93.3%	Reference		
Moderately severe to Severe (≥15)	6.7%	0.3	(0.05 - 2.4)	0.270

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; RR = Relative Risk; VAS = Visual Analog Scale

Boldface indicates statistical significance

*Threshold value defined by Vilagut et al.

†p-value calculated using Poisson's regression with robust error variance

E-POSTER #28 continued

Table 3. Bivariate Analysis for PHQ-9 MCID Drop-Off

Characteristic	Dropped MCID (%)	RR	95% C.I.	p-value†
Overall	18.6%	-	-	-
Age				
18-50 years	68.7%	Reference		
>50 years	31.3%	0.9	(0.3 - 2.5)	0.902
Gender				
Male	62.5%	Reference		
Female	37.5%	0.5	(0.2 - 1.2)	0.114
Body mass index (BMI)				
<30 kg/m^2	60.0%	Reference		
≥30 kg/m^2	40.0%	0.9	(0.4 - 2.3)	0.852
Smoking status				
Non-smoker	**75.0%**	**Reference**		
Smoker	**25.0%**	**2.5**	**(1.1 - 6.4)**	**0.049**
Diabetes				
Non-Diabetic	100.0%	Reference		
Diabetic	0.0%	-	-	-
Ageless CCI				
<1	58.3%	Reference		
≥1	41.7%	0.9	(0.3 - 2.6)	0.852
ASA				
<2	93.3%	Reference		
≥2	6.7%	1.1	(0.2 - 6.8)	0.919
Insurance				
Non-WC	93.7%	Reference		
WC	6.3%	0.2	(0.02 - 1.4)	0.104
VAS Neck				
<7	46.7%	Reference		
≥7	53.3%	1.01	(0.4 - 2.5)	0.978
VAS Arm				
<7	46.7%	Reference		
≥7	53.3%	0.9	(0.4 - 2.4)	0.895
SF-12 MCS*				
Not Depressed <45.6	43.7%	Reference		
Depressed ≥45.6	56.3%	2.1	(0.8 - 5.0)	0.111
PHQ-9				
Minimal to Moderate (<15)	93.7%	Reference		
Moderately severe to Severe (≥15)	6.3%	0.2	(0.03 - 1.6)	0.133

ASA=American Society of Anesthesiologists; CCI=Charlson Comorbidity Index; RR = Relative Risk; VAS = Visual Analog Scale; WC=workers' compensation; SF-12=12-item Short Form; PHQ-9=9-item patient
†p-value calculated using poisson's regression with robust error variance
Boldface indicates statistical significance

E-POSTER #29

Does Screw Length Impact 1-Year Fixation in 3-Level Anterior Cervical Discectomy and Fusion?

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Introduction: Several studies have suggested that enhanced rigid fixation supports arthrodesis following anterior cervical discectomy and fusion (ACDF). Using 2-level ACDF cases, authors recently demonstrated that a ratio of screw length to vertebral body anterior-posterior length not exceeding 75% is significantly associated with interspinous motion (ISM) ≥ 1mm. ISM < 1mm on lateral films has been offered as a radiographic marker of fusion and is comparable to CT-based modalities. Herein, we aim to identify the impact of screw length on fixation in 3-level ACDF over a 1-year period. We hypothesize that a greater screw length to vertebral body ratio is positively correlated with stronger fixation and thus smaller ISM in a level-specific manner.

Materials and Methods: We reviewed all C3-6, C4-7, and C5-T1 ACDF cases performed by the three spine surgeons from November 2005 to December 2019. All cases utilized anterior plates with locking screw mechanisms and plates were secured with two screws into each vertebral body. Patients with use of bone morphogenetic protein (BMP) were excluded. Screw length relative to the instrumented vertebral body was accessed via techniques previously described in Lee et al. to yield a vertebral body (VB) ratio. ISM values were gathered using previously published methods at 6 weeks, 6 months, and 1 year. ISM was assessed only at the respective articulating vertebral bodies relevant to the construct. Data analysis was performed using RStudio.

Results: 68 patients with a total of 268 VB ratios were included in this study. No significant correlation was found between vertebral body ratio and fixation at any level of construct, nor any period post-operatively. A weak, negative correlation was seen between VB ratio and fixation for the middle construct (fig 2). A larger VB ratio had a greater effect on fixation in the early post-operative period, but little effect at the one-year mark. Additionally, when using the 75% VB ratio threshold suggested by Lee et al., there was no significant difference in fixation between the two cohorts for 3-level ACDF.

Conclusion: The data suggests there is no significant correlation between VB ratios, ranging from 58.09% to 99.64%, and fixation in 3-level ACDF when examined in a level-specific manner. It is likely that for 3-level ACDF, in comparison to 2-level ACDF, there is a greater biomechanical force that overshadows the possible effect of a few millimeter increase in screw length.

E-POSTER #29 continued

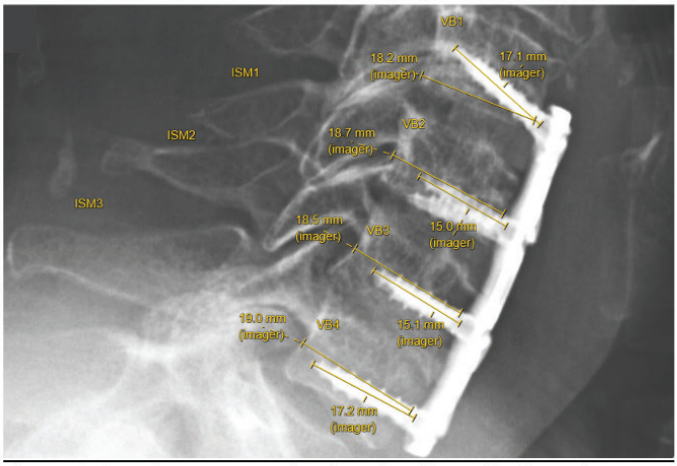

Figure 1: 6 weeks post-operative lateral radiograph of a patient post C4-7 ACDF.
VB ratio was defined as screw length divided by the anterior-posterior diameter parallel to the endplate of the VB at the same level as the screw. Respective ISM levels and vertebral body levels are labeled.

E-POSTER #29 continued

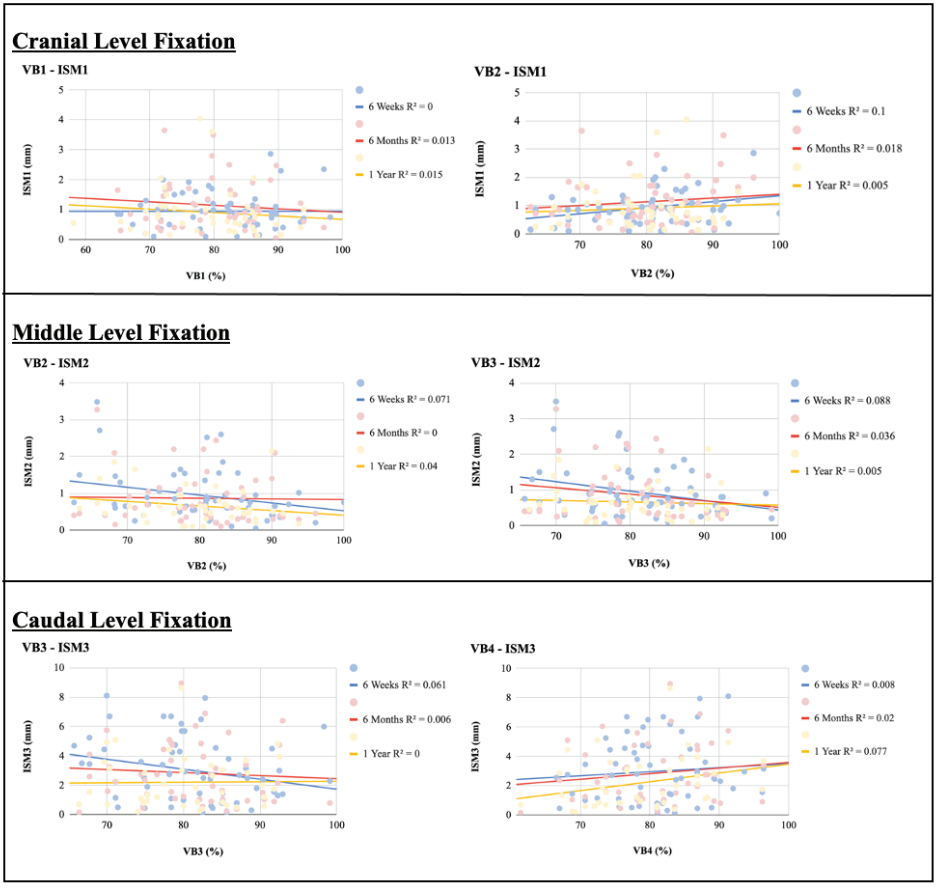

Figure 2: 6 weeks, 6 months, and 1 year scatterplot and trendline for each ISM level, with its two respective VB ratios. R^2 values included in legend.

E-POSTER #30

Outcomes of the subaxial cervical spine tuberculosis operated with the anterior approach surgery

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Fortis Hospital Mohali[1]

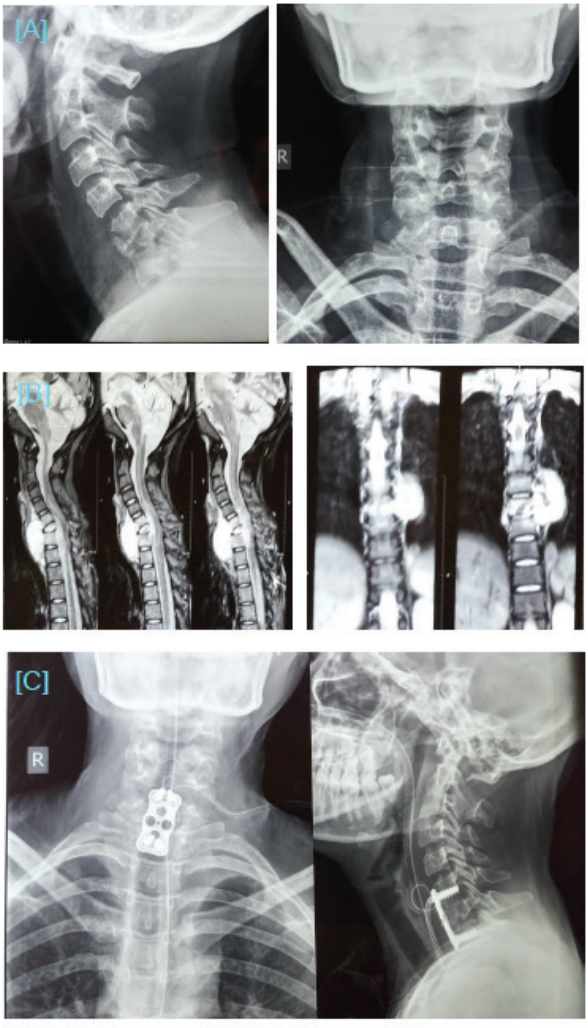
Introduction: Though spinal tuberculosis has a predilection for the dorsal and lumbar spine, a high percentage of morbidity and mortality is associated with cervical tuberculosis. Cervical tuberculosis accounts for about 10% of cases, with the major concerns being quadriparesis/quadriplegia and kyphotic deformity. The study aim was to evaluate the efficacy of anterior instrumentation in patients with subaxial spinal tuberculosis in the reconstruction of the spine, providing pain relief, neurological recovery, and prevention of deformity.

Materials and Methods: Retrospectively, we Included 53 patients with subaxial cervical (C3-C7) tuberculosis who underwent operations with anterior debridement, decompression, bone grafting, and anterior instrumentation by a single surgeon at our institute between January 2016 and June 2019. A review of the demographic data, medical records, and radiological data preoperative and postoperative and at subsequent follow-ups was performed. A five-drug anti-tuberculous treatment was given for 12 months. The mean follow-up was 24 months). Clinical and radiological assessment using flexion and extension radiographs was performed at 24 months for all cases.

Results: The neck pain (VAS) was improved from a preoperative mean of 7.1 to 2.2 at 3-months follow-up. Neurological involvement in the postoperative period was seen in 52 of the 53 patients, 46 of whom showed complete neurological recovery. The Cobb angle at presentation ranged from 3–48 of kyphosis with an average kyphosis of 15.3. The average lordosis after surgery was found to be 17.4 (mean correction of 32.8). The asymmetric wasting in patients with involvement of the cervicodorsal region did not recover completely. MRI at 12-month follow-up shows complete resolution of infection. Flexion-extension radiographs at 24 months did not show any evidence of instability or nonunion.

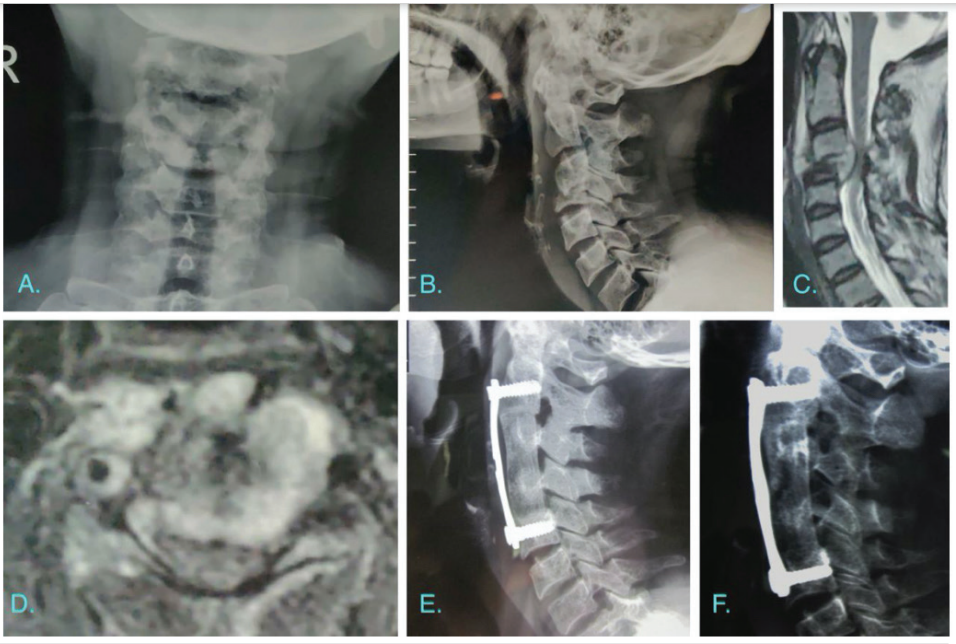
Conclusion: Anterior approach surgery for subaxial cervical tuberculosis provides good correction of kyphosis and provides reasonable neurologic recovery in patients and ensures a long-lasting functional outcome. Early diagnosis and early treatment lead to a good prognosis. Periodic evaluation is a must to look for evidence of improvement and the adverse effect of ATT.

E-POSTER #30 continued



Plain radiographs of Case Illustration revealed (A) destruction of C5 and C6 vertebral bodies. (B) T2 sagittal MRI demonstrated retropulsion of C6 and compression of the spinal cord with severe ventral compression of the cord with loss of cerebrospinal fluid signal with large collection. (C) Plain anterior posterior radiograph depicting anterior surgery with cervical plating. Lateral radiograph after surgery demonstrating restoration of cervical lordosis.

E-POSTER #30 continued



(A, B) Plain radiographs of patient revealed destruction of C3 and C4 vertebral bodies. (C) T2 sagittal MRI demonstrated retropulsion of C3 and prevertebral and epidural soft tissue extension. (D) T2 axial MRI showing severe ventral compression of the cord more on the left side than on the right. (E) Lateral radiographhafter surgery demonstrating good cervical lordosis and reconstruction of the anterior column. (F) Lateral radiograph at 12-month follow-up demonstrating good anterior fusion.

E-POSTER #31

Cervical Radiograph parameters in 1-, 2- and 3- level anterior cervical discectomy and fusion with 12.5° hyperlordotic allografts

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Sheba Medical Center[1]

Introduction: Anterior cervical discectomy and fusion (ACDF) is used to treat cervical degenerative pathology. Lordotic machined cortical allografts have been shown to increase segmental lordosis and improve overall cervical alignment parameters. However, there are a lack of radiographic data with the use of hyperlordotic allografts in the cervical spine. The objective of the study is to characterize the radiographic changes after placement of hyperlordotic allografts in patients undergoing ACDF.

Materials and Methods: A single surgeon created 12.5° hyperlordotic allografts. Radiographs were prospectively reviewed. Cervical parameters recorded included C1-7 lordosis, C2-7 lordosis, C2-7 sagittal vertical alignment (SVA), T1 slope, segmental lordosis of the fusion levels, and disc height changes which were evaluated at three follow-up time periods (preoperative, 6 week and 1-year). Correlation coefficients and linear regression models were performed to determine the relationship between these radiographic measurements.

Results: A total of 69 patients underwent a 1-level (ACDF1), 2-level (ACDF2), or 3-level (ACDF 3) (28 ACDF1, 16 ACDF2, 25 ACDF3) ACDF. The mean values were as follows: preoperative segmental lordosis was 2.36°, disc height was 5.14 mm, C2-7 lordosis was 6.3°, C1-7 lordosis was 41.7°, cervical SVA was 28.6 mm, and the T1 slope was 28.29°. Cervical segmental lordosis significantly increased by 9.03° at 6 weeks and maintained at 7.1° at 1 year. C1-7 lordosis and C2-7 lordosis significantly increased by 3.88° and 5.28° at 6 weeks and 2.74° and 4.18° at 1 year, respectively. There was no significant change in cervical SVA. Overall cervical lordosis was significantly positively correlated to segmental lordosis at 6 weeks ($r=0.753$, $p< 0.001$) and 1 year ($r=0.574$, $p <0.001$). Segmental lordosis was significantly positively correlated to disc height at 6 weeks ($r=0.292$, $p = 0.015$) and 1 year ($r=0.322$, $p=0.035$). Overall cervical lordosis was significantly negatively correlated to SVA at 6 weeks but not significant at 1 year. There was a significant decrease in disc height at 1 year in all cohorts. Symptomatic nonunion rate was 24%.

Conclusion: Hyperlordotic allografts provide a significant improvement in segmental lordosis, C1-7 lordosis and C2-7 lordosis in this population. An increase in disc height is correlated to significant increase in segmental lordosis. However, a significant amount of subsidence (>2.5 mm) occurs at 1 year which may contribute to loss of focal lordosis and progressive worsening of SVA. Surgeons should be aware that hyperlordotic grafts in the cervical spine may ultimately lead to a higher nonunion rate

E-POSTER #32

The Timing and Reasons for Revision Surgery After Cervical Deformity Correction

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Introduction: The incidence of symptomatic cervical deformity (CD) is increasing as the population ages, and as the prevalence of cervical fusion procedures leads to more iatrogenic malalignment.1 Greater attention has been paid to classification and treatment planning for CD in recent years, but less is known about subsequent re-operations.2,3 Here we aim to understand the breakdown of reasons and timing for revision surgery after CD correction.

Materials and Methods: Adult CD patients with one-year follow-up from a prospective, multi-center database were included. Demographics, baseline patient-reported outcome measures (PROMs), and the instances and timing of revision surgery within one year were recorded. Survival analysis with Kaplan Meier curves was then performed. Survival was defined as the number of days until a patient underwent a revision surgery prior to the one-year post-operative mark. If no revision occurred during that time period, the survival was listed as the number of days until one-year follow-up.

Results: 121 patients (61.7±10.0 years, 62% females) were included. The average BMI was 28.4 ± 6.9 kg/m2 and the average Charlson Comorbidity Index was 0.96 ± 1.35. At baseline, the Numeric Rating Scale (NRS) for neck pain was 6.6 ± 2.5, Neck Disability Index (NDI) was 47.2 ± 17.7, modified Japanese Orthopaedic Association (mJOA) score was 13.5 ± 2.7, and EuroQol-5D (EQ-5D) was 0.7 ± 0.1. 19 of the 121 patients (15.6%) underwent a revision surgery within one year. Five revisions were performed for distal junctional kyphosis (DJK), four for myelopathy, three for infection, three for radiculopathy, two for trauma, two for wound problems, one for airway edema, one for a fracture, one due to an intra-operative change of plan (staged procedures), and one for pseudoarthrosis (see Table 1). No re-operations were performed for proximal junctional kyphosis. The cumulative revision rate was 1.7% at the one-week post-operative mark, 6.6% at one-month, 9.1% at three-months, 14.9% at six-months, and 15.6% at one-year (see Table 2). Figure 1 displays this survival analysis as a Kaplan Meier curve. Four patients died within a year and were not included in the analysis - one from pneumonia unrelated to surgery, one from anoxic injury due to sleep apnea, and two from unknown reasons. Of the patients with one-year follow-up, one died from pneumonia 545 days after revision surgery. Five patients with no revision surgery also died - one from a deep surgical site infection, one from cardiopulmonary failure, and three from unknown reasons.

Conclusion: In a retrospective review of prospectively tracked patients undergoing surgery for CD, the overall revision rate at one year was 15.6%. The most common reasons for revision were DJK, myelopathy, infection, and radiculopathy. Survival analysis is a useful method for understanding the temporal distribution of re-operations, as prospective follow-up for this patient population increases.

E-POSTER #32 continued

Table 1: Reasons for Revision Within One Year of Cervical Deformity Correction

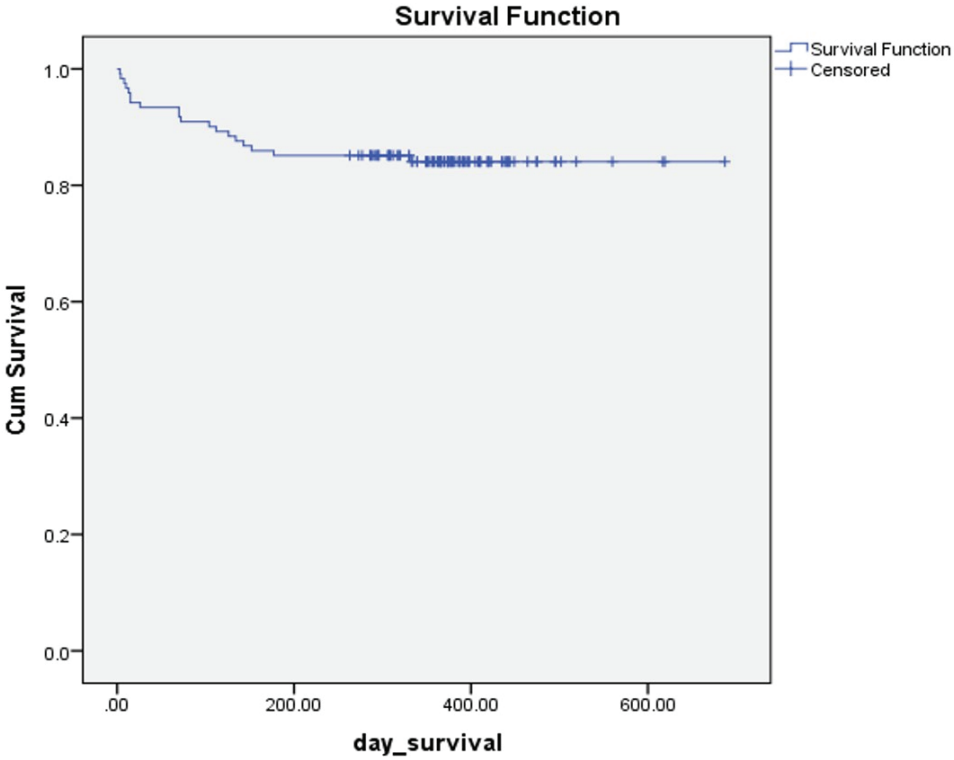
Reason	Frequency
Airway edema	1
Fracture	1
Infection	3
Intraoperative change of plan	1
Distal junctional kyphosis (DJK)	5
Myelopathy	4
Prominence (spinous process / hardware)	2
Pseudoarthrosis	1
Radiculopathy	3
Trauma	2
Wound issue	2

Table 2: Cumulative Revision Rates Within One Year of Cervical Deformity Correction

Days After Surgery	# of Cumulative Revisions	Cumulative Revision Rate (%)
1.0	0	0.0
7.0	2	1.7
30.0	8	6.6
90.0	11	9.1
182.5	18	14.9
365.0	19	15.7

E-POSTER #32 continued

Figure 1: Kaplan Meier Curve for Revisions Within One Year of Cervical Deformity Correction



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.

E-POSTER #33

Cervical Alignment Following Posterior Cervical Fusion Surgery: Cervical Pedicle Screw Versus Lateral Mass Screw Fixation

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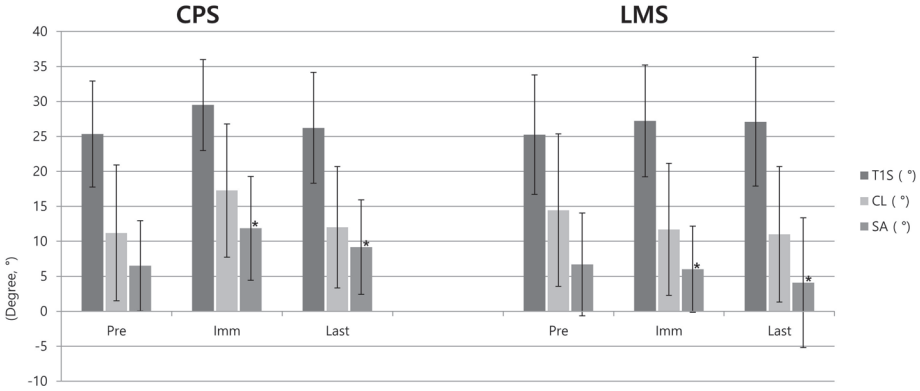
Introduction: Lateral mass screw (LMS) fixation in the subaxial cervical spine has become the preferred method of posterior cervical fusion. Although cervical pedicle screw (CPS) has biomechanical benefits, it also has neurovascular risks. Few studies to date have compared sagittal alignment changes after posterior cervical fusion using CPS and LMS fixation. The purpose of this study was to compare cervical sagittal alignment after posterior fusion surgery with LMS and CPS fixation.

Materials and Methods: From 2006 to 2017, 71 consecutive patients underwent posterior cervical fusion using CPS (n = 51) or LMS (n = 20) fixation. Patients who underwent fusion with both types of screws and those who planned to undergo additional anterior fusion surgery were excluded. The minimum follow-up period was 12 months. C2–C7 Cobb angle for cervical lordosis (CL), fusion segmental angle (SA), C2–C7 sagittal vertical axis (SVA), and T1 slope (T1S) were measured.

Results: Immediate postoperative SA and SVA differed significantly in patients who underwent CPS and LMS fixation. SA changes were more substantial after CPS fixation, with a significant difference maintained until final follow-up. Over time, CL, SVA, and T1S tended to return to their preoperative states regardless of screw type. Two patients who underwent LMS fixation, but none who underwent CPS fixation, required unplanned or additional anterior fusion surgery for revision.

Conclusion: The present study is the first radiologic comparison of LMS and CPS fixation after posterior-only fusion surgery. CPS resulted in more reliable and well-preserved SA correction, whereas CL and SVA did not differ between the two groups over time due to loss of correction.



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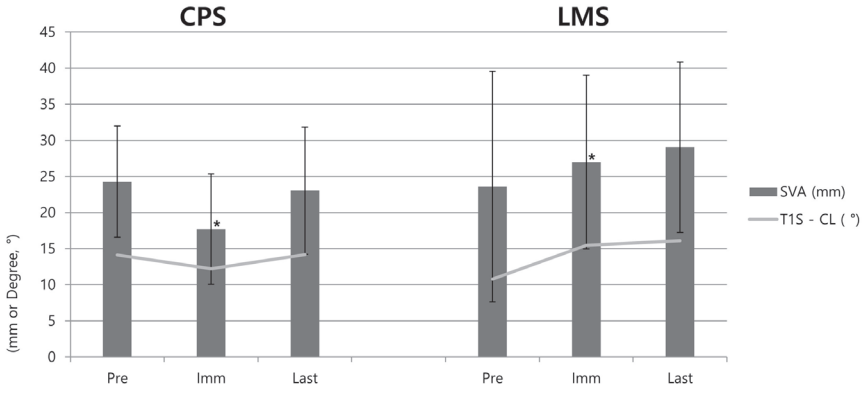

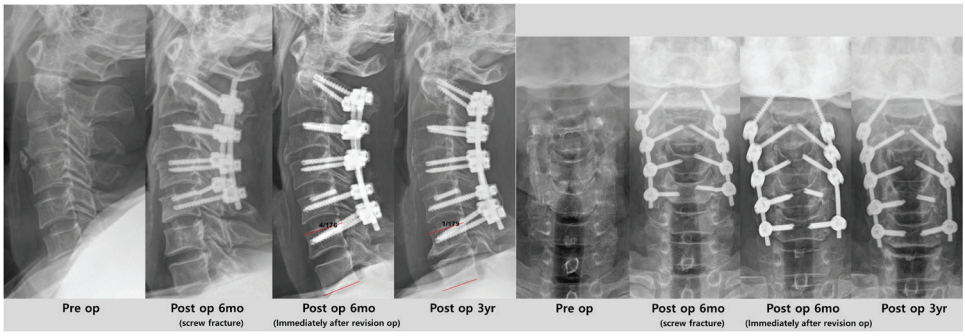

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E-POSTER #34

Does a High Postoperative Opioid Dose Predict Chronic Use after ACDF?

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Introduction: Currently there is an incomplete understanding of the patient level risk factors for chronic opioid use after anterior cervical discectomy and fusion (ACDF). Postoperative opioid prescriptions in spine surgery have been found to commonly exceed the dose necessary for return to function and pain relief, however the direct relationship between postsurgical opioid dose and chronic opioid abuse has yet to be explored. The purpose of this study is to determine if increased postoperative prescription opioid dosing is an isolated predictor of chronic opioid use after ACDF.

Materials and Methods: All patients over age 18 who underwent one- to four-level primary or revision ACDF for cervical spondylosis associated with radiculopathy and/or myelopathy at an academic center between 2016- 2019 were retrospectively identified. Patients lacking descriptive data or opioid utilization records or who had surgery performed for trauma, infection, or malignancy were excluded. Pre- and postsurgical opioid and benzodiazepine prescriptions, including the postoperative peak MME and duration of use, were obtained from the Pennsylvania Prescription Drug Monitoring Program (PDMP) including preoperative opioid and benzodiazepine tolerance, and postoperative mean morphine equivalent (MME) opioid dose, duration of usage, number of prescriptions and pharmacies utilized, and chronicity of use. Univariate analysis compared patient demographics and surgical factors across two binary groups of high vs low postoperative opioid dose (high: MME≥ 90, low: MME< 90) and chronic vs short-term opioid use (chronic: ≥ 120 days or >10 prescriptions). The relationship between chronic opioid use and patterns of immediate postoperative opioid use was evaluated. Binary logistic regressions were created to identify patient specific predictors of high opioid dose and chronic use.

Results: A total of 385 patients met the inclusion criteria. Preoperative opioid tolerance and history of tobacco use were found to be associated with both high postoperative opioid dose and chronic postoperative usage (Table 1). In addition, younger age correlated with receiving high dose prescriptions and obesity and preoperative benzodiazepine use were associated with chronic opioid use patterns (Table 1). Chronicity of postoperative opioid use correlated meaningfully with immediate postoperative opioid use metrics including high single prescription dose ($p<0.001$), change in opioid prescribed ($p<0.001$), private pay scripts ($p<0.001$), and greater than one prescriber ($p<0.001$) and pharmacy ($p<0.001$) (Table 2). High postoperative opioid dose (ß= 1.04, p= 0.018) and preoperative opioid tolerance (ß= 4.17, $p<0.001$) were identified as predictors of chronic postsurgical opioid use on logistic regression (Table 3). Regression also determined younger age (ß= -0.07, $p<0.001$), increased medical comorbidities (ß= 0.38, p= 0.003), and opioid tolerance (ß= 2.27, $p<0.001$) were significant predictors for high MME prescriptions.

E-POSTER #34 continued

Conclusion: High postoperative opioid dose was found to be a significant predictor of chronic opioid use after ACDF regardless of preoperative opioid tolerance. Because a multitude of factors increase patient opioid dose requirements after surgery, further research is required to determine if there exists a causal relationship between high postoperative opioid dosing and chronicity of use.

Table 1: Comparison of Patient Demographics by Opioid Dose and Chronicity

	Chronic Postoperative Opioid Use: >10 prescriptions or ≥ 120 days use			Highest Postoperative Opioid Dose Prescribed		
	Not Chronic N=268	Chronic N=117	P Value	Peak MME < 90 N=268	Peak MME ≥ 90 N=117	P Value
Age	54.9 (12.3)	53.8 (9.83)	0.603	56.0 (12.1)	52.1 (11.5)	**0.003**
Sex:			0.814			0.378
Female	178 (52.0%)	21 (48.8%)		143 (53.4%)	56 (47.9%)	
Male	164 (48.0%)	22 (51.2%)		125 (46.6%)	61 (52.1%)	
BMI	30.1 (7.10)	33.8 (8.06)	**0.002**	30.2 (6.84)	31.2 (8.24)	0.452
CCI	2.16 (1.60)	2.37 (1.57)	0.447	2.20 (1.56)	2.15 (1.68)	0.471
Smoker:			**0.010**			**0.042**
No	216 (63.2%)	17 (39.5%)		172 (64.2%)	61 (52.1%)	
Yes	61 (17.8%)	14 (32.6%)		44 (16.4%)	31 (26.5%)	
Former	65 (19.0%)	12 (27.9%)		52 (19.4%)	25 (21.4%)	
Depression Diagnosis:			0.198			0.359
No	286 (83.6%)	32 (74.4%)		225 (84.0%)	93 (79.5%)	
Yes	56 (16.4%)	11 (25.6%)		43 (16.0%)	24 (20.5%)	
Preop Opioid Tolerance:			**<0.001**			**<0.001**
No	338 (98.8%)	20 (46.5%)		262 (97.8%)	96 (82.1%)	
Yes	4 (1.17%)	23 (53.5%)		6 (2.24%)	21 (17.9%)	
Preop Benzo Use:			**0.001**			0.259
No	285 (83.3%)	26 (60.5%)		221 (82.5%)	90 (76.9%)	
Yes	57 (16.7%)	17 (39.5%)		47 (17.5%)	27 (23.1%)	
Prior Cervical Surgery:			0.228			0.856
No	313 (91.5%)	41 (97.6%)		248 (92.5%)	106 (91.4%)	
Yes	29 (8.48%)	1 (2.38%)		20 (7.46%)	10 (8.62%)	
Number of Levels Fused: (n=383)			**0.026**			0.491
1	108 (31.8%)	14 (32.6%)		89 (33.5%)	33 (28.2%)	
2	153 (45.0%)	18 (41.9%)		117 (44.0%)	54 (46.2%)	
3	75 (22.1%)	7 (16.3%)		56 (21.1%)	26 (22.2%)	
4	4 (1.18%)	4 (9.30%)		4 (1.50%)	4 (3.42%)	
Corpectomy: (n=383)			0.893			0.507
No	311 (91.7%)	39 (90.7%)		244 (92.1%)	106 (90.6%)	
Yes	19 (5.60%)	3 (6.98%)		13 (4.91%)	9 (7.69%)	
Partial	9 (2.65%)	1 (2.33%)		8 (3.02%)	2 (1.71%)	
Cord Compression:			0.718			0.601
No	117 (34.3%)	13 (30.2%)		88 (32.8%)	42 (36.2%)	
Yes	224 (65.7%)	30 (69.8%)		180 (67.2%)	74 (63.8%)	

E-POSTER #34 continued

Table 2: Comparison of Opioid Use Patterns by Chronicity

	Chronic Postoperative Opioid Use: >10 prescriptions or ≥ 120 days use		
	Not Chronic N=342	Chronic N=43	P Value
Peak MME ≥ 90:			**<0.001**
No	254 (74.3%)	14 (32.6%)	
Yes	88 (25.7%)	29 (67.4%)	
> 1 Postop Prescriber:			**<0.001**
No	257 (75.1%)	7 (16.3%)	
Yes	85 (24.9%)	36 (83.7%)	
> 1 Postop Pharmacy:			**<0.001**
No	264 (77.2%)	10 (23.3%)	
Yes	78 (22.8%)	33 (76.7%)	
Change in Opioid Prescribed:			**<0.001**
No	306 (89.5%)	12 (27.9%)	
Yes	36 (10.5%)	31 (72.1%)	
Private Pay Prescriptions:			**<0.001**
No	307 (89.8%)	21 (48.8%)	
Yes	35 (10.2%)	22 (51.2%)	

E-POSTER #34 continued

Table 3: Logistic Regression for Chronic Opioid Use

Chronic Postoperative Opioid Use: > 10 prescriptions or ≥ 120 days use		
Variable	**Estimate**	**P Value**
Peak MME ≥ 90	1.04	**0.018**
Preop Opioid Tolerance	4.17	**<0.001**
Preop Benzo Use	0.54	0.272
Depression	0.54	0.292
Smoking Status:		
No	Reference	
Yes	0.95	0.069
Former	0.24	0.677
CCI	0.20	0.130

E-POSTER #35

The Impact of Preoperative Duration of Symptoms on Patient Outcomes after PCDF

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Introduction: The detrimental effects of prolonged preoperative symptom duration on patient reported outcome improvement after anterior cervical discectomy and fusion were previously established. However, there is a dearth of clinical evidence evaluating the effects of symptom duration on clinical outcomes after posterior cervical discectomy and fusion (PCDF). The purpose of this study is to determine if decreased preoperative symptom duration is associated with greater clinical improvement after PCDF.

Materials and Methods: All patients over age 18 who underwent primary PCDF for cervical spondylotic myelopathy with or without radiculopathy at a single academic institution between 2014- 2020 were retrospectively identified. Patients with a traumatic injury, infection, malignancy, revision procedures, or incomplete medical records were excluded. Patient demographics (age, sex, smoking status, body mass index, Charlson Comorbidity Index, diabetes status, depression and anxiety history), surgical characteristics (number of fusion levels, estimated blood loss), duration of symptoms, and preoperative and one- year postoperative patient reported outcomes measures (PROMs) including the modified Japanese Orthopaedic Association (mJOA), Neck Disability Index (NDI), VAS Neck pain, VAS Arm pain, and Short Form-12 Physical Component (PCS) and Mental Component (MCS) Scores were collected. Univariate and multivariate analyses controlling for demographic and surgical factors were performed to compare outcomes between groups based on symptom duration (< 6 months, 6 months – 2 years, ≥ 2 years).

Results: A total of 131 patients met the inclusion/exclusion criteria. Preoperative symptom duration groups differed significantly by sex (p= 0.003), where a greater percent of females experienced symptoms for more than two years (female: 72.4% vs male: 27.6%). All other demographics and surgical factors were comparable across symptom duration groups (Table 1). Univariate analysis demonstrated significantly decreased improvement in NDI (p= 0.026), MCS (p= 0.036), and PCS (p= 0.032) with longer symptom durations (Table 2). Increased preoperative symptom duration was associated with a significantly decreased percentage of patients achieving the clinically important difference (%MCID) for mJOA (p=0.032). Regression analysis found symptom duration greater than six months to be a predictor of decreased NDI, MCS, and PCS improvement and decreased mJOA %MCID achievement (Table 3).

Conclusion: Increased duration of preoperative symptoms before undergoing PCDF was associated with decreased postoperative improvement in functional status and myelopathic symptoms. While delay in operative treatment may impair functional recovery after PCDF, further research considering patient diagnosis and symptom severity are required to further evaluate the efficacy of early surgical intervention.

E-POSTER #35 continued

Table 1: Patient Demographics by Symptom Duration Groups

Patient Parameter	< 6 Months N=59	6 Months -2 Years N=43	> 2 Years N=29	P Value
Age	58.2 (10.8)	58.9 (10.7)	59.0 (10.3)	0.930
Sex:				**0.003**
Female	20 (33.9%)	19 (44.2%)	21 (72.4%)	
Male	39 (66.1%)	24 (55.8%)	8 (27.6%)	
BMI	31.7 (5.73)	29.9 (6.37)	30.7 (5.73)	0.321
Depression Diagnosis:	16 (27.1%)	16 (37.2%)	10 (34.5%)	0.532
Anxiety Diagnosis:	17 (28.8%)	14 (32.6%)	5 (17.2%)	0.344
Smoking:				0.108
Current smoker	6 (10.5%)	7 (16.3%)	5 (17.2%)	
Former Smoker	11 (19.3%)	9 (20.9%)	12 (41.4%)	
Non-Smoker	40 (70.2%)	27 (62.8%)	12 (41.4%)	
Number of levels fused	3.69 (1.52)	3.28 (1.72)	3.66 (1.65)	0.440
Estimated Blood Loss (cc)	190 (147)	152 (106)	250 (236)	0.423

E-POSTER #35 continued

Table 2: Patient Outcomes According to Preoperative Symptom Duration

Patient Outcome		< 6 Months	6 Months -2 Years	> 2 Years	P Value
mJOA	Preop	13.5 (2.84)	14.0 (3.02)	14.7 (2.69)	0.140
	Postop	14.6 (2.68)	14.4 (3.04)	13.6 (3.21)	0.360
	Δ	1.10 (3.41)	0.33 (2.74)	-1.14 (3.28)	0.059
	MCID Achieved	27.1%	20.9%	3.45%	**0.032**
NDI	Preop	42.9 (20.7)	42.8 (20.8)	41.4 (20.8)	0.943
	Postop	30.0 (17.5)	37.5 (21.6)	37.6 (21.7)	0.140
	Δ	12.9 (18.1)	5.23 (15.7)	3.81 (17.4)	**0.026**
	MCID Achieved	32.2%	16.3%	20.7%	0.157
MCS	Preop	45.6 (12.2)	44.9 (11.2)	48.0 (11.1)	0.493
	Postop	54.2 (10.1)	51.5 (11.6)	50.3 (12.2)	0.294
	Δ	8.61 (10.6)	6.60 (10.7)	2.29 (11.0)	**0.036**
	MCID Achieved	67.8%	58.1%	41.4%	0.060
PCS	Preop	29.2 (7.79)	32.3 (9.45)	32.9 (9.38)	0.150
	Postop	40.1 (10.3)	37.8 (10.6)	38.2 (9.91)	0.548
	Δ	10.9 (9.25)	5.50 (12.3)	5.29 (11.4)	**0.032**
	MCID Achieved	59.3%	44.2%	41.4%	0.175
VAS Neck	Preop	5.72 (2.80)	5.78 (2.80)	4.68 (3.55)	0.412
	Postop	2.19 (2.23)	2.74 (2.85)	1.96 (2.25)	0.601
	Δ	3.53 (2.93)	3.03 (3.18)	2.71 (2.93)	0.455
	MCID Achieved	40.7%	32.6%	27.6%	0.439
VAS Arm	Preop	5.99 (2.96)	6.15 (2.72)	5.34 (3.77)	0.798
	Postop	2.58 (2.30)	3.88 (2.95)	2.83 (2.26)	0.067
	Δ	3.41 (2.96)	2.27 (3.07)	2.51 (3.61)	0.166
	MCID Achieved	59.3%	51.2%	48.3%	0.551

Table 3: Multivariate Regression of Patient Outcomes by Symptom Duration Groups

Predictor	mJOA MCID Achievement		ΔNDI		ΔMCS		ΔPCS	
	ß- Estimate	P value	ß- Estimate	P value	ß- Estimate	P value	ß- Estimate	P value
Symptom Duration: < 6 Months (reference)								
6 Months -2 Years	-0.235	**0.013**	-11.191	**0.007**	-6.628	**0.010**	-6.183	**0.018**
> 2 Years	-0.062	0.440	-8.218	**0.018**	-2.093	0.334	-5.555	**0.012**
Sex: Male	0.004	0.954	-5.505	0.081	-0.794	0.688	-1.491	0.455

E-POSTER #36

Accuracy of an AI visional application for detecting 10-s grip and release test: preliminary results from 1143 participants

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Introduction: The 10-second grip-and-release test is validated for assessing hand dexterity and the severity of cervical myelopathy. Although several systems have been developed to count the number of grip-release cycles automatically, their complexity and instrumental specialization restrained their clinical application. In this study, we aim to develop and verify an artificial intelligent vision-based smartphone application for assessing the 10-s grip and release test.

Materials and Methods: The AI vision-based application was developed using Convolutional Neural Network (CNN) related algorithm. A total of 1143 participants (1056 healthy volunteers and 87 cervical myelopathy patients) were enrolled to perform the 10-s grip and release test with the AI application. All video data collected by the application were extracted and label manually for further CNN algorithm building. Among them 100 cases for training, 500 cases for validating/adjusting, and others for testing. The numbers, speeds, and varying degrees of finger motions were calculated using the application and were compared against manual labeled video recording. The average speed and variable coefficient of finger motion between patients and healthy volunteers were compared.

Results: The application automatically calculated the result of the 10-second grip and release test within 30 seconds (depends on the network speed) for each test. The average numbers of grip-release cycles in 10 seconds were: 26.2±4.7 Grips (healthy participants, counted by AI application), 26.7±5.1 Grips (healthy participants, counted by manual labeled), 18.5±5.2 Grips (patients, counted by AI application), 18.9±5.7 Grips (patients, counted by manual labeled). The total recognition rate of gripping was 97.69%. The Bland-Altman analysis and the intraclass correlation coefficient (ICC=0.91) showed the AI application has excellent reliability. The average grip speed, maximum grip speed, minimal grip speed, and the grip variable coefficient of finger motion (of the less dexterous hand) were 160.5±31 Grips Per Minute (GPM), 194.8±34 GPM, 148.2±27 GPM, 29% for healthy participants, and 111.2±21 GPM, 130.7±27 GPM, 102.5±18 GPM, 39.8% for patients, respectively. The average grip speed, the minimum grip speed, and the grip variable coefficient differed significantly between the patient group and the healthy group (all $P<0.05$). In the patient group, the average speed and the variable coefficient are significantly correlated with the mJOA score (r-value = 0.71).

Conclusion: The AI vision-based smartphone application is valid and reliable for assessing the 10-s grip and release test. Our results showed that this AI application is useful for research and clinical application. Several parameters, such as average grip speed and grip variable coefficient, are valuable for quantitatively evaluating the severity of cervical myelopathy. Further researches may focus on the efficacy of these parameters for hand dexterous evaluation in myelopathy patients.

E-POSTER #36 continued

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

E-POSTER #36 continued

E-POSTER #37

Do Patient Expectations Represent a More Important Clinical Difference? A Study of Surgical Outcomes in the Cervical Spine

Conor Lynch, MS, Elliot Cha, MS, Shruthi Mohan, BS, Cara Geoghegan, BS, Caroline Jadczak, BS, Kern Singh, MD[1]
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Introduction: Minimum clinically important difference (MCID) has been lauded as a more relevant assessment of postoperative outcomes.[1-2] However, patient expectations have also gained attention as an indicator for patient satisfaction.[3-5] Our study aims to compare the impact of achieving an MCID or meeting preoperative expectations on patient satisfaction following cervical spine procedures.

Materials and Methods: A prospectively maintained surgical database was retrospectively reviewed for patients undergoing cervical spine surgery from 2016 to 2020. Inclusion criteria were primary or revision, single- or multilevel cervical disc replacement or anterior cervical discectomy and fusion (ACDF). Exclusion criteria were incomplete expectations surveys or procedures indicated for trauma, infection, or malignancy. Demographic and perioperative characteristics were collected and descriptive statistics were performed. Patients' expectations for postoperative neck and arm pain were assessed preoperatively on a scale from 1-10. Visual analogue scale (VAS) neck and arm pain was assessed at preoperative and postoperative (6-week, 12-weeks, 6-months, 1-year) timepoints. Patient satisfaction regarding their current level of neck and arm pain was recorded at each postoperative timepoint. "Meeting expectations" was defined as postoperative VAS arm and neck scores equaling preoperative expectation scores. Achievement of MCID was determined using the following previously established values: VAS neck ≥ 2.6, VAS arm ≥ 4.1. [6] Linear regression was used to determine if meeting expectations or achieving MCID were predictors of postoperative satisfaction. Differences in effect sizes of expectations met and MCID achievement as predictors of satisfaction were directly compared.

Results: A total of 77 cervical spine patients were included. The cohort had a mean age of 48.8 years, was 40.3% female, and 44.0% obese (Table 1). Myeloradiculopathy was the most common preoperative spinal diagnosis (88.3%) and a majority of patients underwent ACDF (57.1%). Most procedures took place at a single level, mean operative time was 58.0 minutes and mean blood loss was 28.6 mL. Mean preoperative VAS arm pain was 4.6 ± 3.0 and mean preoperative VAS neck pain was 3.4 ± 2.7 (Table 2). Mean satisfaction ranged from 6.4-7.5 for arm pain and 6.6-7.5 for neck pain. A majority of patients met expectations for arm pain through 6-months and at 12-weeks and 1-year for neck pain. A majority of patients achieved MCID for VAS neck through 6-months, but at no timepoints for VAS arm. Meeting expectations for arm and neck pain was a significant predictor of satisfaction at all timepoints except 6-months (all $p \leq 0.003$) (Table 3). Achieving MCID significantly predicted postoperative satisfaction at 6-weeks and 12-weeks for arm pain (both $p \leq 0.013$) and at 12-weeks and 6-months for neck pain (both $p \leq 0.044$). Meeting expectations was a significantly stronger predictor of satisfaction than MCID for both arm and neck pain at 1-year ($p=0.007$, $p=0.012$) (Table 3).

Conclusion: Both MCID achievement and meeting expectations for VAS arm and neck were

E-POSTER #37 continued

significant predictors of satisfaction at short term timepoints. However, meeting expectations was the only significant predictor of satisfaction at 1-year. This suggests patient expectations may be a more valuable metric for assessing patient perceptions of long term pain improvement following cervical spine procedures.

Table 1. Patient Demographics

Characteristic	Total (n=77)
Age (mean ± SD, years)	48.8 ± 9.8
Gender	
Female	40.3% (31)
Male	59.7% (46)
Body Mass Index (BMI)	
<30 kg/m^2	56.0% (42)
≥30 kg/m^2	44.0% (33)
Smoking Status	
Non-Smoker	89.6% (69)
Smoker	10.4% (8)
Diabetic Status	
Non-Diabetic	94.8% (73)
Diabetic	5.2% (4)
ASA score	
≤2	90.3% (65)
>2	9.7% (7)
CCI Score	
<1	27.5% (14)
≥1	72.6% (37)
Ethnicity	
Caucasian	75.3% (58)
African American	10.4% (8)
Hispanic	10.4% (8)
Asian	3.9% (3)
Insurance	
Medicare/Medicaid	2.6% (2)
Workers' Compensation	22.4% (17)
Private	75.0% (57)

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD = standard deviation

E-POSTER #37 continued

Table 2. Patient Reported Outcomes

	VAS Mean ± SD	Satisfaction Mean ± SD	Met Expectations	Achieved MCID*
Arm Pain				
Preoperative	4.6 ± 3.0	-	-	-
6-weeks	2.3 ± 3.0	6.4 ± 3.8	51.6% (33)	34.4% (22)
12-weeks	2.4 ± 2.9	7.4 ± 3.5	57.9% (22)	31.6% (12)
6-months	2.0 ± 2.5	7.5 ± 2.9	56.3% (18)	40.6% (13)
1-year	2.7 ± 2.9	6.9 ± 3.4	35.3% (6)	17.7% (3)
Neck Pain				
Preoperative	3.4 ± 2.7	-	-	-
6-weeks	2.8 ± 2.6	6.6 ± 3.3	42.2% (27)	53.1% (34)
12-weeks	2.3 ± 2.4	7.5 ± 3.0	52.6% (20)	55.3% (21)
6-months	1.7 ± 2.0	7.2 ± 3.5	46.9% (15)	62.5% (20)
1-year	2.2 ± 2.5	7.4 ± 3.4	52.9% (9)	47.1% (8)

*MCID values based on results of Parker et al. [11]
SD = standard deviation

Table 3. Predictors of Satisfaction

	Meeting Expectations		Achieving MCID		
	Coef.	*p-value	Coef.	*p-value	†p-value
Arm Pain					
6-weeks	2.75	**0.003**	2.42	**0.013**	0.737
12-weeks	4.43	**<0.001**	3.29	**0.007**	0.205
6-months	1.61	0.130	1.07	0.358	0.414
1-year	5.09	**0.001**	2.79	0.216	**0.007**
Neck Pain					
6-weeks	2.88	**<0.001**	1.57	0.056	0.136
12-weeks	3.80	**<0.001**	2.00	**0.044**	0.069
6-months	1.87	0.140	3.00	**0.020**	0.524
1-year	4.69	**0.002**	2.15	0.207	**0.012**

*p-values calculated using simple linear regression to assess meeting expectations or achieving an MCID as a predictor of postoperative satisfaction
†p-values calculated using comparison of coefficients to determine differences in effect size between meeting expectations and achieving MCID as predictors of satisfaction
Boldface indicates statistical significance

E-POSTER #38

Machine learning approach in predicting clinically significant improvements after surgery in patients with cervical ossification of the posterior longitudinal ligament

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Introduction: Determining surgical outcomes of the patients with cervical ossification of the posterior longitudinal ligament (OPLL) helps surgeons to provide prognostic information to patients and manage their expectations. Machine learning (ML) is a mathematical model that finds patterns from a large sample of data and makes predictions outperforming traditional statistical methodss [1,2]. This study aimed to create a prognostic model for surgical outcomes in patients with cervical OPLL using ML.

Materials and Methods: This multicenter study prospectively recruited a total of 478 cases from the cervical OPLL surgery case database. Out of 478 patients, 397 and 370 patients had complete follow-up information at 1 and 2 years respectively and were included in the analysis. A minimal clinically important difference (MCID) was defined as an acquired Japanese Orthopaedic Association (JOA) score of 2.5 points or more [3], after which a ML model that predicts whether MCID can be achieved 1 and 2 years after surgery were created. Patient background, clinical symptoms, and imaging findings were used as variables for analysis. The present work used four binary classification models (i.e., LightGBM, XGBoost, random forest, and logistic regression) to predict whether neurological improvements achieved the MCID after surgery, as well as five regression models (LightGBM, XGBoost, random forest, and linear regression with no regularization and Elastic Net) to predict actual postoperative JOA scores. The performance of our models was evaluated using 10-fold cross-validation. Accuracy and area under the curve (AUC) were calculated to evaluate the binary classification model. The coefficient of determination (R2), root mean square error (RMSE), and mean absolute error (MAE) were calculated to evaluate the regression model.

Results: Table 1 shows the baseline characteristics and radiographic data that completed the 1-year follow-up dataset. The mean JOA score was 10.3 preoperatively, 13.4 at 1 year after surgery, and 13.5 at 2 years after surgery. A summary of the accuracy and AUC for each binary classification models predicting the achievement of MCID is presented in Table 2. XGBoost showed the highest AUC (0.72) and high accuracy (67.8) for predicting MCID at 1 year, while random forest had the highest AUC (0.75) and accuracy (69.6) for predicting MCID at 2 years. Table 3 summarizes the R2, RSME, and MAE values of each regression model predicting postoperative JOA scores. Accordingly, random forest exhibited the highest R2 (0.375) for predicting postoperative JOA score at 1 year, while Elastic Net had the highest R2 (0.330) for predicting postoperative JOA score at 2 years. Among the included features, total preoperative JOA score, duration of symptoms, body weight, sensory function of the lower extremity sub-score of the JOA, and age were identified as having the most significance in most of ML models.

Conclusion: The present study showed that the ML-based models have a moderate predictive

E-POSTER #38 continued

ability of surgical outcomes in patients with OPLL. The current study highlights the potential application of ML in predicting spinal surgery outcomes.

Table 1. Baseline characteristics of the patients who completed 1-year follow up

	N=393
Age	64.5±11.5
Male/Female	285/108
Height	162.8±9.7
Body weight	67.9±14.3
Body mass index	25.5±4.2
Comorbidities	
Diabetes	118
Hypertension	146
Malignancy	20
Previous cerebrovascular disease	21
Previous ischemic heart disease	14
Usage of anticoagulants and antiplatelet drugs	62
Smoking history	143
Duration of symptoms	44.0±65.4
Symptoms	
Numbness of upper extremity	347
Numbness of trunk	22
Numbness of lower extremity	225
Clumsy hands	283
Gait disturbance	263
Motor weakness of upper extremity	117
Motor weakness of lower extremity	95
Bladder function disturbance	85
Neck pain	26
JOA score	
Motor function of fingers	2.3 (0-4)
Motor function of shoulder and elbow	-0.2(-2-0)
Motor function of lower extremity	2.0(0-4)
Sensory function of upper extremity	0.9 (0-2)
Sensory function of trunk	1.6 (0-2)
Sensory function of lower extremity	1.3 (0-2)
Bladder function	2.3 (0-3)
Total	10.3 (-2-14.5)
Past history of thoracolumbar spine surgery	44
Type of OPLL	
Segment type	141
Mixed type	171
Continues type	54
Localized type	27
Thickness of OPLL	5.6±1.9
Occupation ratio of OPLL	44.4±15.8
C2-7 angle	
neutral	9.5±11.7
extension	19.9±12.4
flex	-7.0±13.6
ROM	26.9±13.9
K-line negative	131
Thoracic OPLL	81
Lumbar OPLL	43
High signal intensity change on T2 weighted MR image	340
Surgical procedure	
Laminoplasty	207
Posterior decompression with fusion	89
Anterior decompression with fusion	88
Combined anterior and posterior surgery	12
Number of levels involved in surgery	3.8±1.3

JOA, Japanese orthopaedic association; OPLL, ossification of the posterior longitudinal ligament

E-POSTER #38 continued

Table 2. Comparison of performance of the binary classification models to predict achieving MCID.

Models	1-year after surgery		2-year after surgery	
	Accuracy (%)	AUC	Accuracy (%)	AUC
LightGBM	68.8	0.71	65.8	0.72
XGBoost	**67.8**	**0.72**	69.3	0.72
Random forest	65.8	0.72	**69.6**	**0.75**
Logistic regression	62.6	0.70	65.3	0.72

MCID, minimal clinically important difference; AUC, area under the curve

Table 3. Comparison of performance of the regression models to predict postoperative JOA score.

Models	1-year after surgery			2-year after surgery		
	R2	RMSE	MAE	R2	RMSE	MAE
Light GBM	0.340	1.99	1.56	0.295	2.13	1.65
XG boost	0.358	1.96	1.54	0.315	2.10	1.63
Random forest	**0.375**	**1.92**	**1.52**	0.319	2.08	1.60
Linear Regression	0.314	2.02	1.62	0.303	2.10	1.64
Elastic Net	0.359	1.95	1.52	**0.336**	**2.05**	**1.58**

JOA, Japanese orthopaedic association; R2, coefficient of determination; RMSE, root mean square error; MAE, mean absolute error,

E-POSTER #39

Comparison of clinical results between minimally invasive cervical foraminotomy and anterior cervical decompression and fusion for cervical radiculopathy

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Introduction: As a surgical procedure for cervical radiculopathy, anterior cervical decompression and fusion (ACDF) or posterior foraminotomy is generally performed. Recently, the efficacy of minimally invasive cervical posterior foraminotomy has been reported. The purpose of this study was to clarify the efficacy of cervical microendoscopic foraminotomy (CMEF) compared with ACDF for the treatment of cervical disorders with radiculopathy.

Materials and Methods: Consecutive patients with cervical radiculopathy who required surgical treatment were enrolled. All enrolled patients (n = 79) underwent CMEF or ACDF. All patients were reviewed postoperatively for greater than 1 year. The preoperative and 1-year follow-up evaluations included neurological assessment. The primary outcome measure was the numeric rating scale (NRS) for neck and arm pain with a minimal clinically important difference defined as >15%. Secondary outcomes were assessed with additional patient reported outcomes measures (PROMs).

Results: CMEF was performed in 55 patients and 24 patients underwent ACDF. The mean preoperative NRS for neck and arm pain was respectively 5.6 and 6.0 points in the CMEF group and 5.2 and 5.6 points in the ACDF group ($p>0.05$). In both groups, their NRS improved significantly 1 year after surgery ($p<0.05$), and there were no significant differences between the groups ($p>0.05$). The VAS of surgical satisfaction was 82 mm in the CMEF group and 83 mm in the ACDF group ($p>0.05$). There was no significant difference between the groups in SF-36. As for perioperative complications, in the CMEF group, 3 patients had temporary muscle weakness over MMT1 grade, and 2 patients had temporary progressive numbness. In the ACDF group, 1 patient had a temporary dysphagia.

Conclusion: Patients with cervical disorders with radiculopathy were clinically improved in both groups, at 1-year follow-up, which were comparable. However, the transient neurological deterioration had clinically important differences in each group. CMEF had some complications related to nerve root, and ACDF had dysphagia.

E-POSTER #40

Oxygen regulated protein 150 (ORP150) suppresses the development of myelopathy in a rat model of chronic spinal cord compression

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Introduction: The strength of spinal cord compression doesn't always parallel neurological recovery.

To elucidate the discrepancy of locomotor recovery, we modified and developed a rat chronic compression model of rats (Kim et al., Ijima et al.). In our rat model of chronic spinal cord compression, some rats developed myelopathy while others were not. It is suggested that some compensatory neuroprotective mechanism was underlain in the expression of neurological phenotype in rats. Oxygen-regulated-protein150 (ORP150) is a neuroprotective protein expressed in neurons in response to neuronal ischemia. It is also well investigated that ORP150 expression in neurons inhibits neuron death. We hypothesized that the expression of ORP150 in a rat spinal cord of chronic compression might have a relation for the survival of neurons, come to variation of neurological difference among our chronic compression model. In the present study, we aim to elucidate whether ORP150 expression has relation to the severity of neurological recovery among our rat chronic compression model.

Materials and Methods:

We used thirty 8-week-old female SD rats. A water-expansion sheet (3 × 5 × 0.5mm) was inserted under the C4/5 lamina after C6 laminectomy to create a chronic spinal cord compression model. A behavioral evaluation (Basso, Beattie, Bresnahan score: BBB score) was performed for 10 weeks after surgery (Figure 1). The group of rats with the decreased motor function was defined as CSM(+) group (BBB score ≦ 18), and the asymptomatic group was defined as CSM(-) group (BBB score ≧ 19). In the sham group, only C6 laminectomy was performed. At ten weeks postoperatively, the occupancy of the spinal canal by the sheet was calculated by micro-CT, and the spinal cord was extracted, luxol fast blue (LFB) staining, double immunohistochemical staining by NeuN and ORP150 antibodies, and real-time PCR were performed.

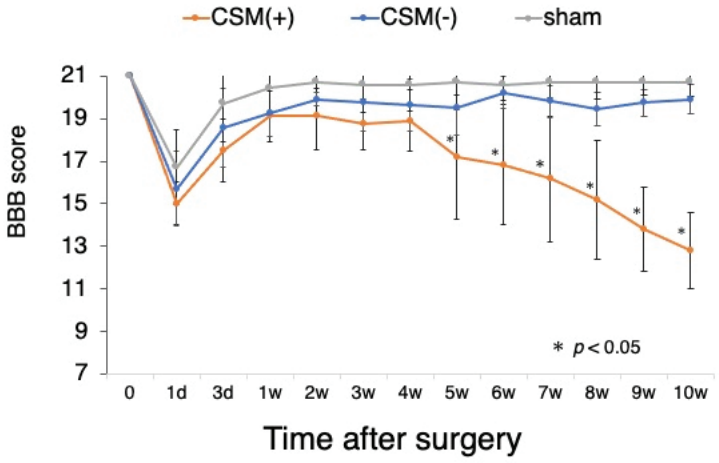
Results: A mean spinal canal occupancy of CSM(+) and CSM(-) groups were 41.0% (±8.8) and 38.0% (±8.7), respectively, with no significance. LFB staining showed that the corticospinal tract's myelinated area was significantly decreased in CSM(+) group ($p < 0.05$). Immunohistochemistry showed that the number of NeuN positive anterior horn neurons was significantly reduced in CSM(+) group. ORP150 positive anterior horn neurons were expressed in both CSM(+) and CSM(-) groups, but their expression was significantly increased in CSM(-) group ($p < 0.05$). (Figure 2). Real-time PCR showed that the RNA expression of ORP150 was significantly increased in CSM(-) group compared with CSM(+) group ($p < 0.05$). (Figure 3).

Conclusion: There was no relationship between the onset of myelopathy and spinal canal occupancy by the expanded sheet. ORP150 has been reported to contribute to long-term cell survival under ischemic conditions in the central nervous system. In both CSM(+) and CSM(-) groups, ORP150 was expressed in neurons, which suggested spinal cord ischemia due to

E-POSTER #40 continued

spinal cord compression. In CSM (-) group, the expression of ORP150 was increased, and it is considered that the onset of myelopathy was suppressed by the protection of neurons.

Figure 1: Graphs illustrating Basso, Beattie, and Bresnahan (BBB) scores. There were significant differences in the locomotor score between CSM(+) and CSM(-) since 5 weeks after surgery. *$p < 0.05$



E-POSTER #40 continued

Figure 2

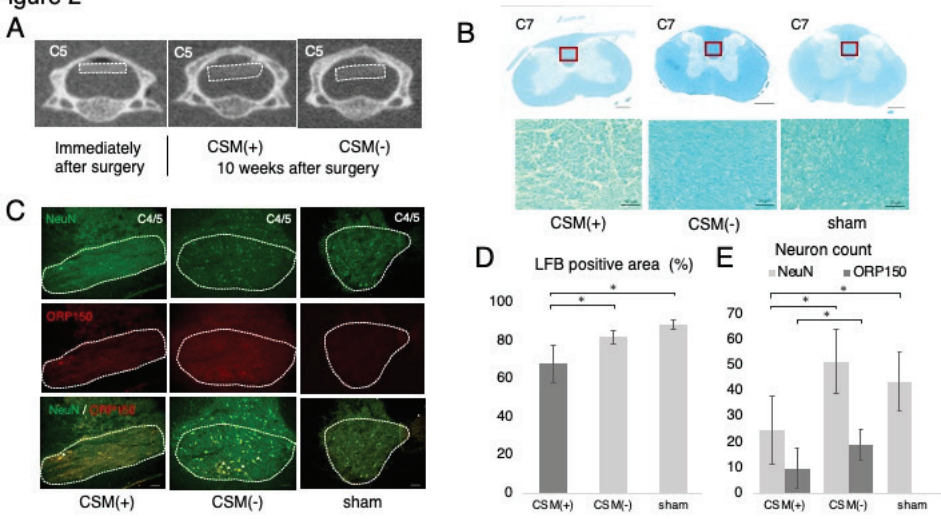
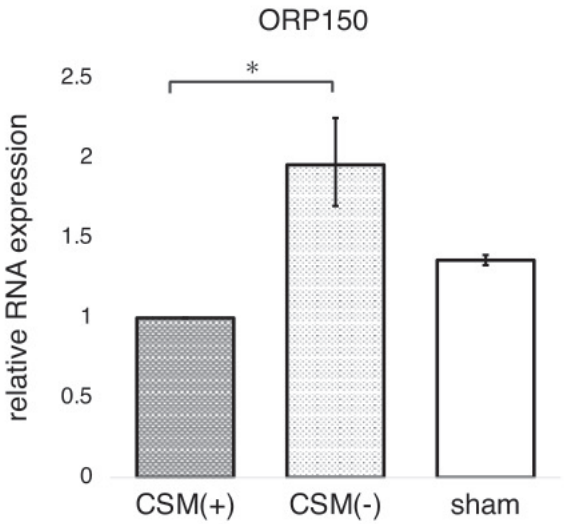


Figure 3: Bar graph shows the relative RNA expressions of ORP150 in the spinal cord at the C4-5 level in CSM(+), CSM(-), and sham-operated rats. Means and SD are indicated (n = 6 of rats for each group). The relative expression of RNA were determined by a comparative Ct ($\Delta\Delta$Ct) method. *$p < 0.05$ by Kruskal-Wallis test.



E-POSTER #41

Automated detection of cervical ossification of the posterior longitudinal ligament in plain lateral radiographs of the cervical spine using a convolutional neural network

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Introduction: Cervical ossification of the posterior longitudinal ligament (OPLL) is a contributing factor to spinal cord injury or trauma-induced myelopathy in the elderly. To reduce the incidence of these traumas, it is essential to diagnose OPLL at an early stage and to educate patients how to prevent falls. Convolutional neural network (CNN) has been developed to mimic the central nervous system in human image recognition, and it automatically and adaptively learns features from data using multiple building blocks. Notably, CNN is an artificial intelligence technique that is useful in the field of image recognition, including for medical imaging. We evaluated the ability of our CNN to differentially diagnose cervical spondylosis and cervical OPLL. We compared the diagnostic accuracy of the CNN with that of expert spine surgeons to validate the CNN as a screening tool for OPLL.

Materials and Methods: We retrospectively analyzed the medical records of patients in our hospital over the past 18 years and enrolled 250 patients with cervical spondylosis, 250 patients with cervical OPLL, and 180 radiographically normal controls. Plain lateral cervical spine radiographs were used for CNN training and validation. In this study, we used the EfficientNetB4 architectural model. The CNN architecture model was built using the deep learning framework TensorFlow.

We evaluated the ability of the CNN model to distinguish cervical spondylosis, OPLL, and normal controls using a validation dataset that was not included in the training dataset. We trained the CNN model using 200 cervical spondylosis cases, 200 OPLL cases, and 130 normal cases. Then, we further validated the performance of CNN in an additional 150 cases using 50 cases in each group. For the 50 patients with OPLL in the test dataset, the type of the OPLL was also recorded. The same 150 test cases (50 cases in each group) were examined by 5 board-certified spine surgeons, and their diagnostic accuracy was compared to that of the CNN.

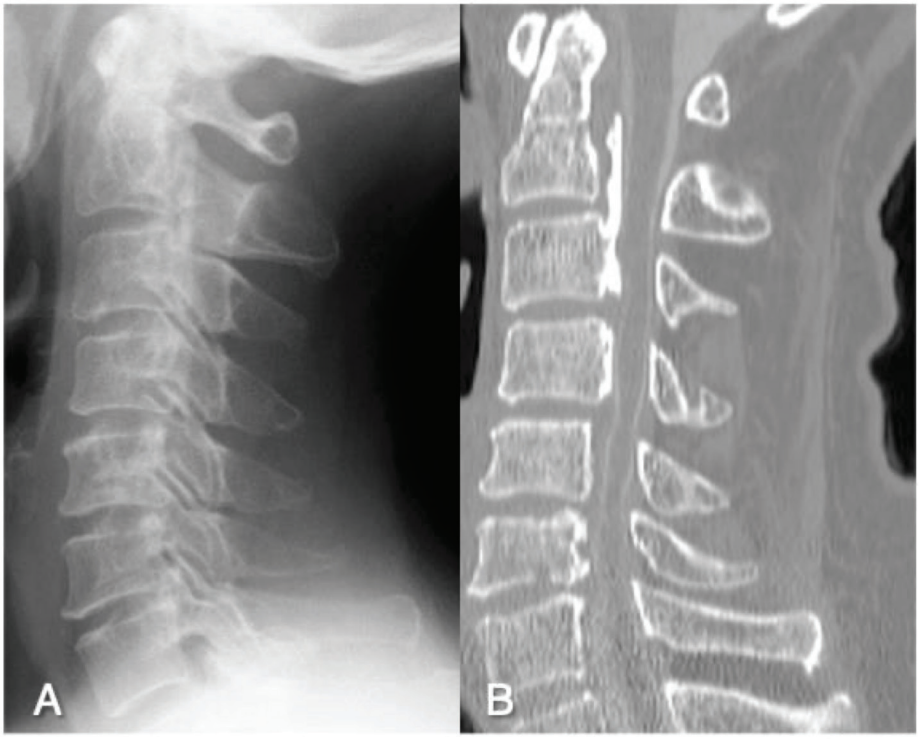
Results: Figure 1 shows representative lateral cervical spine radiographs and their corresponding CTs of OPLL, which the CNN and spine surgeons either diagnosed correctly or misdiagnosed. The accuracy, average recall, precision, and F1 score of the CNN for classification of lateral cervical spine radiographs were 0.86, 0.86, 0.87, and 0.87, respectively (Table 1). The accuracy was higher for CNN compared to any expert spine surgeon, and was statistically equal to 4 of the 5 experts and significantly higher than that of 1 expert. For validation of the OPLL type, the recall scores for segmental and localized types were lower compared to continuous and mixed types in both CNN and spine surgeons (Table 2).

Conclusion: We demonstrated that the CNN differentiated cervical spondylosis, OPLL, and controls using lateral cervical radiographs at a level equal or superior to that of spine surgeons. An artificial intelligence–based diagnostic model of lateral cervical spine radiographs could help non-experts diagnose cervical spine OPLL and also help determine whether further

E-POSTER #41 continued

imaging is needed.

Figure 1: Representative radiographs used in the test dataset and their corresponding computed tomography (CT) images, for the reference of ossification of the posterior longitudinal ligament (OPLL).



E-POSTER #41 continued

Table 1: Performance Metrics of the CNN and Spine Surgeons of Diagnoses Made Using Lateral Cervical Spine Radiographs

	Accuracy	*P* value (compared with CNN)	Average recall	Average precision	Average F1 score
CNN	0.86	-	0.86	0.87	0.87
Spine surgeon 1	0.83	0.50	0.83	0.82	0.83
Spine surgeon 2	0.83	0.43	0.83	0.83	0.83
Spine surgeon 3	0.81	0.22	0.81	0.81	0.81
Spine surgeon 4	0.81	0.20	0.81	0.84	0.83
Spine surgeon 5	0.76	0.018	0.76	0.76	0.76

CNN, convolutional neural network

Table 2: The Recall (Sensitivity) of the CNN and Spine Surgeon for Each OPLL Type

OPLL type	Recall for the CNN	Average recall for spine surgeons
Continuous	83% (5/6)	81%
Segmental	72% (13/18)	63%
Mixed	87% (19/22)	94%
Localized	50% (2/4)	63%

E-POSTER #42

Diabetes Mellitus does not Impact Achievement of a Minimum Clinically Important Difference following Anterior Cervical Discectomy and Fusion

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Introduction: There are currently no studies assessing whether diabetes mellitus (DM) impacts patients' likelihood of achieving a minimum clinically important difference (MCID) in patient reported outcome measures (PROMs) following ACDF.[1-3] Our study aims to assess the impact of DM on achievement of MCID following ACDF.

Materials and Methods: A surgical database was retrospectively reviewed for patients who underwent primary, single level ACDF procedures with posterior instrumentation. Demographic variables, preexisting spinal diagnosis, and operative characteristics were collected. Demographic variables included patient age, gender, body mass index (BMI), smoking status, American Society of Anesthesiologists physical classification (ASA), Charlson Comorbidity Index, insurance status, DM, and hypertension status. Operative variables included level of fusion, operative time (skin incision to closure), estimated blood loss (EBL), length of postoperative, and day of discharge. Visual Analogue Scales (VAS) for arm and neck pain, Oswestry Disability Index (NDI), and Patient-Reported Outcomes Measurement Information System and 12-item Short Form (SF-12) scores for physical function (PF) were recorded at preoperative, 6-week, 12-week, 6-month, and 1-year postoperative timepoints. MCID achievement at each timepoint was calculated using the following values: 2.6 for VAS neck; 4.1 for VAS arm; 8.5 for NDI; 8.1 for SF-12; 4.5 for PROMIS-PF.[4-5] Patients were categorized as diabetic or non-diabetic. Associations of diabetes subgroups with demographic variables, preexisting spinal diagnoses, and operative characteristics were assessed using a Chi squared test and t-test. Intergroup differences in mean PROM scores at each timepoint were determined using a t-test and intragroup differences from baseline were assessed using a paired t-test. Chi squared analysis determined differences in MCID achievement rates by diabetic group at all timepoints.

Results: The cohort of 363 patients had 43 diabetics and 320 non-diabetics. DM status was significantly associated with age, ethnicity, hypertension, ASA, CCI, and insurance type (all $p \leq 0.041$). Postoperative length of stay was significantly greater for the DM group ($p=0.011$). Mean VAS arm and NDI differed at 6-months ($p \leq 0.049$, both) and PROMIS-PF differed from 6-weeks through 6-months ($p \leq 0.039$, all). Non-diabetics significantly improved in VAS neck, VAS arm, NDI, SF-12, and PROMIS PF by 1-year postoperatively ($p<0.01$, all). Diabetics significantly improved in VAS neck, VAS arm, SF-12 PCS, and PROMIS-PF by 1-year (all $p \leq 0.013$) but NDI significantly improved only at 12-weeks ($p=0.038$). Intergroup differences for MCID achievement were demonstrated at 6-months for NDI and SF-12 PCS ($p \leq 0.008$).

Conclusion: Both diabetic and non-diabetic patients demonstrated significant improvements in pain throughout the postoperative period. Physical function improved dissimilarly between groups, with significant changes observed at a later time for diabetic patients. Only non-diabetic patients demonstrated significant improvements in disability. Achievements of MCID were largely similar between groups for all outcome measures at all timepoints. Our results

E-POSTER #42 continued

indicate that patients may realize similar benefits of ACDF surgery, regardless of DM status.

Table 1. Patient Demographics

Demographic	Total (n=363)	Non-Diabetic (n=320)	Diabetic (n=43)	*p-value
Age (mean ± SD)	50.5 ± 10.3	49.6 ± 9.9	57.3 ± 11.0	**<0.001**
Gender				0.511
Female	41.9% (152)	41.3% (132)	46.5% (20)	
Male	58.1% (211)	58.8% (188)	53.5% (23)	
Body mass index (BMI)				**<0.001**
<30 kg/m^2	56.7% (204)	61.0% (194)	23.8% (10)	
≥30 kg/m^2	43.3% (156)	39.0% (124)	76.2% (32)	
Ethnicity				**0.001**
White	74.9% (272)	77.2% (247)	58.1% (25)	
African American	11.9% (43)	9.4% (30)	30.2% (13)	
Hispanic	7.4% (27)	8.1% (26)	2.3% (1)	
Asian	2.2% (8)	1.9% (6)	4.7% (2)	
Other	3.6% (13)	3.4% (11)	4.7% (2)	
Smoking Status				0.737
Non-Smoker	83.2% (302)	83.4% (267)	81.4% (35)	
Smoker	16.8% (61)	16.6% (53)	18.6% (8)	
Hypertension				**<0.001**
Non-Hypertensive	67.7% (246)	73.8% (236)	23.3% (10)	
Hypertensive	32.2% (117)	26.3% (84)	76.7% (33)	
ASA score				**<0.001**
≤2	85.6% (268)	91.3% (251)	44.7% (71)	
>2	14.4% (45)	8.7% (24)	55.3% (21)	
CCI Score				**<0.001**
<2	47.3% (167)	52.9% (164)	7.0% (3)	
≥2	52.7% (186)	47.1% (146)	93.0% (40)	
Insurance				**0.041**
Medicare/Medicaid	8.0% (29)	6.6% (21)	18.6% (8)	
Workers' Compensation	30.9% (112)	31.7% (101)	25.6% (11)	
Private	61.1% (221)	61.8% (197)	55.8% (24)	
Spinal Pathology				
HNP	83.2% (302)	83.1% (266)	83.7% (36)	0.922
Central Stenosis	46.8% (170)	45.0% (144)	60.5% (26)	0.056

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; HNP = herniated nucleus pulposus

Boldface indicates statistical significance

* p-value calculated using two sample t-test or Chi squared test to compare non-diabetic and diabetic groups

E-POSTER #42 continued

Table 2. Mean Patient Reported Outcome Measure Scores

PROM	Non-diabetic (Mean ± SD)	†p-value	Diabetic (Mean ± SD)	†p-value	*p-value
VAS Neck					
Preoperative	6.0 ± 2.6	-	6.1 ± 2.3		0.903
6-weeks	3.5 ± 2.5	**<0.001**	3.3 ± 2.7	**<0.001**	0.673
12-weeks	3.0 ± 2.5	**<0.001**	4.0 ± 2.7	**0.001**	0.092
6-months	2.7 ± 2.6	**<0.001**	4.3 ± 2.8	**0.013**	**0.016**
1-year	3.3 ± 2.8	**<0.001**	3.6 ± 2.7	**0.010**	0.658
VAS Arm					
Preoperative	5.9 ± 2.7	-	6.0 ± 2.5	-	0.835
6-weeks	2.8 ± 2.6	**<0.001**	2.8 ± 2.5	**<0.001**	0.921
12-weeks	2.8 ± 2.9	**<0.001**	3.5 ± 2.8	**<0.001**	0.317
6-months	2.6 ± 2.8	**<0.001**	4.0 ± 2.6	**0.013**	**0.044**
1-year	3.4 ± 3.2	**<0.001**	3.1 ± 3.3	**0.013**	0.758
NDI					
Preoperative	40.3 ± 19.5	-	38.6 ± 20.6	-	0.694
6-weeks	31.7 ± 18.9	**<0.001**	30.0 ± 19.0	0.140	0.682
12-weeks	26.8 ± 19.3	**<0.001**	30.0 ± 20.5	**0.038**	0.507
6-months	22.4 ± 19.4	**<0.001**	32.7 ± 23.8	0.690	**0.049**
1-year	22.9 ± 21.0	**<0.001**	27.3 ± 20.1	0.195	0.464
SF-12 PCS					
Preoperative	37.8 ± 9.9	-	36.4 ± 7.5	-	0.428
6-weeks	37.3 ± 9.1	0.167	35.8 ± 10.6	0.451	0.481
12-weeks	44.3 ± 10.1	**<0.001**	41.7 ± 11.9	**0.014**	0.217
6-months	41.8 ± 10.6	**<0.001**	37.7 ± 9.0	0.079	0.187
1-year	44.1 ± 10.6	**<0.001**	40.5 ± 8.2	**0.003**	0.180
PROMIS-PF					
Preoperative	40.2 ± 7.3	-	37.5 ± 5.2	-	0.124
6-weeks	41.6 ± 7.0	0.071	37.6 ± 6.2	0.797	**0.039**
12-weeks	45.6 ± 9.0	**<0.001**	38.9 ± 11.7	0.315	**0.013**
6-months	47.7 ± 9.8	**<0.001**	47.7 ± 40.9	**0.001**	**0.021**
1-year	47.8 ± 8.7	**<0.001**	46.0 ± 8.9	**0.003**	0.479

VAS = Visual Analog Scale; NDI = Neck disability index; SF-12 = Short Form-12; PROMIS-PF = Patient-Reported Outcomes Measurement Information System physical function
†p-values calculated using paired t-test of pre- vs postoperative scores within groups
*p-values calculated using a two sample t-test of mean scores between groups
Boldface indicates significance

E-POSTER #42 continued

Table 3. MCID Achievement

PROM	Non-diabetic	Diabetic	†p-value
VAS Neck			
6-week	46.0% (93)	44.4% (12)	0.876
12-week	57.4% (109)	45.0% (9)	0.289
6-month	57.6% (95)	34.3% (6)	0.078
1-year	42.1% (37)	46.2% (6)	0.780
overall	67.7% (149)	63.0% (17)	0.619
VAS Arm			
6-week	39.3% (73)	31.8% (7)	0.498
12-week	37.9% (65)	35.3% (6)	0.839
6-month	39.6% (61)	21.4% (3)	0.180
1-year	28.7% (25)	30.8% (4)	0.880
overall	51.2% (104)	40.9% (9)	0.358
NDI			
6-week	45.1% (82)	36.4% (8)	0.438
12-week	58.6% (99)	52.9% (9)	0.653
6-month	**70.3% (104)**	**35.7% (5)**	**0.008**
1-year	59.8% (49)	46.2% (6)	0.356
overall	73.0% (143)	68.2% (15)	0.634
SF-12 PCS			
6-week	21.1% (32)	30.0% (6)	0.365
12-week	38.0% (70)	42.3% (11)	0.676
6-month	**48.5% (48)**	**8.3% (1)**	**0.008**
1-year	46.3% (31)	20.0% (3)	0.062
overall	48.3% (114)	46.8% (15)	0.879
PROMIS-PF			
6-week	35.4% (29)	42.9% (6)	0.590
12-week	52.2% (36)	41.7% (5)	0.502
6-month	60.7% (37)	72.7% (8)	0.447
1-year	65.3% (32)	73.3% (11)	0.562
overall	63.3% (62)	82.4% (14)	0.125

The following MCID values derived from Parker et al.; VAS neck =2.6, VAS arm =4.1, NDI=8.5, SF-12 =8.1; PROMIS MCID values derived from Steinhaus et al: PROMIS-PF = 4.5

VAS = Visual Analog Scale; NDI = Neck disability index; SF-12 = Short Form-12; PROMIS-PF = Patient-Reported Outcomes Measurement Information System physical function

†p-value was calculated for each category using chi squared analysis

Boldface indicates statistical significance

E-POSTER #43

Influence of Preoperative Severity on Postoperative Improvement Among Patients with Myeloradiculopathy Following Anterior Cervical Discectomy and Fusion

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Introduction: Few studies have investigated how neck pain and disability, assessed by neck disability index (NDI) and visual analogue scale (VAS), improve differently among patients with both myelopathy and radiculopathy.[1-3] Our study aims to determine how neck pain and disability improve following ACDF among patients with myeloradiculopathy.

Materials and Methods: Eligible patients were identified through retrospective review of a surgical database. Inclusion criteria was primary, elective, single or multilevel ACDF. Demographics, perioperative information, and patient reported outcome measures (PROM) were collected. PROMs included VAS neck/arm, NDI, 12-Item Short Form physical composite score (SF-12 PCS), Patient-Reported Outcomes Measurement Information System physical function (PROMIS PF), and Patient Health Questionnaire 9 (PHQ-9). Patients were categorized according to preoperative symptom severity: High VAS arm (>7); High NDI (>55); High VAS arm and NDI; and moderate symptoms. Demographics and perioperative information for groups were tested for independence using chi-square analysis or t-test. Impact of preoperative symptom severity on PROM scores and magnitude of change were assessed using linear regression. Achievement of a minimum clinically important difference (MCID) was calculated for all groups using previously established values. Impact of preoperative symptoms on MCID achievement was determined using logistic regression. Alpha value was adjusted for multiple testing using a bonferroni correction.

Results: The study included 187 eligible patients with 14 with High NDI, 46 with High VAS arm, 29 with High NDI and VAS arm, and 98 with neither high VAS arm or NDI. Mean age was 50.2 years, average BMI was 29.4 and 61.0% were male. Insurance collected was the only significant demographic between groups (p=0.014). Majority of ACDFs were single level with a mean operative time of 61.6 minutes, average blood loss of 32.3mL, and average postoperative stay of 13.7 hours. The most prevalent spinal pathology was herniated nucleus pulposus (82.9%). No significant differences in perioperative characteristics were demonstrated. Preoperative VAS neck, VAS arm, NDI, SF-12 PCS, PROMIS PF, and PHQ-9 significantly differed by group (all $p<0.001$). Symptom severity had a significant impact on postoperative VAS neck (all timepoints; $p<0.002$), VAS arm (6-weeks; p=0.007), NDI (6-weeks to 6-months; $p<0.001$), SF-12 PCS (6-months; p=0.004), PROMIS PF (6-weeks; p=0.007), and PHQ-9 (6-weeks and 6-months; $p<0.001$) (Table 1). Magnitude of improvement at all postoperative timepoints differed by severity groups for VAS arm, NDI, and VAS neck, except at 1-year (all $p<0.002$) (Table 2). Overall MCID achievement differed by symptom severity for VAS neck and arm, and NDI ($p<0.005$). MCID achievement demonstrated significant differences between groups at intermittent timepoints for VAS arm (all timepoints), VAS neck (6-weeks), and NDI (6-months) (all $p<0.002$) (Table 3). MCID achievement for physical function PROMs and PHQ-9 were not significantly different.

Conclusion: Patients with myeloradiculopathy demonstrated significant differences in

E-POSTER #43 continued

PROM scores based on severity of preoperative symptoms. PROM improvement and MCID achievement for neck disability, neck pain, and arm pain were the only values that differed based on symptom severity. This suggests patients with myeloradiculopathy can expect differing levels of improvement following ACDF based on the prevalent preoperative symptom.

Table 1. PROM Scores by Preoperative Severity

	Moderate (Mean ± SD)	High NDI (Mean ± SD)	High VAS (Mean ± SD)	NDI/VAS (Mean ± SD)	*p-value
VAS Neck					
Preoperative	4.6 ± 2.1 (98)	6.7 ± 1.4 (14)	7.2 ± 1.8 (46)	8.8 ± 1.1 (29)	**<0.001**
6-weeks	2.9 ± 2.2 (92)	4.4 ± 2.2 (12)	2.8 ± 2.2 (39)	6.0 ± 2.3 (23)	**<0.001**
12-weeks	2.4 ± 2.0 (84)	4.4 ± 1.9 (10)	2.4 ± 2.3 (32)	5.4 ± 3.0 (25)	**<0.001**
6-months	2.2 ± 2.1 (77)	4.4 ± 2.8 (8)	2.0 ± 2.1 (25)	4.7 ± 3.3 (24)	**0.002**
1-year	2.3 ± 2.1 (42)	4.9 ± 2.0 (6)	3.1 ± 2.2 (20)	6.1 ± 3.6 (9)	**<0.001**
VAS Arm					
Preoperative	4.0 ± 2.1 (98)	5.2 ± 1.7 (14)	8.0 ± 0.8 (46)	8.8 ± 0.9 (29)	**<0.001**
6-weeks	2.4 ± 2.4 (92)	4.2 ± 2.7 (12)	2.7 ± 4.0 (41)	4.7 ± 2.8 (28)	**0.007**
12-weeks	2.4 ± 2.7 (82)	3.6 ± 3.2 (10)	2.2 ± 2.3 (32)	4.3 ± 3.5 (25)	0.032
6-months	2.3 ± 2.6 (77)	3.9 ± 2.3 (7)	2.0 ± 2.5 (25)	4.3 ± 3.7 (23)	0.037
1-year	3.0 ± 3.1 (42)	3.7 ± 3.9 (7)	3.4 ± 2.7 (20)	4.4 ± 3.7 (9)	0.300
NDI					
Preoperative	28.4 ± 14.1 (98)	62.7 ± 4.3 (14)	39.7 ± 12.2 (46)	69.0 ± 10.5 (29)	**<0.001**
6-weeks	26.2 ± 16.2 (92)	53.0 ± 17.9 (12)	26.7 ± 15.4 (41)	54.1 ± 17.9 (22)	**<0.001**
12-weeks	22.3 ± 15.8 (82)	49.6 ± 18.9 (10)	22.4 ± 16.6 (32)	45.6 ± 23.2 (25)	**<0.001**
6-months	18.2 ± 15.7 (77)	40.8 ± 24.1 (7)	17.9 ± 17.9 (25)	40.6 ± 23.9 (23)	**<0.001**
1-year	18.3 ± 15.4 (42)	42.3 ± 24.9 (6)	20.7 ± 16.4 (20)	40.7 ± 28.0 (9)	0.016
SF-12 PCS					
Preoperative	36.6 ± 8.9 (83)	25.7 ± 5.4 (10)	36.0 ± 7.9 (40)	28.6 ± 5.9 (27)	**0.001**
6-weeks	36.5 ± 7.8 (59)	28.7 ± 6.2 (9)	38.4 ± 9.5 (24)	29.4 ± 4.9 (18)	0.039
12-weeks	41.6 ± 10.1 (47)	31.5 ± 8.6 (7)	43.0 ± 10.3 (18)	32.8 ± 6.7 (14)	0.290
6-months	44.1 ± 9.8 (48)	34.0 ± 6.6 (7)	41.4 ± 12.6 (14)	34.0 ± 9.3 (14)	**0.004**
1-year	45.1 ± 9.6 (40)	21.9 ± 6.4 (4)	46.0 ± 7.8 (13)	43.6 ± 11.7 (6)	0.931
PROMIS PF					
Preoperative	42.2 ± 6.7 (57)	35.3 ± 6.8 (8)	40.1 ± 6.1 (26)	31.9 ± 4.2 (13)	**<0.001**
6-weeks	43.0 ± 3.2 (46)	36.4 ± 7.6 (7)	41.9 ± 6.8 (18)	34.1 ± 4.0 (7)	**0.007**
12-weeks	46.7 ± 9.5 (37)	37.2 ± 7.0 (5)	48.0 ± 9.5 (12)	38.0 ± 3.1 (6)	0.019
6-months	50.5 ± 8.1 (34)	43.8 ± 3.0 (5)	44.4 ± 9.8 (10)	36.7 ± 8.4 (6)	0.255
1-year	50.8 ± 7.3 (32)	39.2 ± 8.8 (4)	49.3 ± 10.6 (11)	53.9 ± 5.8 (2)	0.020
PHQ-9					
Preoperative	3.8 ± 4.1 (51)	12.8 ± 7.5 (7)	8.4 ± 5.8 (29)	13.8 ± 6.4 (14)	**<0.001**
6-weeks	3.1 ± 3.1 (49)	11.3 ± 7.2 (6)	3.5 ± 3.6 (24)	11.3 ± 7.1 (13)	**<0.001**
12-weeks	2.7 ± 3.0 (45)	13.0 ± 8.6 (5)	2.2 ± 3.0 (18)	9.4 ± 9.6 (11)	0.015
6-months	2.5 ± 3.2 (43)	9.2 ± 6.4 (7)	4.1 ± 4.7 (16)	10.4 ± 7.8 (12)	**<0.001**
1-year	3.8 ± 5.3 (26)	15.0 ± 5.6 (2)	1.3 ± 2.2 (10)	10.5 ± 7.8 (4)	0.462

*p-values calculated using linear regression
Boldface indicates statistical significance; SD = standard deviation

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

E-POSTER #43 continued

Table 2. Postoperative Improvement by Preoperative Severity

	Moderate (Mean ± SD)	**High NDI** (Mean ± SD)	**High VAS** (Mean ± SD)	**NDI/VAS** (Mean ± SD)	*p-value
ΔVAS Neck					
Preoperative	-	-	-	-	
6-weeks	-1.7 ± 2.7	-2.3 ± 2.6	-4.2 ± 2.7	-2.9 ± 5.3	**<0.001**
12-weeks	-2.2 ± 2.6	-2.4 ± 1.7	-4.6 ± 2.8	-3.5 ± 2.7	**0.001**
6-months	-2.2 ± 2.7	-2.6 ± 2.9	-5.1 ± 3.2	-4.2 ± 3.6	**<0.001**
1-year	-2.3 ± 2.8	-2.0 ± 2.8	-3.4 ± 3.0	-2.9 ± 4.2	0.277
ΔVAS Arm					
Preoperative	-	-	-	-	
6-weeks	-1.5 ± 2.9	-0.7 ± 2.9	-5.3 ± 3.9	-4.0 ± 2.9	**<0.001**
12-weeks	-1.6 ± 3.1	-1.2 ± 3.6	-5.8 ± 2.4	-4.5 ± 3.4	**<0.001**
6-months	-1.5 ± 3.0	-0.8 ± 2.5	-6.0 ± 2.6	-4.5 ± 3.6	**<0.001**
1-year	-0.7 ± 3.7	-0.9 ± 3.2	-4.4 ± 2.8	-4.8 ± 3.7	**<0.001**
ΔNDI					
Preoperative	-	-	-	-	
6-weeks	-1.8 ± 15.7	-9.6 ± 17.9	-13.5 ± 16.7	-14.4 ± 17.4	**<0.001**
12-weeks	-7.2 ± 15.8	-13.2 ± 16.8	-17.7 ± 18.2	-24.4 ± 20.5	**<0.001**
6-months	-10.7 ± 16.7	-20.5 ± 25.1	-25.6 ± 17.7	-27.8 ± 23.4	**<0.001**
1-year	-9.1 ± 23.7	-20.3 ± 23.7	-19.7 ± 14.7	-28.8 ± 28.4	**0.002**
ΔSF-12 PCS					
Preoperative	-	-	-	-	
6-weeks	0.5 ± 8.5	2.6 ± 6.6	1.0 ± 9.9	1.3 ± 4.6	0.683
12-weeks	4.4 ± 8.2	5.2 ± 7.7	6.9 ± 12.1	3.2 ± 7.8	0.909
6-months	7.8 ± 8.7	6.8 ± 4.2	7.8 ± 14.2	4.8 ± 10.2	0.403
1-year	8.0 ± 9.1	-3.2 ± 9.3	10.7 ± 9.7	12.9 ± 13.7	0.260
ΔPROMIS PF					
Preoperative	-	-	-	-	
6-weeks	1.0 ± 8.2	-0.02 ± 5.0	1.1 ± 8.3	2.3 ± 3.4	0.782
12-weeks	3.7 ± 7.7	0.4 ± 7.9	9.4 ± 9.9	5.1 ± 5.9	0.158
6-months	7.9 ± 6.3	7.8 ± 7.7	6.5 ± 9.2	4.3 ± 7.1	0.255
1-year	8.6 ± 7.3	3.1 ± 9.1	10.8 ± 10.0	19.0 ± 8.1	0.186
ΔPHQ-9					
Preoperative	-	-	-	-	
6-weeks	-0.5 ± 3.5	-2.6 ± 4.6	-5.0 ± 6.0	-1.0 ± 7.6	0.050
12-weeks	-1.4 ± 4.5	-1.0 ± 3.8	-5.0 ± 4.9	-4.8 ± 8.5	0.017
6-months	-0.9 ± 4.4	-1.7 ± 5.5	-5.0 ± 7.7	-3.7 ± 8.8	0.055
1-year	-0.9 ± 5.6	-7.0 ± 11.3	-5.1 ± 4.2	-2.3 ± 14.5	0.152

*p-values calculated using linear regression

Boldface indicates statistical significance; SD = standard deviation

E-POSTER #43 continued

Table 3. MCID Achievement by Preoperative Severity

	Moderate (Mean ± SD)	**High NDI** (Mean ± SD)	**High VAS** (Mean ± SD)	**NDI/VAS** (Mean ± SD)	*p-value
VAS Neck					
6-weeks	35.9% (33)	50.0% (6)	76.9% (30)	47.8% (11)	**<0.001**
12-weeks	50.0% (42)	50.0% (5)	78.1% (25)	60.0% (15)	0.041
6-months	50.7% (39)	62.5% (5)	80.0% (20)	66.7% (16)	0.050
1-year	47.6% (20)	33.3% (2)	60.0% (12)	33.3% (3)	0.478
Overall	63.9% (62)	83.3% (10)	83.3% (35)	68.9% (20)	0.080
VAS Arm					
6-weeks	21.7% (20)	0.0% (0)	80.0% (32)	36.4% (8)	**<0.001**
12-weeks	25.6% (21)	10.0% (1)	71.8% (23)	48.0% (12)	**<0.001**
6-months	26.0% (20)	14.3% (1)	76.0% (19)	43.5% (10)	**<0.001**
1-year	14.3% (6)	28.6% (2)	60.0% (12)	44.4% (4)	**0.002**
Overall	36.1% (35)	25.0% (3)	88.1% (37)	53.6% (15)	**<0.001**
NDI					
6-weeks	17.4% (16)	33.3% (4)	41.5% (17)	36.4% (8)	0.019
12-weeks	26.8% (22)	40.0% (4)	46.9% (15)	56.0% (14)	0.031
6-months	28.6% (22)	71.4% (5)	76.0% (19)	65.2% (15)	**<0.001**
1-year	33.3% (14)	50.0% (3)	60.0% (12)	44.4% (4)	0.251
Overall	37.1% (36)	58.3% (7)	66.7% (28)	64.3% (18)	**0.003**
SF-12 PCS					
6-weeks	22.0% (13)	22.2% (2)	20.8% (5)	11.1% (2)	0.751
12-weeks	38.3% (18)	14.3% (1)	50.0% (9)	21.4% (3)	0.201
6-months	50.0% (24)	42.9% (3)	50.0% (7)	35.7% (5)	0.801
1-year	37.5% (15)	0.0% (0)	76.9% (10)	50.0% (3)	0.042
Overall	50.7% (37)	30.0% (3)	50.0% (16)	31.8% (7)	0.285
PROMIS PF					
6-weeks	41.3% (19)	14.3% (1)	33.3% (6)	28.6% (2)	0.487
12-weeks	40.5% (15)	60.0% (3)	66.7% (8)	66.7% (4)	0.311
6-months	67.7% (23)	60.0% (3)	60.0% (6)	50.0% (3)	0.852
1-year	75.0% (24)	50.0% (2)	63.6% (7)	100.0% (2)	0.523
Overall	75.9% (41)	62.5% (5)	56.5% (13)	66.7% (6)	0.388
PHQ-9					
6-weeks	26.1% (12)	50.0% (3)	60.9% (14)	25.0% (3)	0.029
12-weeks	31.6% (12)	50.0% (2)	62.5% (10)	60.0% (6)	0.124
6-months	18.2% (6)	25.0% (1)	50.0% (7)	55.6% (5)	0.061
1-year	40.0% (10)	50.0% (1)	60.0% (6)	33.3% (1)	0.718
Overall	38.0% (19)	50.0% (3)	61.5% (16)	53.9% (7)	0.249

*p-values calculated using logistic regression
Boldface indicates statistical significance; SD = standard deviation

E-POSTER #44

Using Natural Language Processing to Predict Clinically Significant Improvement in mJOA Score 12 Months After Cervical Decompression

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Introduction: Degenerative cervical myelopathy (DCM) is a condition caused by changes in the vertebral column of the neck leading to compression and subsequent dysfunction of the spinal cord. Surgical decompression is used to treat those with severe or progressive symptoms. Unfortunately, it is not possible to easily predict who will have an optimal outcome from surgical treatment and who will have persistent and severe functional deficits. Here, we utilize the preoperative history and physical exam notes, imaging reports, and age to build a natural language processing (NLP)-based machine learning (ML) model that predicts which patients undergoing surgical decompression will have an improvement of ≥ 3 points on the modified Japanese Orthopedic Association (mJOA) score—the minimum clinically important difference in score among patients with severe DCM (mJOA <12).1

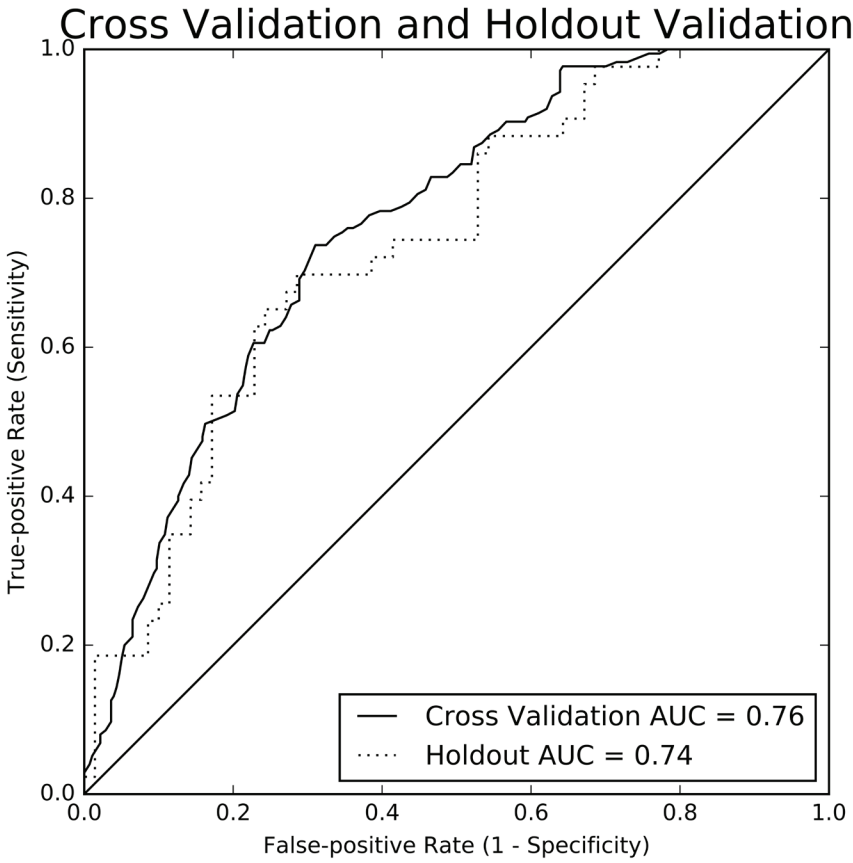
Materials and Methods: We retrospectively reviewed 565 adults surgically treated for DCM at a high-volume academic center. Age and text from preoperative notes and imaging reports were collected, as well as baseline and 12-month follow-up mJOA score. Text was treated by isolating single words or pairs of words as individual variables. 96 different models were trained using 80% of the data and ranked according to area under the receiver operating curve (AUC) to identify the top performing model. The difference between actual and predicted values for this top-performing model were used as a new, additional variable to train the final model, which was then validated on 20% of the data withheld from initial training.

Permutation importance was used to determine the relative impact of each input on the model's predictive accuracy. Word clouds were created to visualize which words or two-word phrases best predict post-operative improvement of ≥3 points from baseline mJOA.

Results: A light gradient boosted machine algorithm best predicted improvement in mJOA with an AUC = 0.76 on cross-validation and 0.74 on holdout validation (Figure 1). Feature importance shows that baseline mJOA followed by imaging text, then patient age, and then H&P text were the most important variables to the model. The probability of ≥ 3 point improvement decreased with increasing baseline mJOA and increasing patient age. Words and phrases such as "change," "broad-based," "flavum," and "prominent" were associated with poorer outcome, while words such as "mild," "edema," and "foraminal stenosis" were associated with ≥ 3 point improvement in mJOA (Figure 2).

Conclusion: Surgical decompression is the definitive treatment for severe and progressive DCM. However, it is difficult to predict which patients will experience meaningful improvement in their symptoms following surgery. In this study, we use NLP to construct a model that predicts ≥ 3 point improvement in mJOA score following decompression of cervical myelopathy. We previously demonstrated that NLP is more effective than a discrete variable ML model at predicting an important postoperative outcome among brain tumor patients, and that it can be readily implemented as a point-of-care clinical tool.2 Such a tool for DCM could facilitate improved patient counseling and shared decision-making.

E-POSTER #44 continued



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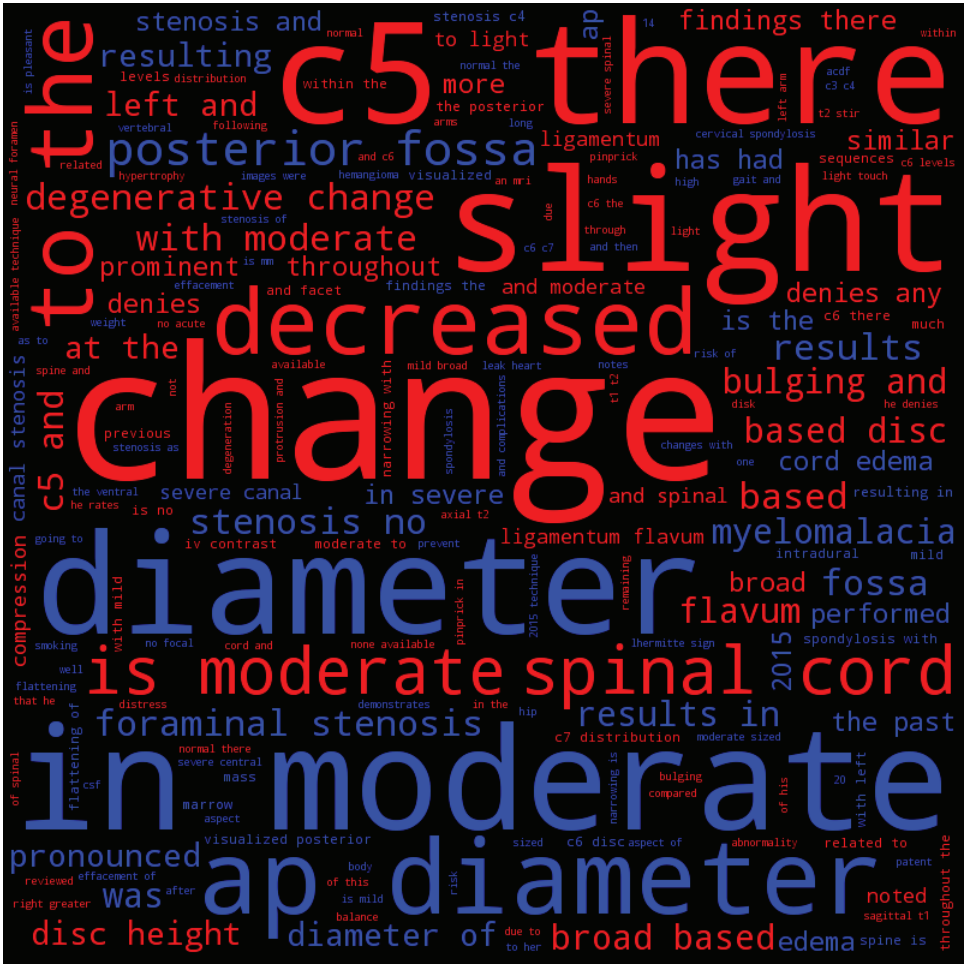

E-POSTER #45

Fate of hydroxyapatite-based porous lamina spacers following expansive open-door cervical laminoplasty: A quantitative long-term study

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Introduction: The expansive open-door laminoplasty has become a widely adopted surgical procedure for treating multilevel cervical myelopathy (CSM), and hydroxyapatite (HA) ceramic has been used as a lamina spacer due to its high biocompatibility. Previous studies [1] demonstrated minimal resorption of HA spacers during the first postoperative year, however none of these studies elucidated the long-term fate of this material. The present study aimed to examine the resorption kinetics of HA spacers at a minimum two-year follow-up as well as the correlation of HA resorption rate with patient demographics and clinical outcomes.

Materials and Methods: Among the 262 patients who underwent expansive open-door laminoplasty [2] with porous HA spacers in 2010-2019, 19 patients underwent computed tomography (CT) scans of cervical spine after the second postoperative year. The reason for CT scans was to investigate the cause of persistent neck pain or to check for injuries after accident. HA spacers, which have a porosity of 72-74% and a compressive strength of 8-10MPa, were transplanted at two spinal levels of each patient and we assessed a total of 38 spacers with minimum two-year CT follow-up. Data was collected on patient demographics such as age, gender, pathology, observation period, and JOA scores [3] as well as surgical data including spinal levels and dimension of implanted spacers. The data of three-dimensional CT scans performed immediately after surgery and at the latest during the follow-up were used and the remnant HA volume was measured from a semi-automated volumetric analysis [4,5] using the SYNAPSE VINCENT imaging software program (Fig1A). Residual HA ratio was defined as residual HA volume / initial HA volume. Lamina opening angle [6] and hinge status were also assessed. SPSS 18 was used for all statistical analyses.

Results: Table 1 shows patients demographics. All patients demonstrated postoperative improvement and bony union was observed in all hinge sides of laminae at one year postoperatively. In fig1, the residual HA was correlated with time in vivo (B: $r = -0.604$; $p<0.01$), patient's age at surgery (C: $r = 0.414$; $p = 0.013$), and initial volume of HA (D: $r = -0.408$; $p = 0.015$), while it was not correlated with gender, pathology, spinal levels, the opening angle, initial JOA scores, and the recovery rate. Multivariate linear regression analysis demonstrated that time in vivo was a significant predictor of residual HA ($R2=0.411$; $\beta=-0.489$; 95%CI, -0.006/-0.002; $p=0.02$). Biopsy findings obtained from one patient showed remnant HA and fibrous tissues without significant osteogenesis (Fig 2)

Conclusion: The present study with an average of four-year follow-up demonstrated that porous HA spacers were significantly resorbed over time, while previous shorter-term clinical or in vivo animal studies did not due to the extremely slow resorption kinetics of this material. Clinical outcomes were not correlated with HA resorption rate, which was corroborated by the finding that lamina opening angle was not correlated with HA resorption rate. These results also suggest that the long-term maintenance of the angle depends directly more on bony union of hinge sides than on spacer effect of implanted HA or its osteoconductivity.

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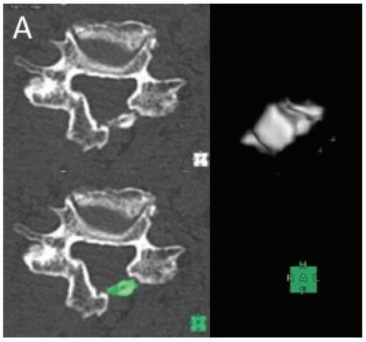

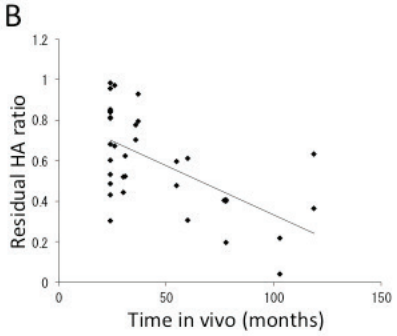

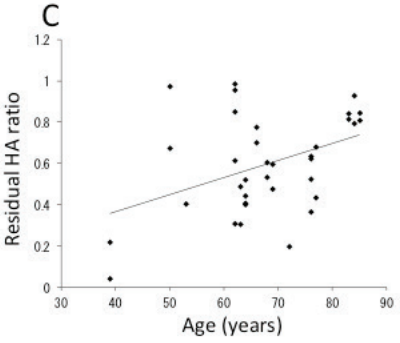

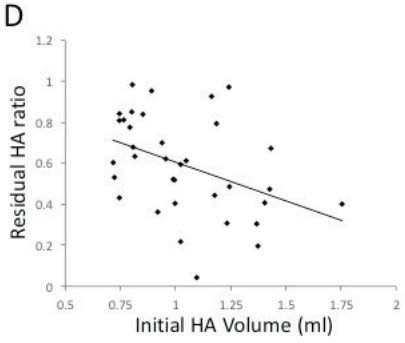

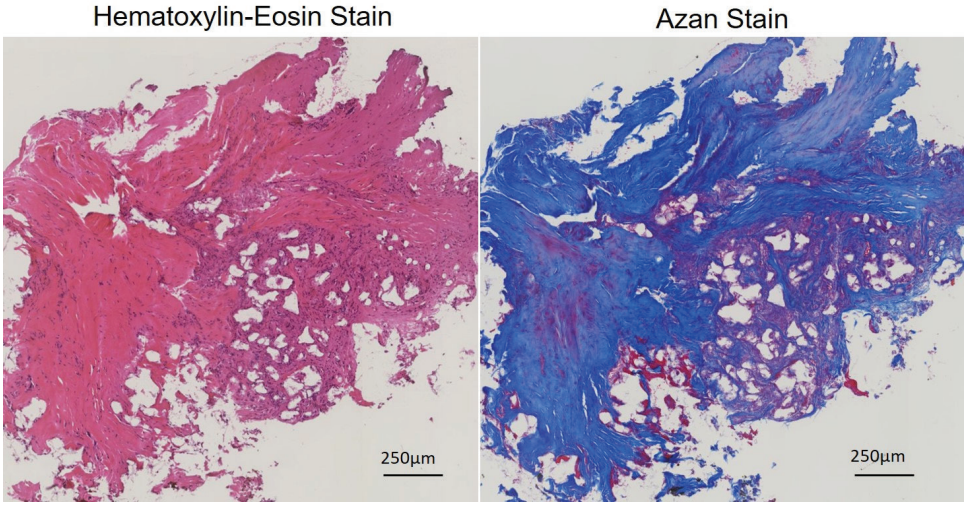

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Table 1 : Demographic data of Patients.

Number of Samples (Patients/HA spacers)	19 / 38
Age (years)	67 (39–85)
Sex (male/female)	14 / 5
Pathology (CSM/OPLL)	13 / 6
Mean follow-up (months)	47.3 (25–119)
JOA score	
Preoperative	10.3 (4–15)
Postoperative	13.7 (8.5–17)
Recovery rate	45.9% (−112.5–100)

E-POSTER #46

Lateral Mass Screw Accuracy: Effect of Surgeon Experience with Freehand Technique vs. a Facet-Based Drill Guide

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Seaspine[1]

Introduction: Lateral mass screw fixation is the most common method of posterior cervical spine instrumentation. Numerous freehand techniques for screw placement have been adopted that use angles and anatomical landmarks to achieve ideal screw trajectory. These techniques rely on surgeon experience and mastery of the techniques to avoid screw malpositioning. A novel lateral mass drill guide (LM Guide) has been developed that uses the facet joint to control sagittal screw trajectory and provide a reproducible means of placing lateral mass screws. This study compares the accuracy of lateral mass screw placement using the lateral mass drill guide, compared to a standard technique using anatomic landmarks and lateral fluoroscopy.

Materials and Methods: Lateral mass screws were placed from C3-C7 in fourteen cadaver specimens. Screws were placed bilaterally using standard anatomic landmarks ("freehand technique") on one side and the LM Guide on the other, with the side randomized each specimen. For the freehand technique, a sagittal trajectory was targeted parallel to the facet joint, and lateral angulation to avoid vertebral artery injury. The LM Guide was inserted into the facet joint at each level and the screw pilot hole was drilled at a controlled trajectory parallel to the joint, through the guide. In every case, 3.5 x 14 mm screws were placed. Four spine surgeons with varying levels of clinical experience participated (3 attendings, 1 fellow). Each surgeon operated on 2-4 cadavers for a total of 20-40 screws placed per surgeon.

Cadaveric specimens were imaged with high-resolution CT to assess screw placement. Using sagittal reconstructions, three blinded observers evaluated screw trajectory by measuring screw angle relative to the adjacent facet joint, with final trajectory presented as a mean of all three observers. Screw breach was assessed with CT imaging and classified as: facet joint violation, transverse foramen violation or neuroforamen violation.

Statistical analyses were performed using Minitab (Minitab, USA). Screw trajectories between techniques were analyzed using a paired t-test (left vs. right). Statistical significance was assumed at $p<0.05$.

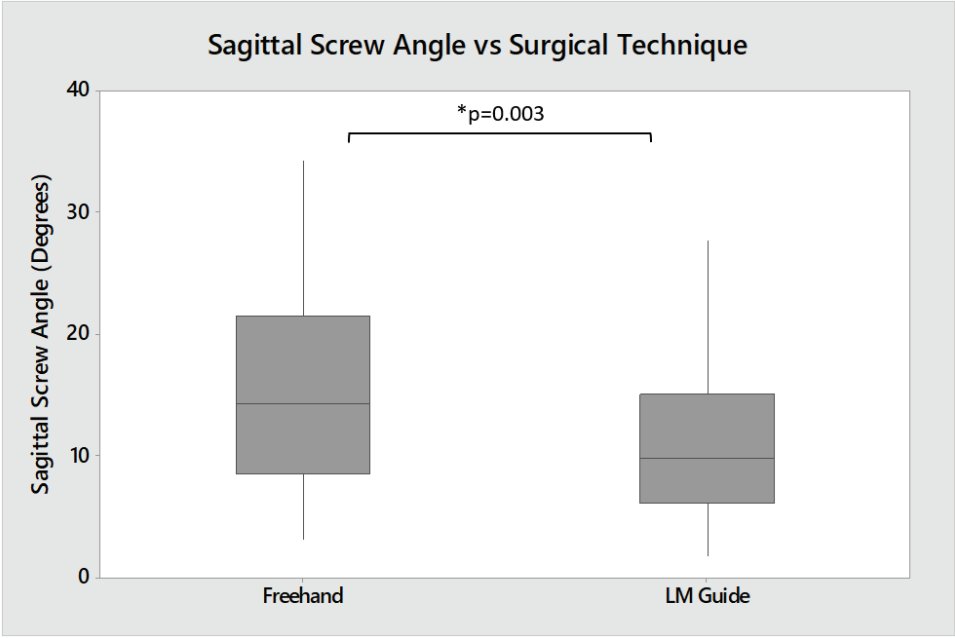
Results: Screw placement using the LM Guide yielded significant reduction in sagittal screw angle compared to Freehand (Fig 1). This corresponded to a lower rate of screw breach with the LM Guide, 2/58 (3.4%) vs. 8/72 (11.1%) respectively, and generally more consistent screw angulation across each level (Fig 2). The two instances of screw breach using the LM Guide were associated with osteophyte growth over the facet joint that changed the angle of the instrument and could be avoided with minor burring.

Notably, the LM Guide enhanced accuracy of screw placement by the less-experienced surgeon fellow, with a significant reduction in sagittal angle and no screw breaches associated with the LM Guide compared to 3 freehand breaches (Table A).

Conclusion: Freehand lateral mass screw placement techniques are inherently variable, with

E-POSTER #46 continued

screw position impacted largely by patient anatomy and surgeon experience. We present a novel LM Guide to accurately and reproducibly place lateral mass screws across subaxial levels, yielding a reduction in sagittal angle and screw breach rates compared to freehand techniques regardless of surgeon experience.



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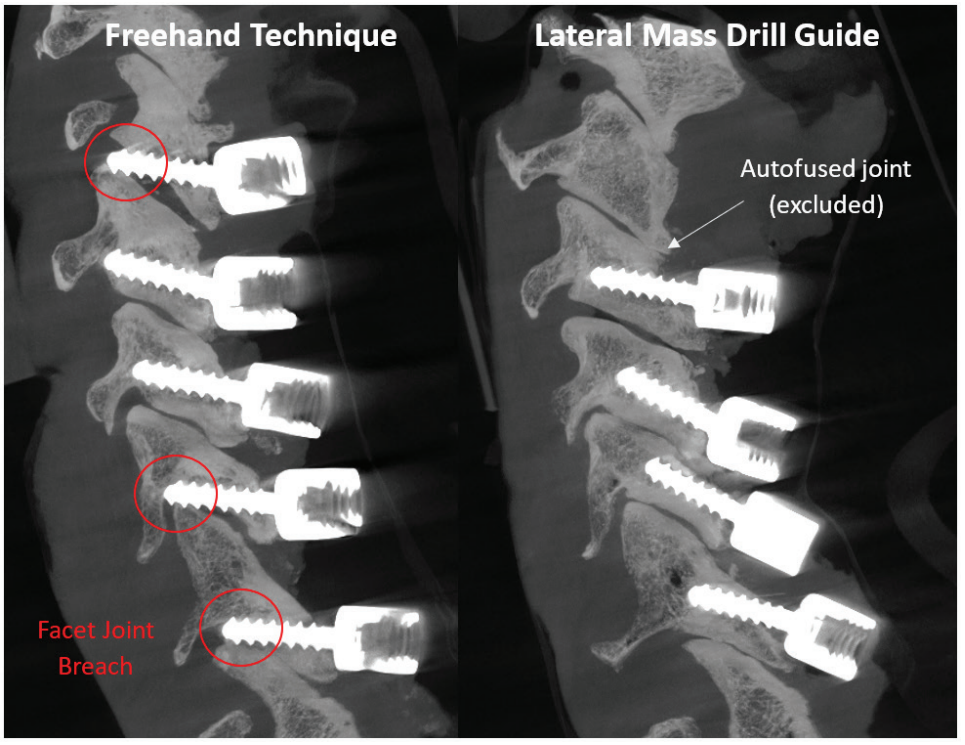

Surgeon Experience	Surgical Technique	Sagittal Screw Angle (°)			Screw Breaches		
		Mean	StDev	P value	Facet Joint	Neural Foramen	Transverse Foramen
Attending	Freehand	15.91	8.88	0.082^	5	0	1
	LM Guide	13.37	7.91		2	0	0
Fellow	Freehand	14.55	9.39	0.021^	3	0	0
	LM Guide	7.21	4.86		0	0	0

Note: one screw in the freehand group breached both the facet joint and the transverse foramen. This was considered a single breach for statistical analysis. ^Sagittal screw angle for the attendings and fellow were compared based on surgical technique within each group using a paired t-test (left vs right); p<0.05 was considered statistically significant.

E-POSTER #47

Morphological changes of deep extensor neck muscles in relation to the maximum level of compression and canal compromise in patients with degenerative cervical myelopathy

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Concordia University[1]

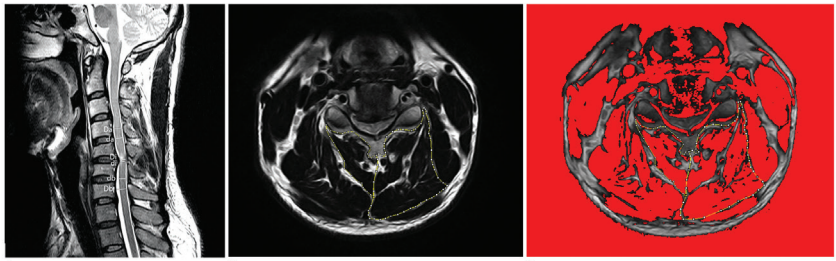
Introduction: The deep extensor neck muscles, especially the cervical multifidus (MF) and semispinalis cervicis (Scer), are often impaired in patients with cervical disorders (1,2). This study aimed to examine the relationship between morphological changes of the deep extensor neck muscles in patients with degenerative cervical myelopathy (DCM) and the level of maximum spinal compression and canal compromise.

Materials and Methods: A total of 171 patients from a Prospective DCM-International cohort study database were included in this study. Total cross-sectional area (CSA), functional CSA (fat free area, FCSA), ratio of FCSA/CSA (fatty infiltration) and asymmetry of the MF+SCer together, and deep extensor muscles as a group (e.g., MF, SCer, semispinalis capitis, splenius capitis) were obtained bilaterally from axial T2-weighted MR images at mid-disc, at the level of maximum cord compression and the level below (fig 1B, C). The level and degree maximum spinal cord compression (MSCC) and maximum canal compromise (MCC) was determined using the following formulas MSCC= [1 −di (da + db)/ 2] × 100, and MCC = [1 −Di (Da + Db)/ 2] × 100 as defined by Fehlings et al. (5) (fig 1A). The FCSA was measured using a highly reliable thresholding technique described in a previous study (3) (fig 1C), and the relative percent asymmetry in CSA, FCSA and FCSA/CSA was calculated using: [(L − S)/L] x100, where L is the larger side, and S is the smaller side (4). The relationship between the muscle parameters of interest, MSCC and MCC was assessed using multivariate linear regression models, adjusting for age, BMI and sex. Separate models were used for each muscle group and spinal level.C and MCC was assessed using multivariate linear regression models, adjusting for age, BMI and sex. Separate models were used for each muscle group and spinal level.

Results: The average MSCC and MCC was 42.84% (SD=17.7) and 45.38% (SD=14.96), respectively. Greater MF+Scer fatty infiltration (e.g., lower FCSA/CSA) was associated with greater MCC (P= 0.025) and MSCC (p=0.049) at the same level. Greater asymmetry in MF+SCer CSA was also associated with greater MCC (p=0.006). Similarly, greater asymmetry in FCSA and FCSA/CSA of the entire extensor muscle group was associated with greater MCC (p=0.011, p=0.013). There was no significant association between muscle measurements obtained at the level below the level of maximum compression, MCC and MSCC.

Conclusion: Greater MCC is associated with increased fatty infiltration and greater asymmetry of the deep extensor cervical muscles in patients with DCM. Our findings also suggest that MCC is a better indicator of cervical muscle morphological changes than MSCC. Whether such markers of muscle degeneration can be modified with pre- or post-operation rehabilitation exercise to impact patient heath related quality-of-life scores and neck function warrant further investigations. Given the importance that patients with DCM place on neck pain, this work has important translational significance.

E-POSTER #47 continued



A. B. C.

Figure 1. (A) Measurements required for MCC and MSCC calculation. Di, Da, and Db measure the diameter of the spinal canal at the site of compression and at the normal site above and below, respectively; di, da, and db indicate the diameter of the spinal cord at the site of compression and at the normal site above and below respectively. (B) Measurements of the Total CSA of the MF+SCer muscles and extensor muscles group on axial T2-weighted image at the C5-C6 level. (C) The image shows the application of a signal threshold filter (ImageJ) to highlight the fat-free muscle area and obtain the FCSA muscle measurements.

E-POSTER #48

Fusion and Subsidence Rates of Vertebral Body Sliding Osteotomy: Comparison of 3 Reconstructive Techniques for Multilevel Cervical Myelopathy

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Introduction: Vertebral body sliding osteotomy (VBSO) was previously reported as a technique to decompress spinal canal by translating the vertebral body anteriorly and is indicated for cervical myelopathy caused by spondylosis or ossification of the posterior longitudinal ligament (Figure 1). However, not much has been reported regarding fusion and subsidence rates of VBSO, which provides a unique construct composed of mobilized vertebral bodies and interbody spacers. Therefore, this study was conducted to compare the fusion and subsidence rates of VBSO, anterior cervical discectomy and fusion (ACDF), and anterior cervical corpectomy and fusion (ACCF).

Materials and Methods: One hundred and sixty-eight patients who underwent VBSO, ACDF, or ACCF for the treatment of cervical myelopathy and were followed-up for more than 2 years were retrospectively reviewed. Fusion and subsidence rates, visual analog scale (VAS) scores for neck pain, neck disability index (NDI), and Japanese Orthopaedic Association (JOA) scores were assessed. Results of the VBSO, ACDF, and ACCF groups were compared using Student's t-test and chi-square test.

Results: The fusion rate at 1-year postoperatively and the final follow-up for VBSO was 92.9% (37/42). VBSO demonstrated a higher 1-year fusion rate than ACDF (77.9% [74/95], p=0.04) and ACCF (74.2% [23/31], p=0.04). However, the fusion rate at the final follow-up did not demonstrate significant difference. The mean amount of subsidence (ACDF group, 1.5±1.2 mm; VBSO group, 1.5±1.5 mm; p=1.00) and rate of significant subsidence of > 3 mm (ACDF group, 13.7% [13/95]; VBSO group, 14.3% [6/42]; p=1.00) were similar for ACDF and VBSO. Furthermore, the mean amount of subsidence in VBSO was significantly less than that in ACCF (1.5±1.5 mm vs 2.4±2.0 mm; p=0.04). Neck pain VAS, NDI, and JOA scores were not significantly different among the groups (Table 1). Among the 3 surgical procedures, ACCF had the most complications: 2 (6.5%) temporary neurological deterioration, 3 (9.7%) reoperation, 3 (9.7%) graft dislodgement, and 4 (12.9%) dural tear. There was only one complication (dural tear) in the VBSO group, making its complication rate comparable to that of ACDF.

Conclusion: VBSO demonstrated a higher solid fusion rate at 1-year follow-up than ACDF and ACCF and less subsidence than ACCF. The higher 1-year fusion rate of VBSO could be explained as follows. First, local bone grafts inserted along the lateral slits may have aided faster union in VBSO. Second, sufficient bone marrow exposure by making lateral slits would also have enhanced solid union (Figure 2). Finally, VBSO provides multiple fixation points with screws inserted into mobilized fragments, making the lever arm created with this construct shorter and more stable than that in ACCF. Furthermore, its complication rate was lower than that of ACCF while clinical outcomes demonstrated by neck pain VAS, NDI, and JOA scores were similar to ACDF and ACCF. Therefore, VBSO is safe, provides a stable construct with favorable radiographic and clinical outcomes, and can be resorted to when the shape/location of the pathologic foci and sagittal alignment favor its application without much concern for

E-POSTER #48 continued

pseudarthrosis or subsidence.

Table 1. Radiographic results and patient reported outcome measures

Radiographic results							
					p value		
		ACDF (n = 95)	VBSO (n = 42)	ACCF (n = 31)	ACDF vs. VBSO	ACDF vs. ACCF	VBSO vs. ACCF
Fusion rate	ISM 6 m	38 (40.0%)	30 (71.4%)	6 (19.4%)	<0.01*	0.05	<0.01*
	ISM 12 m	70 (73.7%)	39 (92.9%)	21 (67.7%)	0.01*	0.65	0.01*
	ISM Final	79 (83.2%)	39 (92.9%)	28 (90.3%)	0.18	0.40	0.69
	InGBB 12 m	74 (77.9%)	39 (92.9%)	23 (74.2%)	0.04*	0.81	0.04*
	ExGBB 12 m	55 (57.9%)	35 (83.3%)	4 (12.9%)	<0.01*	<0.01*	<0.01*
Subsidence	Subsidence (mm)	1.5±1.2	1.5±1.5	2.4±2.0	1.00	0.02*	0.04*
	Subsidence > 3 mm	13 (13.7%)	6 (14.3%)	11 (35.5%)	1.00	0.02*	0.05

Patient reported outcome measures						
				p value†		
	ACDF (n = 95)	VBSO (n = 42)	ACCF (n = 31)	ACDF vs. VBSO	ACDF vs. ACCF	VBSO vs. ACCF
Neck pain VAS						
Preoperative	3.3±2.5	3.0±2.5	4.6±3.1	0.49	0.06	0.03*
Final follow-up	2.3±2.4	2.1±2.4	2.4±2.5	0.71	0.80	0.60
p value‡	0.02*	0.12	0.05			
NDI						
Preoperative	12.0±6.6	14.0±7.6	18.3±11.1	0.11	<0.01*	0.13
Final follow-up	7.2±5.4	8.5±7.5	10.0±6.1	0.34	0.04*	0.41
p value‡	<0.01*	<0.01*	<0.01*			
JOA						
Preoperative	12.7±3.5	12.8±2.2	13.3±4.0	0.88	0.55	0.58
Final follow-up	15.3±1.7	15.2±1.8	15.9±1.5	0.80	0.18	0.17
p value‡	<0.01*	<0.01*	<0.01*			
JOA Recovery rate	56.5±31.7	61.5±30.0	62.1±34.9	0.45	0.49	0.94

ACDF, anterior cervical discectomy and fusion; VBSO, vertebral body sliding osteotomy; ACCF, anterior cervical corpectomy and fusion; ISM, interspinous motion; InGBB, intragraft bone bridging; ExGBB, extragraft bone bridging;
Fusion rate and subsidence >3 mm were analyzed using chi-square test;
Subsidence (mm) was analyzed using a student's t-test
†Student's t-test was used to compare two groups
‡Paired t-test was used to compare preoperative and postoperative measurements
* *p* value < 0.05

E-POSTER #48 continued

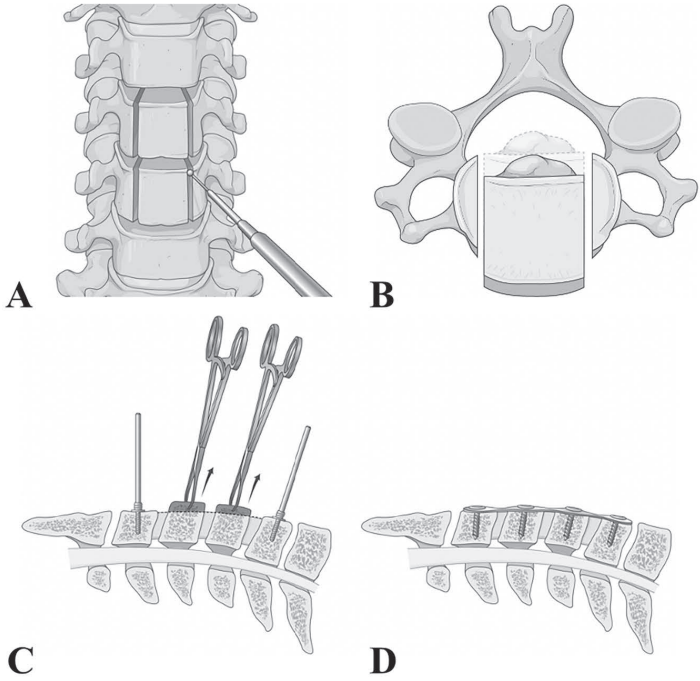

Figure 1. Surgical procedures of vertebral body sliding osteotomy (A) Two lateral slits are made using a high-speed burr at the base of the uncinate process. (B) Anterior translation of the vertebral body with ossification of the posterior longitudinal ligament mass with gentle traction. (C) While holding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

E-POSTER #48 continued

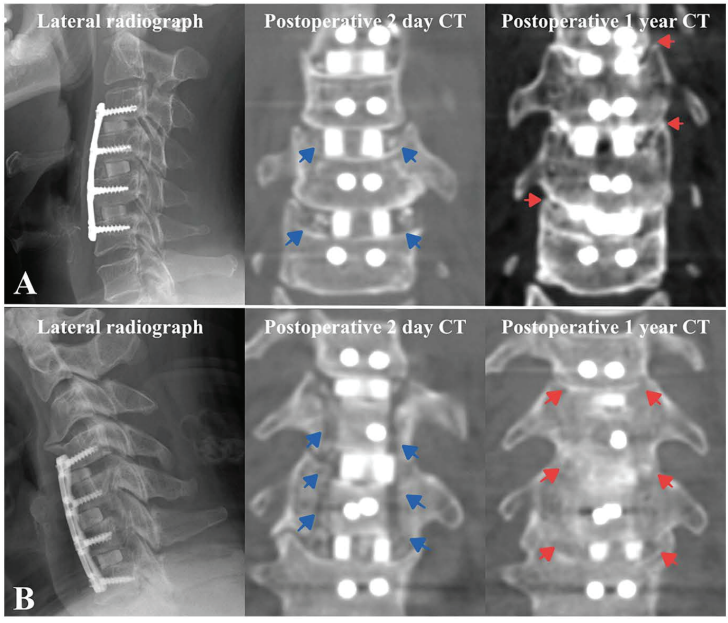

Figure 2. Construct comparison between vertebral body sliding osteotomy (VBSO) and anterior cervical discectomy and fusion (ACDF). (A) Lateral radiograph demonstrates 3-level ACDF with anterior plating which provides multi-point fixations. Although local auto bone grafts are inserted at the disc spaces (blue arrows), multiple cortical discontinuity (red arrows) are observed despite bone bridge formation at 12 months follow-up CT. (B) Lateral radiograph demonstrates 2-level VBSO involving 3-level discectomies. Bone grafts are inserted longitudinally along the lateral slits in VBSO (blue arrows). More abundant bone bridge formation with continuous cortical density (red arrows) is observed in 12 months follow-up CT.

E-POSTER #49

Segmental Height Decrease Adversely Affects Foraminal Height and Segmental Lordosis, But Not Clinical Outcome After Anterior Cervical Discectomy and Fusion Using Allografts

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Introduction: The clinical impact of segmental height decrease (SHD) might be different when using allografts as interbody spacers for ACDF compared to using cages, as SHD would be the sum of allograft height decrease and subsidence of allograft into the vertebral body. However, there is a paucity of evidence evaluating the true impact of SHD on fusion rates and clinical outcomes when using allografts as an interbody spacer. Therefore, the present study was conducted to elucidate the significance of SHD in clinical and radiographical outcomes in ACDF when using allografts.

Materials and Methods: We retrospectively reviewed 77 patients who underwent ACDF using allografts as interbody spacers and were followed-up for at least 2 years. Cervical lordosis, segmental lordosis, segmental height, foraminal height, fusion, allograft fracture, or resorption were assessed. Significant SHD was defined as that ≥2 mm. The neck pain visual analog scale (VAS) score, arm pain VAS score, and neck disability index (NDI) were also recorded. Segments with significant SHD (SH-D) were compared with segmental height-maintained (SH-M) segments.

Results: Thirty-one patients (40.3%) and 33 segments (25.6%) demonstrated significant SHD. SH-D segments demonstrated significantly lower segmental lordosis (3.6±4.2 vs 1.0±4.9; $p<0.01$), foraminal height (9.5±1.1 vs. 8.7±0.8; $p<0.01$), and fusion rate (75 [78.1%] vs 19 [57.6%]; $p=0.04$) than SH-M segments at 1-year follow-up. Foraminal height was even lower than preoperative values with significant SHD. However, neck and arm pain VAS, and NDI did not demonstrate a significant difference between patients with and without significant SHD (Table 1) (Figure 1). Logistic regression analysis demonstrated that higher allograft height ($p=0.03$) and allograft resorption or fracture ($p=0.02$) were associated with increased risk of significant SHD. Logistic regression analysis also demonstrated that allograft resorption or fracture ($p<0.01$) was associated with the risk of nonunion (Table 2).

Conclusion: Significant SHD was associated with decreased foraminal height and segmental kyphosis. However, clinical results were still favorable with the occurrence of significant SHD. Higher allograft height and allograft resorption or fracture were risk factors for significant SHD. Allograft resorption or fracture, but not significant SHD, was associated with an increased risk of pseudarthrosis. Therefore, over-distracting the segment with high allograft to restore foraminal height would occasionally fail since higher allograft height would cause significant SHD that would result in decreased foraminal height as demonstrated in this study.

E-POSTER #49 continued

Table 1. Radiographic results and patient reported outcome measures

Variables		SH-M segments	SH-D segments	P value
Allograft	Height	6.0±0.7	6.4±0.7	<0.01*
	AP length	13.3±1.3	13.9±0.6	<0.01*
	Fracture or resorption	46 (47.9%)	26 (78.8%)	<0.01*
	Resorption	28 (29.2%)	16 (48.5%)	
	Fracture	5 (5.2%)	2 (6.1%)	
	Both	18 (18.8%)	10 (30.3%)	
Fusion		75 (78.1%)	19 (57.6%)	0.04*
Segmental height	Preoperative	28.9±2.6	29.0±2.5	0.90
	Postoperative	30.2±2.4	30.6±2.2	0.35
	Final	29.7±2.5	28.0±2.3	<0.01*
Foraminal height	Preoperative	9.1±1.0	9.1±0.9	0.81
	Postoperative	10.0±1.1	10.1±0.9	0.49
	Final	9.5±1.1	8.7±0.8	<0.01*
Segmental lordosis	Preoperative	0.5±4.8	0.8±5.2	0.77
	Postoperative	5.0±4.1	4.8±5.5	0.82
	Final	3.6±4.2	1.0±4.9	<0.01*
Variables		SH-M group	SH-D group	P value
Global lordosis	Preoperative	13.9±9.4	13.1±10.4	0.67
	Postoperative	19.4±8.4	16.4±9.1	0.10
	Final	18.0±8.4	16.1±15.3	0.40
Patient reported outcome measures				
Variables		SH-M group	SH-D group	P value
Neck pain VAS	Preoperative	7.5±2.2	7.1±2.0	0.44
	1 year	1.5±1.6	1.2±1.4	0.44
	Final	1.0±1.6	0.8±1.3	0.63
Arm pain VAS	Preoperative	8.0±1.4	7.8±1.8	0.68
	1 year	1.8±1.7	1.8±1.5	0.88
	Final	1.5±3.4	0.9±1.1	0.33
NDI	Preoperative	21.8±6.4	19.3±4.4	0.07
	1 year	10.2±6.8	7.5±5.3	0.07
	Final	7.2±5.8	5.4±3.8	0.16

SH-M, segmental height-maintained; SH-D, segmental height-decreased; VAS, visual analogue scale; NDI, neck disability index

* $p < 0.05$

E-POSTER #49 continued

Table 2. Results of logistic regression analysis demonstrating factors related to significant segmental height decrease and fusion

Significant segmental height decrease				Fusion			
Univariate analysis	Odds ratio	Confidence interval	P value	Univariate analysis	Odds ratio	Confidence interval	P value
Age	0.990	0.96-1.03	0.56	Age	0.999	0.97-1.03	0.96
Sex	2.757	1.13-6.72	0.03*	Sex	2.978	1.23-7.22	0.02*
Preop segmental height	1.010	0.87-1.18	0.90	Preop segmental height	1.166	1.00-1.36	0.05*
Postop segmental height	1.083	0.92-1.28	0.35	Postop segmental height	1.158	0.98-1.37	0.09*
Preop segmental lordosis	1.013	0.93-1.10	0.77	Preop segmental lordosis	1.068	0.98-1.16	0.11
Postop segmental lordosis	0.990	0.91-1.08	0.82	Postop segmental lordosis	0.943	0.87-1.03	0.18
Postop-preop segmental height	1.480	0.98-2.2	0.06*	Postop-preop segmental height	0.846	0.57-1.26	0.41
BMD	4.040	0.33-49.86	0.28	BMD	6.642	0.52-85.5	0.15
Allograft height	2.165	1.21-3.89	0.01*	Allograft height	1.209	0.71-2.06	0.49
Allograft AP length	2.190	1.14-4.24	0.02*	Allograft AP length	1.106	0.79-1.56	0.56
Allograft resorption or fracture	4.037	1.60-10.19	<0.01*	Allograft resorption or fracture	7.395	2.64-20.69	<0.01
Multivariate analysis				Multivariate analysis			
Sex	1.433	0.48-4.24	0.52	Sex	2.768	0.86-8.93	0.09
Postop-preop segmental height	1.515	0.93-2.46	0.93	Preop segmental height	1.150	0.74-1.79	0.53
Allograft height	2.073	1.06-4.06	0.03*	Postop segmental height	0.842	0.52-1.36	0.48
Allograft AP length	1.934	0.95-3.95	0.07	Allograft resorption or fracture	6.872	2.40-19.65	<0.01*
Allograft resorption or fracture	3.147	1.16-8.54	0.02*				

Preop, preoperative; postop, postoperative; BMD, bone mineral density; AP, anteroposterior

* P value <0.10 was considered significant

† P value <0.05 was considered significant

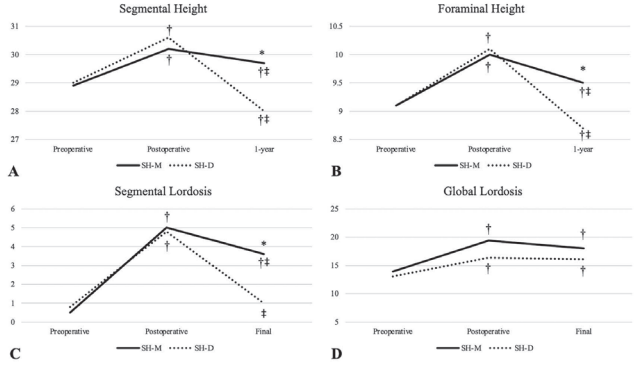

Figure 1. Radiographic results (A) Segmental height (B) Foraminal height (C) Global cervical lordosis (D) Segmental cervical lordosis

* Significant difference between the segmental height-maintained (SH-M) and segmental height- decreased (SH-D) segments or between the SH-M and SH-D groups

† Significant difference compared to preoperative measurements

‡ Significant difference compared to postoperative measurements

E-POSTER #50

Delineation of Alignment Goals for Adult Cervical Deformity Correction that are Associated with Achievement of both Optimal Clinical and Functional Outcomes

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Introduction: Surgical correction of cervical deformity (CD) has been associated with superior alignment and functional outcomes. It remains unclear which baseline and postoperative radiographic parameters correlate with improved health-related quality of life (HRQL) metrics and minimized complication rates. The purpose of this retrospective cohort study was to determine radiographic alignment targets associated with optimal clinical and functional outcomes in operative CD patients.

Materials and Methods: Included: Operative CD patients with UIV above C7 and with pre-(BL) and up to 2-year(2Y) postop radiographic/HRQL data. Cervical deformity was defined as meeting at least one of the following radiographic parameters: C2-C7 lordosis < -15°, TS-CL >35°, segmental cervical kyphosis >15° across any 3 vertebra between C2-T1, C2-C7 SVA >4cm, McGregor's slope >20°, or CBVA > 25°. An optimal outcome by 2Y postop was defined as 1) no DJF, and 2) meeting Virk et al. good clinical outcome [≥2 of the following: NDI <20 or meeting MCID, mild myelopathy (mJOA ≥14), NRS-Neck ≤5 or improved by ≥2 points from BL]. Regression analysis and conditional inference tree (CIT) identified BL and 3-month (3M) postop radiographic thresholds predictive of an optimal outcome.

Results: 119 CD patients met inclusion criteria (61.2±10.5yrs, 63%F, BMI 29.0±7.5kg/m2, CCI: 1.00 ±1.31) and underwent surgery (levels fused 7.5±3.7, EBL 990mL, op time 547min). By approach, 19.3% anterior-only, 44.5% posterior-only, and 36.1% combined. Mean BL radiographic parameters: sacral slope 34.3°, PT 19.6°, PI-LL 1.4°, SVA 1.9mm, T2-T12 kyphosis -46.8°, T1S 29.0°, C2-C7 lordosis -9.0°, TS-CL 38.2°, C2S 37.7°, cSVA 44.0mm, C2-T3 -18.0°, and C2-T3 SVA 75.2mm. Mean BL HRQLs were as follows: NRS back 5.0, NRS neck 6.7, NDI 47.9, mJOA 13.5, and EQ5D 0.74. By 2Y postop, there were 12 cases of DJF. 50 patients (42%) met the good clinical outcome criteria. Overall, 48 patients (40.3%) had an optimal outcome. Regression analysis with CIT identified the following baseline radiographic thresholds predictive of an optimal outcome: C2-T3 >9.7° (OR: 15.9, p =0.010) and C2S <34.0° (OR: 3.9, p =0.001). The following 3M postoperative radiographic thresholds were predictive of an optimal outcome: TS-CL <36.8° (OR: 15.1), C2-C7 lordosis >9.3° (OR: 4.2), cSVA <36.8mm (OR: 5.3), C2-T3 >16.8° (OR: 17.3), and C2S <29.4° (OR: 9.9); all p<0.05.

Conclusion: This study identified new baseline radiographic thresholds as well as postoperative realignment goals predictive of favorable functional and clinical outcomes in cervical deformity patients. Optimal outcomes may be achieved when surgical correction adequately addresses the TS-CL mismatch, cSVA, and C2 slope.

E-POSTER #51

Improvements in Cost Effectiveness of Adult Cervical Deformity Corrective Surgery over Time: Analysis of a Prospective Adult Cervical Deformity Database

Peter Passias, MD[1], Nicholas Kummer, BS, Oscar Krol, BA, Virginie Lafage, PhD[2], Renaud Lafage, MS, Alan Daniels, MD, Andrew Schoenfeld, MD, Robert Hart, MD, Douglas Burton, MD, Christopher Shaffrey, MD, Shay Bess, MD, Christopher Ames, MD
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Introduction: As operative measures and field knowledge advance, we hope that there is an improvement in outcomes for adult cervical deformity surgery. This improvement can be described by cost effectiveness, which encompasses operative cost, poor outcomes such as complications, and patient-reported measures.

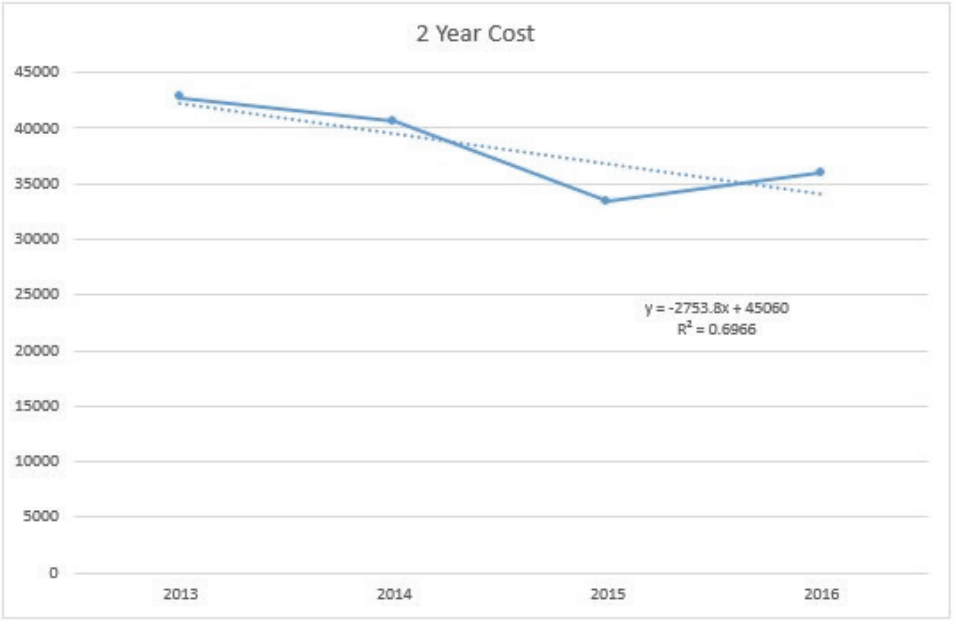
Materials and Methods: Included CD patients with baseline (BL) and up to 2-year (2Y) HRQL data from 2013-2017. 2017 was combined with 2016 due to an incomplete year of data. ANCOVA estimated marginal means of complications and reoperations adjusting for BL age, sex, surgical approach, and invasiveness. Cost was calculated using PearlDiver and assessed for Complications/Major Complications and Comorbidities according to CMS.gov. QALYs were calculated from EQ5D and utilized 3% discount rate for residual decline to life expectancy (LE, 78.7 years). This data represents national average Medicare costs by surgical approach, complications, and revision status. Trendline analysis noted changes over time.

Results: Included 132 patients - 24 in 2013, 52 in 2014, 24 in 2015, 32 in 2016. Total cost by 2Y trended downward (2013: $42,754; 2016: $39,155), with a yearly $2,753 decrease (R2=0.6966). Concurrently, 2Y EQ5D improvement increased (2013: 0.0113; 2016: 0.0697), resulting in a 0.0172 increase per year in QALYs gained at 2Y (R2=0.8109) and a 0.2358 increase per year in QALYs gained at LE (R2=0.8533). Cost per QALY at 2Y decreased by $6,057 per year (R2=0.0497) and at LE by $67,478 per year (R2=0.6588). Total cost at 2Y for those with Distal Junctional Kyphosis was $98,357 vs $59,129 for non-DJK; cost per QALY was $46,932 vs $28,571, respectively.

Conclusion: Between 2013 and 2017, total cost for cervical deformity surgery decreased – possibly due to complication reductions – while EQ5D improvement has increased, leading to improved cost effectiveness.

References: Brown AE, Lebovic J, Alas H, et al. A cost utility analysis of treating different adult spinal deformity frailty states. J Clin Neurosci. 2020;80:223-228. doi:10.1016/j.jocn.2020.07.047

E-POSTER #51 continued



E-POSTER #52

Influence of Staged vs Same Day Surgical Approach on Cervical Deformity Corrective Surgery Cost Effectiveness

Nicholas Kummer, BS, Lara Passfall, BS, Oscar Krol, BA, Sara Naessig, BS, Bhaveen Kapadia, MD, Shaleen Vira, MD, Peter Passias, MD[1]
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Introduction: When determining surgical approach, a surgeon may elect to choose a "staged" method, in which a patient has recovery time between surgeries that would normally involve a change in position. Whether one method is more cost effective than the other is unknown.

Materials and Methods: Adult Cervical Deformity patients with available baseline and up to 2-year Neck Disability Index data were included. Cost was calculated using the PearlDiver database. Reimbursement consisted of a standardized estimate using regression analysis of Medicare pay-scales for services within a 30 day window including length of stay and death. This data is representative of national average Medicare cost differentiated by complication/comorbidity outcome, surgical approach, and revision status. Cost per Quality-Adjusted Life Year (QALY) at 1Y were calculated according to single position approach (Single), combined same day approach (Same), and combined staged approach (Staged).

Results: Of 104 patients that met inclusion criteria (52.4% Female, 56.04±9.5years, 28.9±6.9kg/m2), 26 were Same, 18 were Staged, and 60 were Single-approach. Total cost for Single patients was $52,622, compared to $53,507 for Same and $62,765 for Staged (p=0.629). Utility Gained at 1Y was 0.223 for Single, 0.251 for Same, and 0.174 for Staged (p=0.719). This translated to QALY gained at 1Y of 0.4331 for Single, 0.4869 for Same, and 0.3381 for Staged. Cost effectiveness was determined via cost per QALY: Single = $121,500; Same = $109,893; Staged = $185,640.

Conclusion: Costs by procedure when stratified by single approach compared to combined same day and staged approaches were roughly similar. While cost effectiveness was lower among staged patients, the similar overall costs and utility gained regardless of approach may show that cost effectiveness does not outweigh potential benefits of this surgical method when compared to others.

References: Brown AE, Lebovic J, Alas H, et al. A cost utility analysis of treating different adult spinal deformity frailty states. J Clin Neurosci. 2020;80:223-228. doi:10.1016/j.jocn.2020.07.047

E-POSTER #53

Diminishment of Distal Junctional Kyphosis Rates among Surgically Corrected Cervical Deformity Patients over Time

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Introduction: Given advancements in cervical deformity corrective surgery procedures over the years and previous findings in improved outcomes, we might also expect the instance of Distal Junctional Kyphosis (DJK), one of the most common complications among patients with cervical correction, to decrease due to these improvements.

Materials and Methods: Patients with Cervical Deformity (CD) with UIV above C7 who had baseline and up to 2-year HRQL data were isolated in a prospectively collected multicenter CD database. These patients were assessed for presence of post-operative distal junctional kyphosis (DJK) by noting the change in angle between the Upper Instrumented Vertebrae (UIV) and UIV-2. Patients were separated by the year that they received surgery (2014, 2015, 2016, 2017), and instances of DJK by 2-year follow up among these patients were adjusted for covariates including age, sex, and surgical approach via estimated marginal means ANCOVA.

Results: Of 97 CD patients (56.82±10.43 years old, 68% Female, 22.7% anterior surgical approach, 43.3% posterior approach; 34.0% combined approach) with HRQL follow-up at baseline and up to 2 years, 31 (32.0%) of these developed some form of DJK between 6 weeks and 2 years postoperatively. There were 24 patients that received surgery in 2014, 36 in 2015, 13 in 2016, and 16 in 2017. Controlling for age, sex, and surgical approach, overall rates of DJK by year were as follows: 2014: 48.9%; 2015: 24.8%; 2016: 60.1%; 2017: 9.4% (p=0.029). This indicated an 8.3% decrease in DJK rates per year (R2=0.219).

Conclusion: Rates of Distal Junctional Kyphosis have decreased at a rate of 8.3% since 2014, verifying improvements in surgical methods for adult cervical deformity corrective surgery may have also reduced rates of this complication.

E-POSTER #54

The Effect of Sagittal Alignment on Outcomes, Reoperation Rates, and Development of Distal Junctional Kyphosis in Adult Cervical Deformity Patients

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Introduction: Global Spinal Malalignment plays a vital role in cervical spinal deformity corrective surgery outcomes, however, there is a paucity in literature on the effects that the individual sagittal parameters have on outcomes. The objective of this retrospective cohort study of a single-center database was to investigate the impact of sagittal malalignment on cervical deformity patient outcomes.

Materials and Methods: Inclusion criteria: operative CD patients (Cervical kyphosis>10°, with cSVA>4cm or CBVA>25°) and >18yrs with up to 2Y radiographic and HRQL follow-up. Significant differences in surgical, radiographic, and clinical factors and outcomes were determined. Deformity in PT, SVA, and PILL was defined using the SRS-Schwab criteria. "Unmatched" refers to patients who were under corrected or over corrected according to the Schwab age-adjusted parameters (Lafage et al.)

Results: 112 CD patients met inclusion criteria (58.3yrs, 46% Female, 28.3 kg/m2). Overall, 27 (24%) of these patients developed DJK. At BL patients presented with the following radiographic profile: PT (18.3), PILL (-.65), SVA C7-S1 (-6.54), cSVA C2-C7 (23.5), and TS-CL (25.2). Patients with DJK had a higher L1-S1 (34 vs 9.2) and T12-S1 (57 vs 35, both $p<0.05$) and trended towards a higher cSVA (-11.7 vs -3.7), C2-T3 (57.6 vs 37.4), and C2-S1 (17 vs 5.9, $p>0.05$). Patients with a deformity in PT at baseline developed more DJK by 2Y (26% vs 11%), had more DJF (7% vs 2%) and a higher NDI and NSR back pain. Patients with mismatch at BL had higher rates of DJK (30% vs 22%), and patients with SVA deformity at BL had a lower mJOA, SWAL Food selection, SWAL Communication, and a higher EQ5D. Patients with a mismatched alignment in Roussouly pre-operatively had higher rates of DJK at 3M (18% vs 12%), 6M (26% vs 16%), 1Y (24% vs 14%), and 2Y (26% vs 13%, all $p<0.05$). Patients who were unmatched in SVA by 2Y had higher rates of DJK development at 2Y (25% vs 6%), and those unmatched in PILL by 2Y had higher rates of 2Y DJK (31% vs 19%) and higher 2Y NDI (38 vs 31). Patients who had a mismatch in Roussouly post-operatively had higher rates of DJK by 2Y (33% vs 23%, all $p<0.05$).

Conclusion: Global Spinal Malalignments play an important role in the outcomes of cervical spinal deformity corrective surgery. The presence of abnormal global sagittal malalignment at baseline is associated with higher rates of DJK development and worse clinical outcomes, while patients who maintained poor sagittal alignment up to 2Y were associated with significantly greater development of DJK and inferior neck disability index scores.

E-POSTER #55

Treatment of Severe Adult Cervical Deformities Classified by Radiographic Criteria is Associated with Inherent Risk

Nicholas Kummer, BS, Oscar Krol, BA, Lara Passfall, BS, Renaud Lafage, MS, Virginie Lafage, PhD[1], Shaleen Vira, MD, Peter Passias, MD[2]
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Introduction: Criteria for determining severity of cervical deformity by radiographic measures has been previously established by Ames et al and modified by Passias et al. The present study sought to investigate whether being classified as severe deformity by means of any of these modifiers would place patients at greater risk compared to their lower deformity counterparts.

Materials and Methods: Surgically eligible patients with cervical deformity and a Upper Instrumented Vertebrae < C7 were isolated. Patients were first categorized by Ames modifiers and severe patients within certain radiographic thresholds (C2-C7 SVA >8cm, Chin-Brow Vertical Angle<-10 or >25, TS-CL>20, mJOA<12, or C7-S1 SVA>9.5cm) were isolated from the remainder of the cohort. Descriptive analysis analyzed cohort demographics, and ANCOVA produced estimated marginal means of outcome measures while adjusting for covariates including age, sex, surgical approach, and baseline Neck Disability Index score. In a subanalysis, patients were separated into quartiles based on C2-C7 Angle, TS-CL, C2-T3 Angle, C2 Slope, and McGergor Slope (MGS) and those who met at least one of the severe quartile criteria were grouped and analyzed for complication and reoperation rates.

Results: Out of 517 total patients in the database, a cohort of 50 patients was selected based on inclusion criteria (58.3 years, 60% female, 29.6kg/m2, 8% anterior surgical approach, 60% posterior surgical approach, 32% combined approach), 17 were categorized as severe by 1 or more modified Ames criteria. Adjusting for baseline age, sex, baseline Neck Disability Index score, and surgical approach, patients in this cohort at baseline had higher instance of Distal Junctional Failure (DJF) by 2 Years (32.3% vs 8.9% (p=0.071)). These patients also trended higher instance of overall reoperation (34.3% vs 19.5%, p=0.191) and significantly greater instance of overall complications (94.7% vs 62.0%, p=0.032). Regardless of severity grouping, the NDI score for patients at 1Y between groups were statistically similar (p=0.638).

When analyzing patients by Quartile grouping for C2-C7 Angle, TS-CL, C2-T3 Angle, C2 Slope, and MGS, there were 21 patients that were in the "worst" quartile for any one of these parameters. These values for patients within the high quartile cohort and those who were not can be seen in the TABLE. Via ANCOVA, these patients within at least one major quartile had higher rates of DJF (34.2% vs 4.1%, p=0.010) and overall complications (91.4% vs 59.7%, p=0.023) compared to their counterparts who were not within any major quartiles.

Conclusion: Patients who are classified with one or more severe radiographic criteria for cervical deformity are more at risk for developing complications or DJF. Despite the higher complication rates for patients in the severe deformity category, these patients improved in NDI at similar rates to the other patients in the cohort, indicating that surgery is worthwhile for patients regardless of initial severity.

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E-POSTER #55 continued

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	C2-C7	TS-CL	C2-T3	C2 Slope	MGS
No Upper Quartile Values	-1.02	27.45	3.46	25.25	-1.46
At Least One Upper Quartile	-8.02	44.78	-31.02	42.50	7.91

E-POSTER #56

Longer Operative Time Associated with Prolonged Length of Stay, Non-Home Discharge and Transfusion Requirement after Anterior Cervical Discectomy and Fusion: an Analysis of 24,593 Cases

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Introduction: Prolonged operative time of single-level anterior cervical discectomy and fusion (ACDF) has been associated with adverse postoperative outcomes [1,2]. The current literature does not contain a comprehensive quantitative description of these associations. This study characterized the associations between ACDF operative time and 1) 30-day postoperative healthcare utilization, and 2) the incidence of local wound complications, need for transfusion, and mechanical ventilation.

Materials and Methods: The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried for single-level ACDF cases (2012–2018) using current procedural terminology codes. A total of 24,593 cases were included. Primary outcomes included healthcare utilization (lengths of stay [LOS], discharge dispositions, 30-day readmissions, and reoperations) per operative time category. The secondary outcome was the incidence of wound complications, blood transfusion, and need for ventilation per operative time category. Multivariate regression models determined operative time categories associated with increase in risk while adjusting for patient demographics and baseline comorbidities. Predictive spline regression models were constructed to visualize associations.

Results: Multivariate regression demonstrated that compared to a reference operative time of 81-100-minutes, the 101-120-minute category was independently associated with higher odds of LOS >2 days (OR: 1.36, 95%CI (1.18-1.568) ; p<0.001) and non-home discharge (OR: 1.341, 95%CI (1.081-1.664); p=0.008). Three-times greater odds of LOS >2 days (OR: 3.367, 95%CI (2.719-4.169); p<0.001) and twice the odds of non-home discharge (OR: 2.174, 95%CI (1.563-3.022); p<0.001) were detected at 181-200-minutes. The highest operative time category (≥221 minutes) was associated with the highest odds of LOS>2 days (OR: 4.838, 95%CI (4.032 - 5.804); p<0.001), non-home discharge (OR: 2.687, 95%CI (2.045-3.531); p<0.001) and reoperation (OR:1.794, 95%CI (1.094-2.943); p=0.021). Patients within the 201-220 and the ≥221-minute categories exhibited a significant association with greater odds of blood transfusion (OR: 8.57, 95%CI (2.321-31.639); p<0.001, and OR: 11.699, 95%CI (4.179-32.749); p=0.001, respectively). There was no significant increase in the odds of 30-day readmission, any wound complications, any wound infection, or the need for mechanical ventilation across the various operative time categories (p>0.05). Spline regression demonstrated that the odds of LOS >2 days, non-home discharge disposition, and bleeding requiring transfusion events began to rise, starting at 94 (Figure 1), 91.6 (Figure 2), and 93.3 (Figure 3) minutes of ACDF operative time, respectively.

Conclusion: The current study demonstrates that prolonged operative time is associated with increased odds of healthcare utilization and transfusion after single-level ACDF. Operative times greater than 90 minutes may carry higher odds of postoperative complications.

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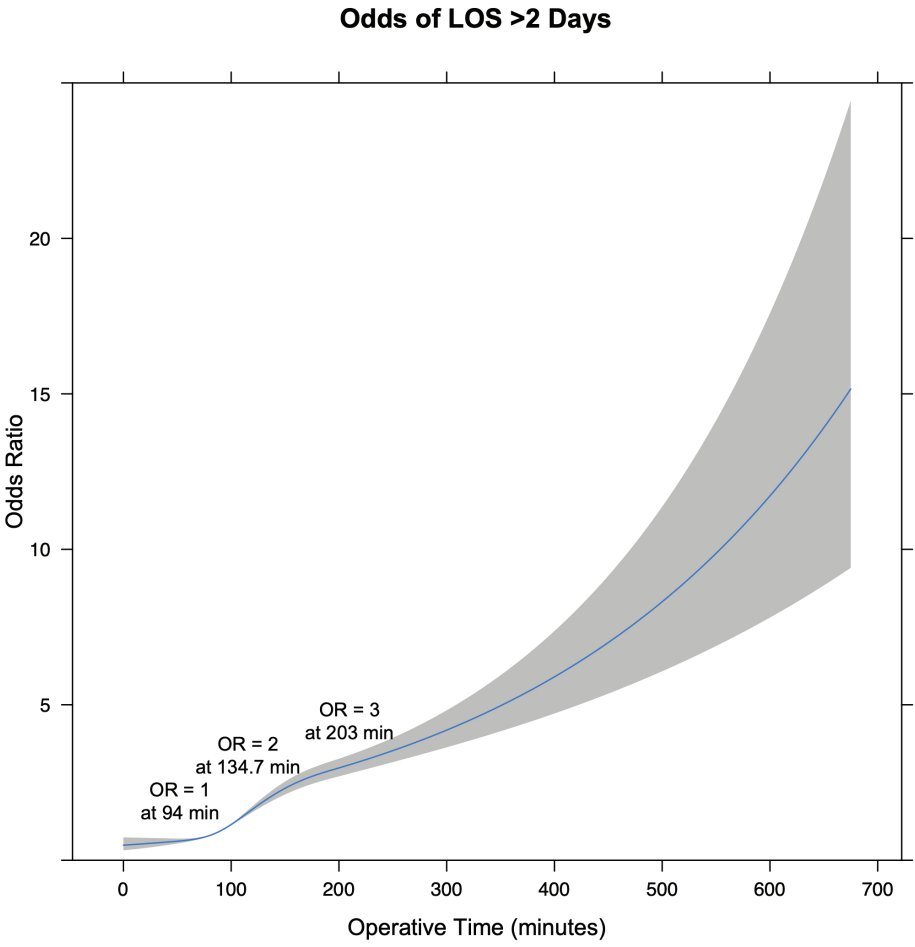

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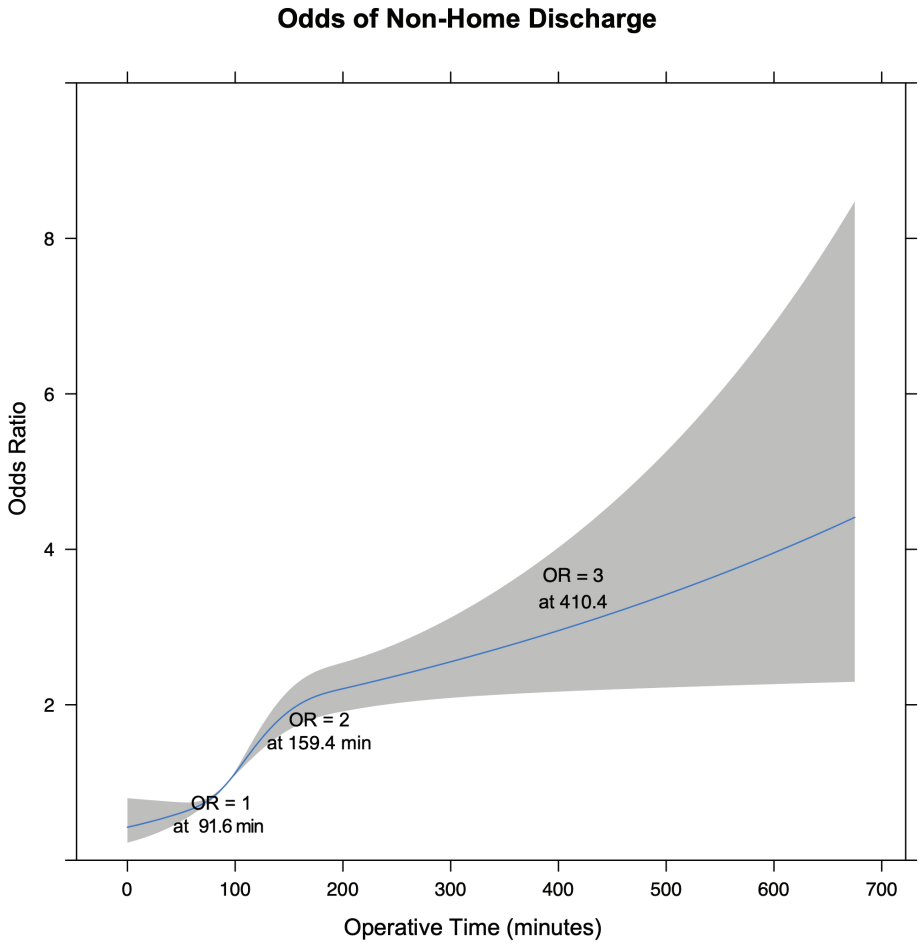

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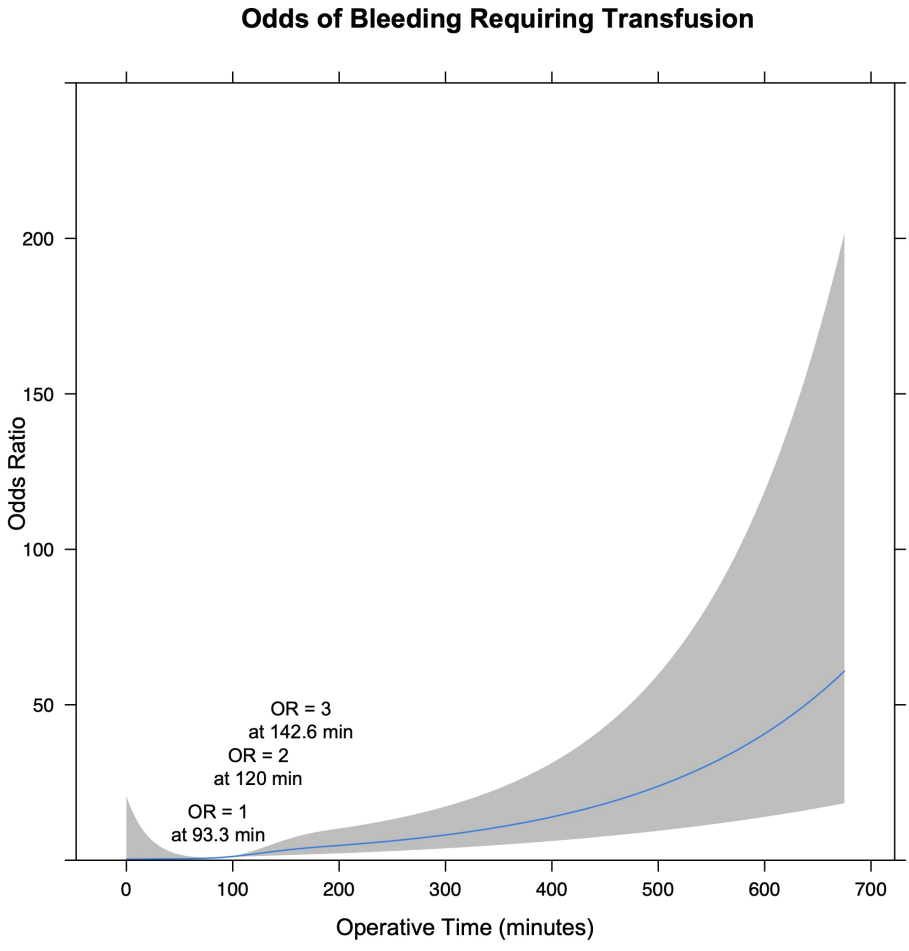

E-POSTER #57

Clinical adjacent segment pathology after anterior cervical decompression surgery for cervical degenerative disc disease: a single center retrospective cohort study with long-term follow-up

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Introduction: The most commonly used surgical procedure for treating patients with single- or multilevel cervical degenerative disc disease (CDDD) is anterior cervical discectomy, either with fusion (ACDF) or, in Europe, without (ACD) [1]. Both techniques show good short-term results [2,3]. However, in the years following surgery, new complaints of radiculopathy and/or myelopathy commonly develop at a segment adjacent to the site of previous surgery, also known as clinical adjacent segment pathology (CASP) [4]. The underlying mechanism is thought to be compensation for the loss of motion in the fused segment, resulting in overstraining of the adjacent segments in addition to progression of natural degeneration. This occurs at an estimated cumulative rate of 1.6% to 4.2% per year after fusion surgery, and the majority of patients require an additional surgery for CASP [4,5]. Current literature reports inconsistent incidence rates and controversial risk factors in the development of CASP. The aim of this study was to determine the incidence of additional surgeries due to CASP after anterior cervical decompression surgery for CDDD.

Materials and Methods: This is a single-center, retrospective cohort study with long-term follow up. Chart review was performed to identify eligible patients. Patients were included if they underwent anterior decompression surgery for CDDD between January 2012 and December 2019. Only adult patients with radiculopathy and/or myelopathy due to degenerative causes were included. The primary outcome measure was the occurrence of additional surgery due to CASP. Secondary outcome measures were risk factors in the development of CASP and long-term clinical outcomes.

Results: A total of 673 patients were included, the average follow-up period was 4.4 years [Figure 1]. Most patients underwent ACDF (95.4%). A total of 61 (9.1%) patients developed CASP, of whom 44 (6.5%) required additional surgery [Table 1]. A significantly higher risk on CASP was observed in those that underwent ACD in comparison to ACDF. Baseline degeneration at the index level and at the adjacent levels was not significantly different between patients with and without CASP [Table 2]. This argues against natural degeneration being the only significant factor in the development of CASP.

Conclusion: In cohort of 673 CDDD patients with 4.4 years follow-up, 9.1% developed CASP and 6.5% required additional surgery as a consequence of CASP.

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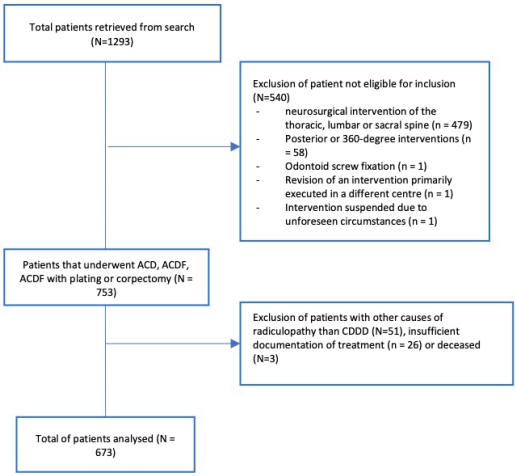

Figure 1. Flowchart of patient selection.

ACD = Anterior Cervical Discectomy, ACDF = Anterior Cervical Discectomy and Fusion, CDDD = Cervical Degenerative Disc Disease

E-POSTER #57 continued

Number of patients with CASP (N=673) (%)	
Newly diagnosed CASP	61 (9%)
Additional surgery for CASP	44 (6.5%)
Surgical Technique used for additional surgery for ASDis (N=44)	
ACD	2 (4.5%)
ACDF	25 (56.8%)
ACDF + plating	6 (13.6%)
Corpectomy + plating	1 (2.3%)
Circumferential spondylodesis	3 (6.8%)
Dorsal foraminotomy	6 (13.6%)
Unknown	1 (2.3%)
Level of additional surgery in relation to primary surgery (N=44)	
Above	18 (40.9%)
Below	19 (43.2%)
Both above and below	6 (13.6%)
Unknown	1 (2.3%)

Table 3. Primary outcome measurements.

CAPS = Clinical Adjacent Segment Pathology, ACD = Anterior Cervical Discectomy, ACDF = Anterior Cervical Discectomy and Fusion.

E-POSTER #57 continued

Pre-operative Kellgren's score	Mean of total group (N)	SD	No CASP	SD	CASP	SD	Significance p-value
Average of all levels	0,82 (N=663)	±0,7189	0,82 (N=625)	±0,7193	0,84 (N=38)	±0,7216	0,919
Average of index level (N=377)	1,85 (N=377)	±1,0351	1,86 (N=357)	±1,0361	1,70 (N=20)	±1,0311	0,848
Average of the level **above** index level (N=656)	1,01 (N=656)	±1,0797	1,00 (N=619)	±1,0729	1,10 (N=37)	±1,2009	0,179
Average of the level **below** index level (N=468)	1,12 (N=468)	±1,2356	1,11 (N=445)	±1,2315	1,30 (N=23)	±1,3292	0,443

Table 4. Kellgren Score

Number of patients are represented as not all KS were available. CASP = Clinical Adjacent Segment Pathology, SD = Standard Deviation.

E-POSTER #58

Surgical approaches to tumors of the occipito-cervical, subaxial cervical, and cervicothoracic spine: An algorithm for standard versus extended anterior cervical access

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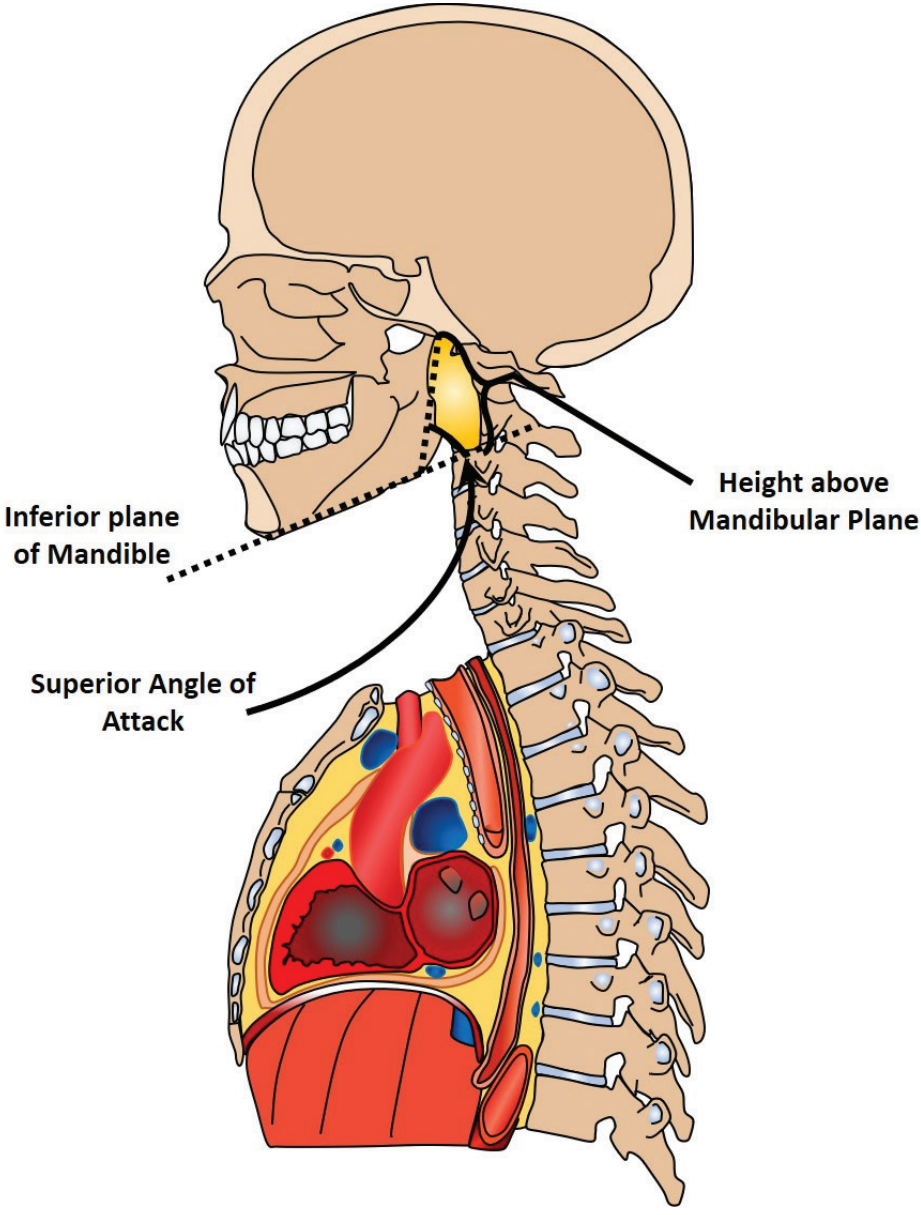
Introduction: Multiple different approaches can be used for tumors of the cervicothoracic vertebral column.1–5 The aggressiveness and direction of the approach are often dictated by the tumor pathology, bony column involved, and spinal levels affected. Our purpose in the present study was to develop a preliminary algorithm for the surgical management of these lesions based upon a 10-year multisurgeon experience. Additionally, we sought to identify which lesions might benefit from a more aggressive approach.

Materials and Methods: We reviewed all patients treated for vertebral column tumors involving the occipito-cervicothoracic spine (occipitocervical junction-T4) over a 10-year period at a comprehensive cancer center. Data were recorded about tumor pathology, tumor morphology, and surgical approach employed. Anterior surgical approach were classified as transoral/transnasal, pure transcervical, or extended transcervical (transcervical with the addition of a transmandibular or transsternal approach). For tumors extending above the plane of the inferior mandibular border, angle of attack was defined as the angle inscribed by the inferior mandibular plane and line connecting the superior tumor pole and mandibular angle (Figure 1). For those extending below the thoracic inlet, angle of attack was defined as the angle inscribed by the plane of the thoracic inlet and the line connecting the jugular notch and inferior tumor pole (Figure 2).

Results: We included 115 patients; mean age was 56.7yr, 56% were male, average tumor size was 26.5cm^3, and 34% were primary tumors. Single-stage procedures were used for 60% of patients (10.5% anterior-only, 49.6% posterior-only) and 40% had multistage approaches (30.4% two-stage, 8.7% 3- or 4-stage). A combined transmandibular-transcervical approach was only used in lesions involving the C2 and C3 levels. Angled angle of attack was significantly steeper (42.5±9.5 versus 6.1±13.3°; p=0.01) and superior tumor extent above the inferior plane of the mandible was significantly higher (3.69±2.18 versus 0.33±0.78; p=0.002). Lateral tumor extent, tumor size, nor inferior angle of attack significantly differed between approach groups. Based upon the results, a preliminary algorithm was proposed using tumor pathology (primary versus metastatic), tumor location, and tumor morphology as decision-making nodes (Figure 3).

Conclusion: Here we present a preliminary decision-making algorithm for the management of vertebral column tumors of the cervicothoracic spine. Based upon this single center experience, we suggest which patients, assessed via a combination of tumor histology and regional anatomy, may benefit from extended anterior surgical access.

E-POSTER #58 continued



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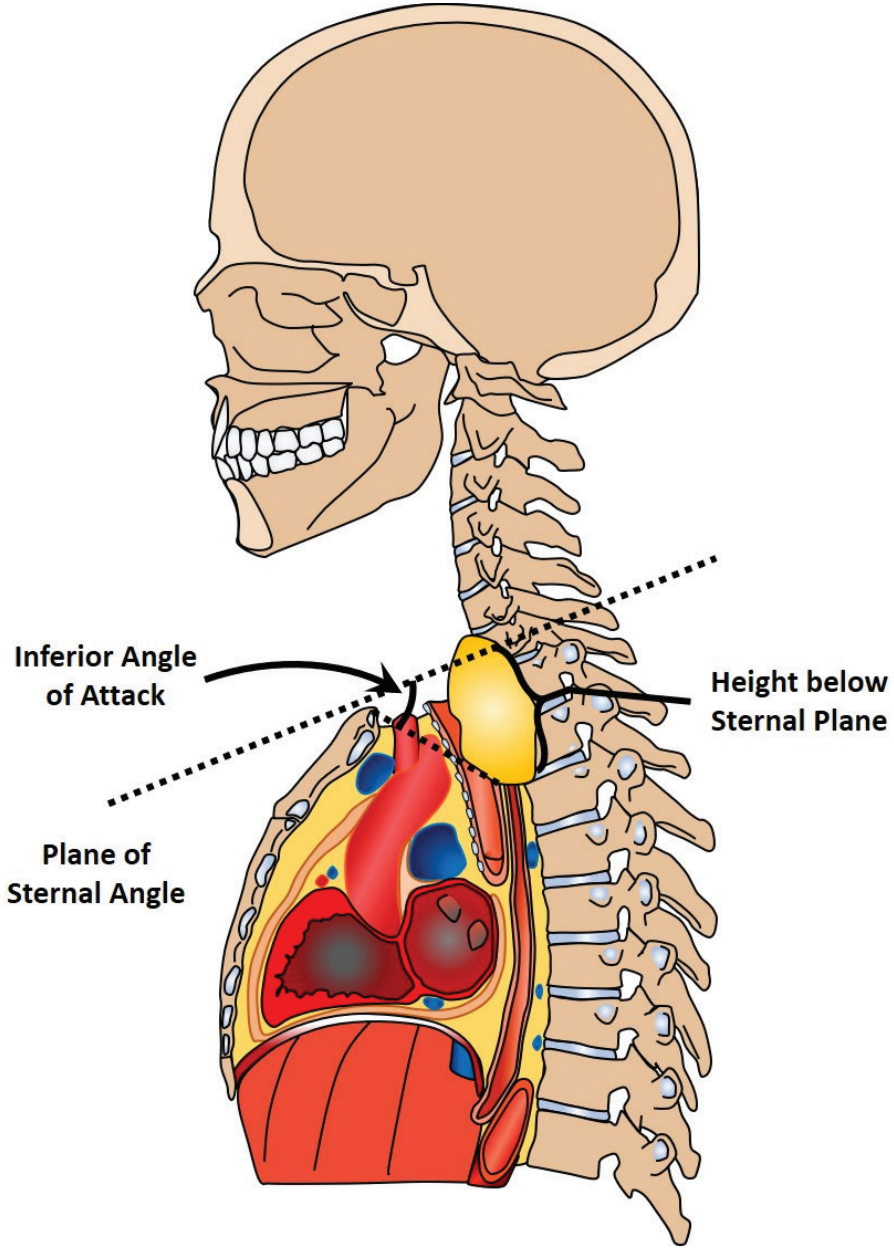

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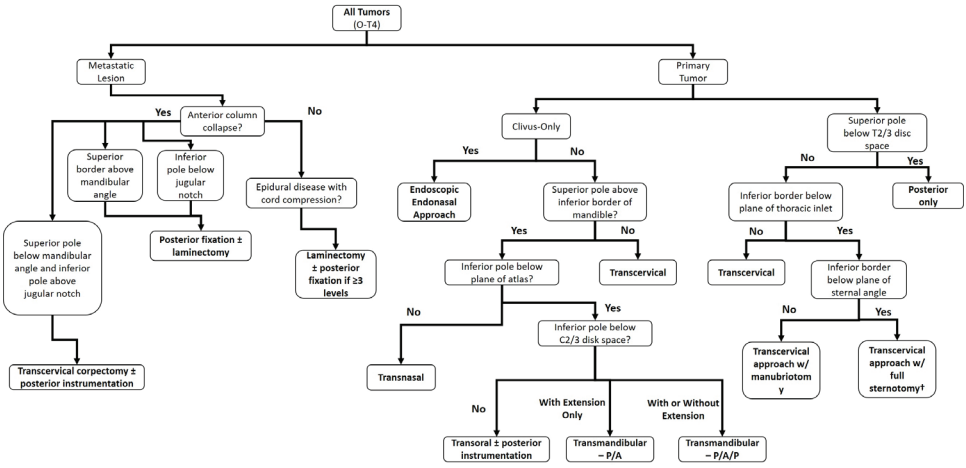

Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

E-POSTER #59

Development of a machine learning model for prediction of C5 palsy after instrumented cervical fusion

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Introduction: C5 palsy is a common post-operative complication of cervical fusion, occurring in 5-24% of patients.[1,2] Although the prognosis of C5 palsy is typically favorable, patients are often unable to perform basic activities of daily living, resulting in increased healthcare costs and decreased quality of life.[3] Accurate prediction of C5 palsy is thus of clinical utility. Advanced machine learning (ML) methods have grown in popularity across numerous disciplines due to their ability to recognize complex, non-linear relationships – often outperforming logistic regression (LR). We aim to build an ML algorithm for prediction of C5 palsy after instrumented cervical fusion. Additionally, we aim to compare the performance of this model with logistic regression (LR) and other standard ML models. We hypothesize that the ML model will identify novel predictive features compared to LR.

Materials and Methods: All adult patients who underwent instrumented cervical fusion at our institution between 2013-2020 were included. The primary outcome was C5 palsy within index admission or follow-up encounters. Surgical approach, indications, pre-operative neurologic status, pre-operative laboratory values, and medical/psychiatric comorbidities were included as explanatory features. We built an LR model and four standard ML models representing different classes of modeling approaches: XGBoost, gradient boosting, AdaBoost, random forest. Five-fold stratified cross-validation was used to avoid model overfitting. Discrimination and calibration were assessed with area under the receiver operating characteristic curve (AUROC) and Brier score, respectively. We ranked the contribution of the included variables to model performance.

Results: A total of 1,024 patients were included in this study. There were 52 cases of C5 palsy (5.1%). The XGBoost model demonstrated the highest discrimination (AUROC: 0.752 + 0.057) compared to LR (0.722 + 0.037) (Table 1). This model was well-calibrated with a Brier score of 0.048 + 0.002. Pre-operative non-motor neurologic symptoms, presence of paresthesias, myelopathy, and male sex are important to both the XGBoost and LR models. Six of the ten most important features to XGBoost model performance are markedly less important for LR: thoracic fusion, psychiatric comorbidity, pre-operative motor deficit, diabetes, trauma, and corpectomy (Table 2).

Conclusion: We report an ML model that accurately predicts C5 palsy after instrumented cervical fusion, outperforming LR. Most prior applications of ML were built with administrative databases and were unable to reliably predict outcomes after cervical fusion. This represents the first ML algorithm for prediction of C5 palsy to our knowledge. The finding that over half of the features most important for XGBoost differ from those for LR is notable, suggesting that the superior accuracy of advanced ML methods stems from their ability to capture complex factor-factor interactions that regression is unable to detect.

By providing accurate prognostic information, this algorithm may facilitate an understanding of surgical risks and benefits – improving the informed consent process. Individualized risk

E-POSTER #59 continued

prediction for patients may allow for a better understanding of risks and benefits, preparing them for possible C5 palsy. This tool may also aid with identifying potentially modifiable risk factors such as diabetes and bipolar disorder, helping to accurately risk-stratify patients and decrease likelihood of C5 palsy.

Table 1. Discrimination and calibration of logistic regression and advanced ML models

Model	AUROC	Brier score
XGBoost	**0.752 ± 0.057**	0.050 ± 0.003
Logistic Regression	0.722 ± 0.037	0.048 ± 0.002
Gradient Boosting	0.740 ± 0.030	0.048 ± 0.002
AdaBoost	0.669 ± 0.075	0.161 ± 0.083
Random Forest	0.681 ± 0.061	0.048 ± 0.002

E-POSTER #59 continued

Table 2. Relative feature importance for C5 palsy after instrumented cervical fusion

Feature	Rank in gradient boosting (Rank in logistic regression)
Binary features	
Non-motor neurologic symptoms	1 (8)
Thoracic fusion	2 (14)
Myelopathy	3 (1)
Psychiatric comorbidity	4 (12)
Male sex	5 (7)
Pre-operative motor deficit	6 (36)
Diabetes mellitus	7 (41)
Trauma	8 (11)
Pre-operative paresthesias	9 (10)
Corpectomy	10 (39)
Continuous features	
Number of fused levels	1 (2)
Body mass index	2 (3)
Pre-operative white blood cell count	3 (6)
Charlson comorbidity index	4 (5)
Pre-operative hemoglobin	5 (4)
Age	6 (1)

E-POSTER #60

A Comparison of Postoperative Opioid Use in Patients Undergoing Cervical Laminectomy with Instrumented Fusion versus Cervical Laminoplasty with Reconstruction

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Introduction: Degenerative cervical myelopathy is commonly treated with cervical laminectomy with instrumented fusion (LF) or cervical laminoplasty with reconstruction (LP). Prior retrospective studies have not established which procedure is associated with higher risk of prolonged postoperative pain and subsequent long-term use of opioids which have known risks of dependence, addiction, and overdose. Therefore, we aimed to compare patients undergoing LF to those undergoing LP in terms of opioid use at 6 months after surgery.

Materials and Methods: We identified patients undergoing non-revision LF or LP procedures for treatment of cervical myelopathy in both a single-surgeon series cohort (2004-2018; Mount Sinai Hospital, New York, NY) and a nationally representative cohort drawn from the IBM® MarketScan® database (2014-2016). We recorded use of any opioid medication within 6 months of surgery and identified differences in unadjusted opioid use rates between LF and LP patients using a z-test. Multivariable logistic regression was used to evaluate the association between procedure type and postoperative opioid use at 6 months while adjusting for covariates. Adjusted odds ratios (aOR) with 95% confidence intervals (CI) were obtained. P-values less than 0.05 were considered significant.

Results: The single-surgeon cohort comprised 185 LF and 79 LP patients. Without adjusting for covariates, LF patients had a higher rate of 6-month opioid use (LF 16%, LP 5%, $p = 0.02$). After adjusting for age, sex, procedure time, year of surgery, number of spine levels involved, and preoperative opioid use, LF (compared to LP) patients had higher odds of 6-month postoperative opioid use (OR 2.89 95% CI 1.06 - 7.85, $p = 0.04$). The national cohort comprised 1,606 LF and 210 LP patients. Without adjusting for covariates, there was no significant difference in 6-month opioid use between LF and LP patients (LF 10%, LP 7%, $p = 0.09$). After adjusting for age, sex, comorbidities, and preoperative opioid use, we found no significant difference in odds of 6-month postoperative opioid use between LF and LP patients (OR 0.68 95% CI 0.38 - 1.18, $p = 0.17$).

Conclusion: These preliminary data comparing results from a single-surgeon series to a national cohort demonstrate the importance of validating findings from observational studies using various data sources. Our single-surgeon findings suggest that cervical LF (compared to LP) is associated with a higher rate of 6-month opioid use and imply that LF is associated with longer duration of postoperative pain, perhaps due to the greater overall dissection involved in LF versus LP. However, our national cohort analysis did not corroborate the single-surgeon cohort findings. In this ongoing study we further aim to compare LF to LP in more detail including total consumption of opioids in oral morphine equivalents and patterns of recovery including time on opioid medication and postoperative resource utilization. These analyses will further inform if LP may be the preferred surgical intervention over LF for cervical myelopathy

E-POSTER #60 continued

patients with a history of substance abuse, comorbid psychiatric disorders, sedative medication use, or other risk factors for chronic opioid use.

Table 1. Comparison of demographics, perioperative characteristics, comorbidities, and postoperative opioid medication use between cervical laminoplasty and cervical laminectomy with fusion patients in the single-surgeon cohort (n = 264).

	Laminoplasty	Laminectomy with fusion	Univariable Analysis	
	Mean (SD) or Count (%)	Mean (SD) or Count (%)	Statistical test	P-value
Number of patients	79	185	-	-
Demographic and Perioperative Variables				
Age (years)	62 (11)	62 (12)	t-test	0.97
Male sex (%)	62 (78.5%)	122 (65.9%)	z-test	**0.04**
BMI	30.0 (7.2)	28.8 (11.3)	t-test	0.59
Had previous spine surgery (%)	26 (32.9%)	47 (25.4%)	z-test	0.21
Anesthesia time (min)	247 (39)	299 (63)	t-test	**0.02**
Procedure time (min)	127 (24)	175 (53)	t-test	**<0.001**
ASA physical status (%)				
1	3 (3.8%)	4 (2.2%)		
2	46 (58.2%)	73 (39.5%)	chi-squared	0.18
3	28 (35.4%)	80 (43.2%)		
4	1 (1.3%)	4 (2.2%)		
Estimated blood loss (mL)	251 (120)	495 (314)	t-test	**<0.001**
Length of stay (days)	3.4 (2.5)	4.3 (2.4)	t-test	**0.03**
Number of spine levels operated on	6.1 (0.8)	5.3 (0.9)	t-test	**0.05**
Opioid use within 1 month before surgery (%)	15 (19.0%)	32 (17.3%)	z-test	0.74
Comorbidities				
Asthma (%)	4 (5.1%)	16 (8.6%)		0.31
Diabetes mellitus (%)	14 (17.7%)	22 (11.9%)		0.21
Hypertension (%)	37 (46.8%)	89 (48.1%)		0.85
Hyperlipidemia (%)	36 (45.6%)	60 (32.4%)	z-test	**0.04**
Coronary artery disease (%)	11 (13.9%)	21 (11.4%)		0.56
COPD (%)	2 (2.5%)	4 (2.2%)		0.85
Arthritis (%)	4 (5.1%)	11 (5.9%)		0.78
GERD (%)	13 (16.5%)	20 (10.8%)		0.20
Outcomes				
Opioid use at 6-month follow-up (%)	4 (5.1%)	28 (15.1%)	z-test	**0.01**

E-POSTER #60 continued

Table 2. Comparison of demographics, perioperative characteristics, comorbidities, and postoperative opioid medication use between cervical laminoplasty and cervical laminectomy with fusion patients in the IBM® MarketScan® database national cohort (n = 1,816).

	Laminoplasty	**Laminectomy with fusion**	**Univariable Analysis**	
	Mean (SD) or Count (%)	Mean (SD) or Count (%)	Statistical test	P-value
Number of patients	210	1606	-	-
Demographic and Perioperative Variables				
Age (years)	54 (7)	54 (7)	t-test	1.00
Male sex (%)	140 (66.7%)	898 (59.1%)	z-test	**0.003**
Length of stay (days)	2.8 (2.3)	3.3 (2.9)	t-test	**0.006**
Preoperative chronic opioid use (%)	49 (23.3%)	586 (37.1%)		**<0.001**
Comorbidities				
Asthma (%)	12 (5.7%)	204 (12.7%)		**0.002**
Diabetes mellitus (%)	39 (18.6%)	420 (26.2%)		**0.02**
Hypertension (%)	115 (54.8%)	991 (61.7%)		0.05
Hyperlipidemia (%)	106 (50.5%)	864 (53.8%)	z-test	0.36
Coronary artery disease (%)	18 (8.6%)	130 (8.1%)		0.24
COPD (%)	27 (12.9%)	364 (22.7%)		**0.001**
Arthritis (%)	40 (19.0%)	454 (28.3%)		**0.005**
GERD (%)	43 (20.5%)	442 (27.5%)		**0.03**
Outcomes				
Opioid use at 6-month follow-up (%)	14 (6.7%)	167 (10.4%)	z-test	0.09

E-POSTER #61

Heated tobacco products could impair bone union after cervical fusion surgery: in vivo and in vitro study

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Introduction: A wide variety of tobacco products are available worldwide such as combustible cigarettes, electrical cigarettes, and heated tobacco products (HTPs). Since global combustible cigarette sales have been declining, the tobacco industry has rapidly been marketing new products, including HTPs [1]. The tobacco producers claim that HTPs are less harmful than traditional cigarettes, because the HTPs systems operate at lower temperatures (240–350°C) than conventional cigarettes (> 600°C), and produce lower levels of harmful chemicals such as tar than conventional cigarettes when used [2-5]. In the United States, the Food and Drug Administration authorized the marketing of HTPs in 2019. Due to the expected shrinking of the e-cigarette market in the near future, HTP consumption is predicted to increase rapidly [6]. However, there have been no studies that have assessed the effect of HTPs on osteoblastic differentiation and bone union which is critical issues for some kinds of cervical surgery such as anterior cervical discectomy and fusion. Therefore, the purpose of this non-industry-supported study was to investigate the effect of HTPs on cell viability, osteoblast differentiation in vitro, and bone union in vivo by comparing with those of conventional combustible cigarettes.

Materials and Methods: Cigarette smoke extracts (CSEs) were generated from combustible cigarette (cCSE) and HTPs (hCSE). CSE concentrations were standardized by assessing optical density. Preosteoblast (MC3T3E1) cells were incubated with normal medium, or with cCSE or hCSE. The viability of cells was assessed via MTT assay. After the osteoblastic differentiation of cCSE- or hCSE-exposed MC3T3E1 cells, alkaline phosphatase (ALP) activity was assessed. To assess in vivo effects of cCSE and hCSE, femoral midshaft osteotomy was performed in a rat model, and saline, cCSE, or hCSE was injected intraperitoneally once every five days. After four weeks of treatment, bone union was assessed using μCT and biomechanical test.

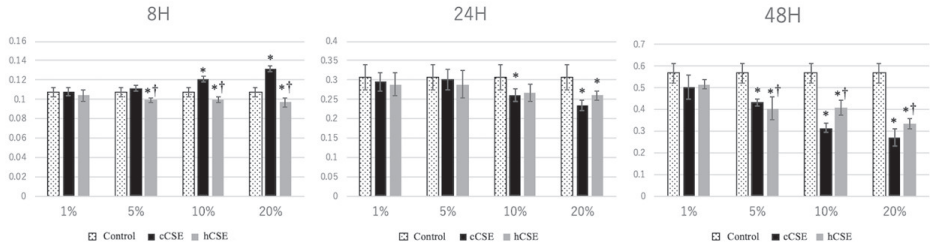
Results: MC3T3E1 cell viability was reduced when treated with either cCSE or hCSE in a time- and concentration-dependent manner (Figure1). ALP activity after osteoblastic differentiation of cells incubated with cCSE was significantly lower than that of cells not treated with extracts or treated with hCSE. Moreover, levels of osteoblastic differentiation in untreated cells and in those treated with hCSE significantly differed. In vivo assessment of the cortical region of the femoral midshaft revealed that both cCSE and hCSE administration significantly decreased bone mineral content four weeks post-surgery compared to levels observed in untreated animals (Table1). Additionally, cCSE- and hCSE-exposed femurs had significantly lower bone volumes than unexposed femurs (Figure2). No significant differences in μCT-analyzed parameters were observed between cCSE- and hCSE-treated femurs. In biomechanical test, both cCSE and hCSE administration significantly decreased maximum load and elastic modulus (Table1).

Conclusion: Although manufacturer-sponsored studies have mostly shown the health

E-POSTER #61 continued

benefits of switching from conventional cigarettes to HTPs [7], current independent study revealed that the HTPs use negatively affects bone union to a degree similar to that of combustible cigarettes. Cervical spine surgeons should recommend HTP smoking cessation to achieve adequate bone union fort the patients who undergo the cervical fusion surgery.

Figure1: Viability of MC3T3E1 cells treated with the indicated concentrations of cigarette smoke extract.



*significant difference compared with control group; † significant difference compared with cCSE group

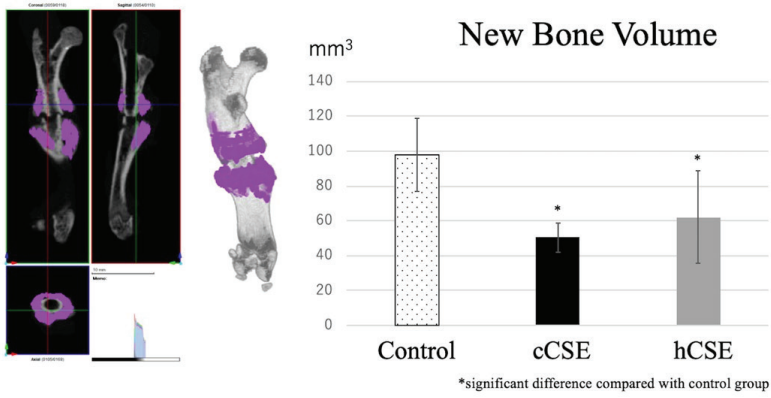
Table 1. μCT analysis and biomechanical assessment of the cortical bone region at the femoral midshaft

	Control	cCSE	hCSE	P-Value
μCT assessment				
BMC (mg/cm^3)	107.0 ± 11.9	94.5 ± 13.0*	89.0 ± 10.1*	.049
BMD (mg)	624.5 ± 38.5	537.8 ± 35.7*	577.4 ± 73.3	.036
Ct.Th (mm)	0.52 ± 0.004	0.54 ± 0.003	0.54 ± 0.003	.559
CSA (mm^2)	7.76 ± 1.52	9.89 ± 0.85*	8.76 ± 1.33	.033
Biomechanical assessment				
Maximum load (N)	71.4 ± 8.7	39.3 ± 13.9*	41.0 ± 13.5*	.015
Elastic modulus (N/mm^2)	$31.6\times10^6 \pm 12.3\times10^6$	$15.2\times10^6 \pm 5.6\times10^{6*}$	$10.3\times10^6 \pm 6.3\times10^{6*}$	.019

Mean ± SD values are shown, *significant difference compared with control group
BMC: bone mineral content; BMD: bone mineral density; Ct.Th: cortical thickness; CSA: cross-sectional area

E-POSTER #61 continued

Figure2: The quantification of new bone volume in the femoral midshaft



E-POSTER #62

The improvement of mental-related quality-of life after cervical surgery for the patients with cervical spondylotic myelopathy

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Introduction: Cervical surgery is associated with significant improvements in physical function postoperatively for the patient with cervical spondylotic myelopathy (CSM) [1, 2]. The physician-assessed functional status significantly recovered within 1 year postoperatively, with further recovery up to 2 years postoperatively [3]. We hypothesized that patient reported mental quality-of-life (QOL) would improve with some delay, subsequent to improvements in physical function and physical QOL. To test our hypothesis, the primary aim of the current study was to delineate the improvement process of mental QOL after surgery for CSM with a focus on individual change, using the minimal clinically important difference (MCID) framework.[4] The secondary aim was to identify the preoperative variables associated with improvement for mental QOL.

Materials and Methods: One hundred consecutive patients who underwent laminoplasty for CSM, with complete clinical data preoperatively and 3 months and 2 years postoperatively, were enrolled. The Short Form-36 physical component summary (PCS) and mental component summary (MCS) scores were used as parameters of physical and mental QOL, respectively, and 4.0 was defined as MCID for both parameters[5]. We determined the number of patients who achieved an improvement in the PCS and MCS greater than the MCID at 3 months and 2 years postoperatively. For the PCS and MCS each, patients who achieved an improvement greater than the MCID at both 3 months and 2 years postoperatively were considered to have "maintained improvement". Additionally, patients failed to achieve an improvement greater than the MCID at 3 months, but achieved an improvement greater than MCID at 2 years postoperatively were considered to have "late improvement". To evaluate the preoperative factors related with the mental QOL improvement at 2 years postoperatively, preoperative clinical scores were compared between patients with improvements greater and less than the MCID. Significant variables were included in a multinomial logistic regression analysis and further validated in a receiver-operating characteristic (ROC) curve analysis.

Results: A total of 64 and 48 patients achieved meaningful improvement (>MCID) in PCS and MCS scores at 3 months postoperatively, with maintained improvement in 46/64 (71.9%) and 34/48 patients (70.8%), respectively (PCS vs MCS: p=0.912, Table1). Additionally, 15/36 patients (41.7%) and 8/52 patients (15.4%) achieved late improvement in PCS and MCS scores, respectively (PCS vs MCS: p=0.007, Table1). In terms of the preoperative factors related with the MCS improvement, the preoperative "social functioning (SF)" score was independently associated with MCS score improvement (p=0.001, Table2). ROC curve analysis validated the ability of preoperative SF to predict MCS score improvement at 2 years postoperatively (area under the curve: 0.744, Figure1).

Conclusion: Up to 45% of the patients experienced a meaningful improvement in their mental QOL at 2 years postoperatively. Contrary to our hypothesis, the mental QOL improvement was decided within 3 months postoperatively, and there was a low chance

E-POSTER #62 continued

of improvement over the next 21 months. The improvement was significantly related with the preoperative SF sore. These results can suggest that the to establish the patient's social functioning again immediately after surgery could be a key to achieve the QOL improvement.

Table 1. Cross-tabulated improvements in PCS and MCS scores

Patients who improved at 3 months			
	Improved at 2y	Not improved at 2 y	p-value
SF-36 PCS (n=64)	46	18	0.912
SF-36 MCS (n=48)	34	14	
Patients who did not improved at 3 months			
	Improved at 2y	Not improved at 2 y	0.007
SF-36 PCS (n=36)	15	21	
SF-36 MCS (n=52)	8	44	

The definition of "Improved" is the patients who showed the positive change of the PCS or MCS score more than MCID (=4.0 points). #: Chi-squared test, MCID: Minimal Clinically Important Difference, SF-36: Short form-36, PCS: physical component summary, MCS: Mental component summary, 3m: 3months, 2y: 2 years

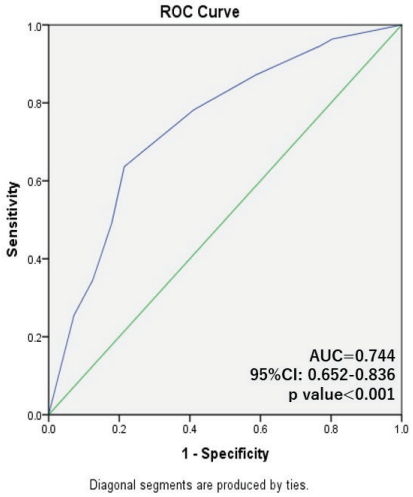
Table2 Preoperative factor relating with MCS improvement by more than the MCID

	Univariate analysis			Multivariate analysis	
	No-change group	Improvement group	p-value	aOR	p-value
Age	66.0±11.1	64.6±12.3	0.557 #		
Gender (female)	33	32	0.848 *		
Preop cJOA score					
Total score	9.7±3.2	9.9±3.2	0.775 #		
Finger motion	2.0±0.9	2.2±1.0	0.257 #		
U/E motion	-0.4±0.5	-0.4±0.5	0.853 #		
L/E motion	1.9±1.0	1.8±1.2	0.540 #		
U/E sensory	0.9±0.4	0.9±0.5	0.490 #		
Trunk sensory	1.7±0.5	1.7±0.5	0.853 #		
L/E sensory	1.3±0.5	1.3±0.6	0.792 #		
BBD	2.3±1.0	2.2±1.0	0.605 #		
Preop SF-36					
PF	43.2±28.6	41.4±32.0	0.748 #		
RP	39.2±30.3	30.9±31.1	0.161 #		
BP	40.7±22.5	32.3±24.0	0.065 #		
GH	47.4±16.0	44.3±20.6	0.383 #		
VT	42.4±24.1	30.9±21.2	0.010 #	1.03	0.069
SF	66.1±28.2	39.5±29.4	<0.001 #	0.97	0.001
RE	55.6±32.4	32.7±30.1	<0.001 #	0.98	0.071
MH	61.1±21.7	44.2±25.7	<0.001 #	0.98	0.076

Mann-Whitney U test, * Chi-squared test. Preop: Preoperative, cJOA: cervical Japanese Orthopaedic Association, U/E: upper extremity, L/E: lower extremity, BBD: bowel bladder disfunction, SF: Short form, PF: physical functioning, RP: physical role limitations, BP: bodily pain, GH: general health perceptions, VT: energy/vitality, SF: social functioning, RE: emotional role limitations, MH: mental health

E-POSTER #62 continued

Figure1



E-POSTER #63

Comparison of Clinical and Radiographic Outcomes After Collar Use Following Cervical Laminoplasty

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Introduction: To date, there are few studies examining the use of a cervical collar on clinical and radiographic outcomes in patients undergoing cervical laminoplasty. We aim to compare clinical and radiographic outcome in patients with or without collar post-operatively.

Materials and Methods: Patients who underwent laminoplasty by three surgeons from 2009-2020 were retrospectively studied. A portion of patients wore cervical collar after cervical laminoplasty while the rest did not. Demographic variables, surgical factors, radiographic measurements, and clinical outcomes were collected. Univariate analysis was used to determine baseline differences. Multivariate regression was performed to correct for confounding variables.

Results: There were 310 (194 male) met inclusion criteria, with 161 patients wearing post-operative cervical collar while 149 patients did not.. The mean age was 63.6 years, and mean follow-up was 1.61 ± 1.70 years. Univariate analysis demonstrated no statistically significant differences in baseline patient characteristics.

Multivariate regression showed no differences in post-operative neck pain (p=0.12), post-operative arm pain (p=0.56), post-operative mJOA (0.27), post-operative EQ-5D (p=0.25), post-operative cervical lordosis (CL) (p=0.11), post-operative T1 slope (p=0.28), post-operative CL-T1 slope (p=0.97), post-operative cervical sagittal vertical axis (cSVA) (p=0.56), and post-operative k-line tilt (p=0.56).

However, post-operative sagittal vertical axis (SVA) was found to be significantly different between the two groups (p=0.04), with patient wearing a cervical collar having 15.2 mm higher SVA than those without collar.

Conclusion: Wearing a cervical collar after laminoplasty does not improved neck pain and may increase cervical sagittal malalignment from possible muscle atrophy due to deconditioning. Base on our currently findings, routine used of cervical collar after cervical laminoplasty is not recommended.

E-POSTER #63 continued

Table 1. Summary of demographic and preoperative radiographic variables using univariate analysis

	Overall	No collar	Collar	P-value	Coefficient
All patients	310	149	161		
Age (years)	63.6 ± 12.6	64.3 ± 12.4	62.9 ± 12.8	0.32	0.99
Male Sex	194	91	103		
Female Sex	116	58	58	0.68	
BMI		29.2 ± 10.6	27.8 ± 5.4	0.14	1.48
SVA (mm)		41.0 ± 45.8	45.4 ± 38.7	0.59	-0.54
TK (°)		33.0 ± 13.9	30.5 ± 13.5	0.36	0.93
CL (°)		11.9 ± 8.5	11.2 ± 8.2	0.53	0.62
T1 (°)		31.6 ± 10.3	31.0 ± 10.3	0.67	0.42
CL-T1 (°)		20.5 ± 9.6	20.6 ± 9.2	0.93	-0.09
CSVA (°)		32.6 ± 15.1	32.3 ± 16.9	0.89	0.14
K-line Tilt (°)		17.2 ± 10.1	16.5 ± 9.1	0.56	0.58

E-POSTER #63 continued

Table 2. Summary of postoperative outcomes and radiographic variables using multivariate analysis

	Beta coefficient (95% CI)	P-value
Neck Pain	-0.85 (-1.93, 0.23)	0.12
Arm Pain	-0.62 (-2.73, 0.91)	0.35
mJOA	1.60 (-1.32, 4.53)	0.27
NDI	-1.34 (-2.51, 2.10)	0.85
EQ-5D	0.08 (-0.06, 0.22)	0.25
SVA (mm)	15.2 (0.42, 30.06)	0.04
TK (°)	-2.75 (-7.17, 1.67)	0.22
CL (°)	-1.71 (-3.78, 0.36)	0.11
T1 (°)	-1.35 (-4.11, 2.33)	0.59
CL-T1 (°)	-0.05 (-2.51, 2.41)	0.97
CSVA (°)	1.07 (-2.59, 4.74)	0.56
K-line Tilt (°)	0.75 (-1.80, 3.31)	0.56

E-POSTER #64

Natural Language Processing of Operative Note Dictations to Automatically Generate CPT Codes for Billing

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Icahn School of Medicine at Mount Sinai[1] NYP Och Spine Hospital / Columbia Univ[2] Columbia University Irving Medical Cente[3] Columbia University Medical Center[4]

Introduction: Medical notes contain a rich supply of medical data, yet the format of unstructured text precludes this data from being readily used by computers for data mining. Using natural language processing in combination with machine learning on standard operative notes may allow for efficient billing, maximization of collections and minimization of coder error. We hypothesize that a machine learning algorithm can accurately identify billing cpt codes on unstructured patient operative notes.

Materials and Methods: This was a retrospective analysis of medical notes from a large, single-center academic institution's database comprised of cases from a single surgeon. Inclusion criteria included patients who underwent elective spine surgery by a single senior surgeon from 9/2015 to 1/2020. Algorithm performance was measured by performing receiver-operating characteristic analysis and calculating the area under the receiver-operating curve and the area under the precision recall curve.The data was randomized with 70% used for training and 30% used for testing. Labels (CPT codes) were generated by the billing and coding department.

Natural language processing techniques were used to analyze standard operative notes and train an algorithm to automatically generate CPT codes. A deep learning natural language processing algorithm (long short-term memory network with attention) and a Random Forest algorithm were both trained and tested on operative notes to predict CPT codes. CPT codes generated by the billing department were compared to those generated by our model.

Results: 391 operative dictations fit our inclusion criteria. The random forest machine learning model had an area under the receiver-operating curve of 0.94 and an area under the precision-recall curve of 0.85. The deep learning long short term memory model had a final area under the receiver-operating curve of 0.72 and an area under the precision-recall curve of 0.44. The CPT-by-CPT accuracies for the 14 most common CPT codes were generated for each model. These show that the random forest model had a weighted average, class-by-class accuracy of 87%. The long short term memory, deep learning model had a weighted average, CPT-by-CPT accuracy of 59%. The attention map (Figure 2) shows that the long short term memory model looks closely at certain words in the operative dictation to generate a prediction of cpt codes. The models took 0.1 seconds on average to "read" an operative note and generate a CPT code prediction for that note.

Conclusion: Combining natural language processing with machine learning is a valid approach for automatic generation of cpt billing codes. Machine learning models can learn to "read" a surgeon's operative dictations and quickly produce the CPT codes for billing. The random forest machine learning model outperformed the long short term memory deep

E-POSTER #64 continued

learning model in this case. However, with a sufficiently large training sample, these models can be used by orthopaedic or neurosurgery departments to allow for efficient billing, maximization of collections, and minimization of coder error.

Note: dict daniel k riew md admit date 08202018 discharge date procedure date 08202018 surgeon daniel k riew md preoperative diagnosis cervical spondylosis with myelopathy c4 through 7 postoperative diagnosis cervical spondylosis with myelopathy c4 through 7 procedure 1 anterior cervical corpectomy of c5 removing 75% of the vertebral body on the right side 2 anterior cervical diskectomy fusion at c6-7 3 anterior cervical plating c4 through 7 with a biomet maxan green plate 4 anterior cervical fusion c4-5 5 anterior cervical fusion additional level c5-6 6 structural fresh frozen iliac crest allografting 7 local autologous bone grafting 8 demineralized bone matrix allograft plus extra-extra small bmp grafting 9 microdissection for corpectomy assistant joseph osorio md anesthesia general endotracheal blood loss 75 ml complication none indication for operation patient is from florida was referred to us by dr nate lowen as she had multilevel cervical spondylosis with myelopathy she had undergone full conservative treatment and having failed this elected to proceed with surgery risks and benefits explained to the patient she accepted and wished to proceed description of procedure after successful induction of general anesthesia and intubation the patient was prepped and draped in the usual manner a standard smith-robinson approach was utilized to expose the anterior cervical spine thru a left-sided approach we elevated the longus colli localized the correct level and placed in retractors after exposure we started out with a c5 corpectomy and we decompressed 75% of the vertebral body leaving a thin wedge of bone posteriorly on the right side but otherwise thoroughly decompressing the 4-5 and 5-6 levels and then we reconstructed with a struct fresh frozen iliac crest allograft to bridge from c4 down to c6 on the left side there was a little bit of room left over so we used a unicortical small wedge graft to put into the uncinates at both levels and then turned our attention to the c6-7 level where we did a thorough diskectomy and put in 1 tricortical and 1 bicortical bone graft side by side along with local autograft demineralized bone matrix we used an extra- extra small bmp that was divided about 50% into the c6-7 level the other 50% at c4-5 and c5-6 that we put into small cavities that we cut into the iliac crest allograft we then took an anterior cervical plate biomet maxan green plate put 2 screws into c4 1 into c5 in the remaining 25% of the bone on the left side and 2 screws into c6 2 screws into c7 obtained an x-ray which confirmed that everything was in good position we achieved hemostasis put bone wax in front of the plate tisseel to seal everything in vancomycin powder hemostatic agents and depo-medrol 40 mg then we put in the drain and closed the wound in layers i used the microscope for better visualization of the spinal cord and nerve roots during the entire procedure and the corpectomy was performed using microdissection techniques and principles she tolerated the operation well both dr osorio and i were present for the entire operation attestation i was present for the all key parts of the procedure i understand that section 1842b7d of the social security act generally prohibits medicare physician fee schedule payment for the services of assistants at surgery in teaching hospitals when qualified residents are available to furnish such services i certify that the services for which payment is claimed were medically necessary and that no qualified resident was available to perform the services i further understand that these services are subject to post-payment review by the medicare carrier dd 08202018 dt 08202018 mdq232723 232723750820 electronic signatures riew k daniel k md signed on 21-aug-2018 14 24 authored transcriptionist it entered on 20-aug-2018 00 00 entered last updated 21-aug-2018 14 24 by riew k daniel k md

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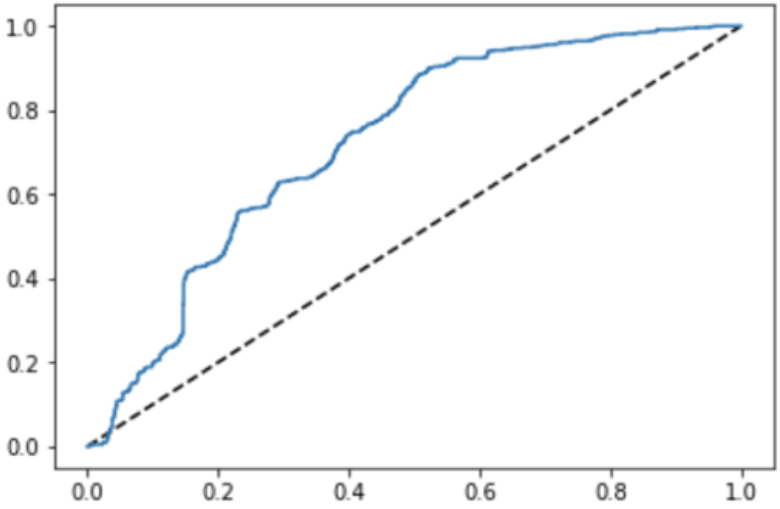
Predicted
['20931', '20936', '22585', '20930', '63081', '22856', '22858', '22846', '22551']
True
['20931', '20936', '22585', '20930', '63081', '22554', '22846', '22551']
```

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.

E-POSTER #64 continued

CPT	AUC	Accuracy
22853	0.961	90.5%
22856	0.993	98.4%
20931	0.939	81.7%
22552	0.900	76.9%
20930	0.806	76.9%
69990	0.964	86.5%
22845	0.877	82.5%
22858	0.997	98.4%
22554	0.948	88.9%
22585	0.882	82.5%
22846	0.861	82.5%
22851	0.911	93.7%
22551	0.918	92.1%
20936	0.856	78.6%
63081	0.941	85.7%

E-POSTER #64 continued



AUROC score: 0.7231737933268545

CPT	AUC	Accuracy
22845	0.626	58.7%
22585	0.663	60.3%
20931	0.930	85.7%
22858	0.907	84.9%
69990	0.873	83.3%
22552	0.694	63.5%
22863	0.568	35.7%
63081	0.899	80.2%
22856	0.008	2.4%
22846	0.431	41.3%
20936	0.647	55.6%
22551	0.809	74.6%
20930	0.640	61.1%
22554	0.882	75.4%
22851	0.252	31.7%

E-POSTER #65

Impact of Smoking on Clinical Outcomes After Posterior Cervical Fusion

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Rothman Orthopaedic Institute[1] Rothman Institute[2] The Rothman Institute at Thomas Jefferson University[3]

Introduction: Posterior cervical fusion (PCF) is commonly performed for cervical spondylotic disease, including radiculopathy and/or myelopathy. In anterior cervical decompression and fusion (ACDF), smoking has shown to decrease fusion rates while increasing rates of infection, adjacent-segment disease, and dysphagia, but has not been shown to be associated with clinical outcomes. There is limited research investigating the relationship between smoking and clinical outcomes in PCF. Accordingly, the purpose of this study was to investigate how smoking status impacts patient reported outcomes following PCF.

Materials and Methods: Electronic medical records (EMR) were reviewed for all patients =18 years who underwent PCF between 2013 and January 2020 at a single institution. Exclusion criteria included less than 11-months patient reported outcome measure (PROM) follow-up data, revision procedures, or a preoperative diagnosis of tumor or infection. Patient characteristics and demographic data were obtained from the EMR. Patients were separated into three groups: current smokers, former smokers, and never smokers. A delta score (?) was calculated for all PROMs. Analysis of variance (ANOVA) tests were utilized for comparing continuous data between groups. Categorical data were compared using Pearson's chi-square tests. Alpha was set at 0.05. Patients were then regrouped into current smoking status (current smokers vs. former smokers/never smokers) and independent two-sample t-tests were utilized for comparing continuous data between groups in place of ANOVA.

Results: Of the 207 patients in the cohort, 35 (16.9%) were current smokers, 52 (25.1%) were former smokers, and 120 (58.0%) were never smokers. The never smoker group had significantly lower rates of depression (current 37.1%, former 38.5%, never 20.0%; p=0.017) and anxiety (current 40.0%, former 30.8%, never 17.5%; p=0.012) (Table 1). Current smokers had significantly lower mental component scores (MCS-12) postoperatively when compared to former smokers and never smokers (46.8 vs. 53.7 and 52.2, p=0.038) (Table 2). Based on the current smoking status of the 207 patients, 35 (16.9%) were current smokers and 172 (83.1%) were non-smokers. Groups differed in rate of preoperative history of anxiety (smokers: 40.0% vs. non-smokers: 21.5%, p=0.036). Non-smokers reported higher postoperative MCS-12 scores (52.7 vs. 46.8, p=0.014) as well as lower preoperative visual analog scale (VAS) Arm scores (5.23 vs. 6.36, p=0.033) (Table 3).

Conclusion: The results of the study suggest that smoking status does not significantly impact patient reported outcomes for patients undergoing PCF. Further research is required to evaluate the surgical outcomes after PCF in the setting of nicotine and tobacco use.

E-POSTER #65 continued

Table 1. Patient demographics by smoking history

	Current smoker (N=35)	Former smoker (N=52)	Never smoker (N=120)	P-value
Age (years)	59.1 (11.5)	60.2 (11.1)	60.3 (11.3)	0.730
Sex				0.586
Female	19 (54.3%)	23 (44.2%)	54 (45.0%)	
Male	16 (45.7%)	29 (55.8%)	66 (55.0%)	
BMI	30.5 (6.30)	28.9 (4.51)	30.5 (6.26)	0.324
PMH of depression	13 (37.1%)	20 (38.5%)	24 (20.0%)	**0.017***
PMH of anxiety disorder	14 (40.0%)	16 (30.8%)	21 (17.5%)	**0.012***
Estimated blood loss (mL)	172 (86.1)	188 (107)	255 (368)	0.965
Number of levels fused	3.69 (1.73)	3.62 (1.65)	3.92 (1.95)	0.481
Symptom duration				0.080
<6 months	11 (31.4%)	19 (38.0%)	56 (49.1%)	
6 months – 2 years	14 (40.0%)	14 (28.0%)	39 (34.2%)	
>2 years	10 (28.6%)	17 (27.9%)	19 (16.7%)	

*Indicates statistical significance ($p<0.05$).

Abbreviations: Body Mass Index (BMI), Past Medical History (PMH)

E-POSTER #65 continued

Table 2. Patient reported outcome measurements comparisons by smoking history

		Current smoker (N=35)	*Former smoker (N=52)*	*Never smoker (N=120)*	*P-value*
MCS-12	Preoperative	44.8 (12.0)	48.2 (11.6)	45.4 (11.5)	0.273
	Postoperative	46.8 (13.4)	53.7 (9.99)	52.2 (11.1)	**0.038***
	Delta	2.06 (14.7)	5.51 (9.20)	6.80 (11.3)	0.101
	MCID	17 (48.6%)	27 (51.9%)	67 (55.8%)	0.721
	Follow-up (days)	650 (297	698 (384)	694 (365)	0.952
PCS-12	Preoperative	30.9 (7.55)	32.6 (9.67)	30.4 (8.51)	0.306
	Postoperative	37.3 (10.8)	38.6 (10.7)	38.3 (10.6)	0.754
	Delta	6.42 (12.6)	5.97 (10.8)	7.84 (11.7)	0.407
	MCID	14 (40.0%)	24 (46.2%)	61 (50.8%)	0.509
	Follow-up (days)	650 (297	698 (384)	694 (365)	0.952
NDI	Preoperative	42.2 (19.1)	39.2 (20.2)	42.4 (22.1)	0.704
	Postoperative	39.7 (22.5)	32.7 (20.6)	32.5 (20.4)	0.200
	Delta	2.51 (21.8)	6.46 (19.6)	9.93 (18.9)	0.154
	MCID	7 (20.0%)	12 (23.1%)	34 (28.3%)	0.543
	Follow-up (days)	644 (353)	771 (505)	704 (467)	0.817
VAS Neck	Preoperative	6.38 (2.82)	5.57 (3.28)	5.56 (3.26)	0.405
	Postoperative	3.57 (2.88)	2.78 (2.35)	3.04 (2.85)	0.536
	Delta	2.81 (3.70)	2.79 (3.28)	2.52 (3.21)	0.645
	MCID	18 (51.4%)	27 (51.9%)	59 (49.2%)	0.935
	Follow-up (days)	675 (385)	695 (392)	627 (365)	0.453
VAS Arm	Preoperative	6.36 (3.01)	5.48 (3.01)	5.13 (3.15)	0.085
	Postoperative	3.26 (2.95)	2.02 (2.31)	2.56 (2.76)	0.131
	Delta	3.09 (3.59)	3.45 (3.03)	2.57 (3.15)	0.229
	MCID	12 (34.3%)	18 (34.6%)	36 (30.0%)	0.791
	Follow-up (days)	675 (385)	695 (392)	627 (365)	0.453
MJOA[1]	Preoperative	12.7 (3.52)	14.1 (2.78)	13.8 (3.07)	0.285
	Postoperative	14.2 (2.65)	14.5 (3.17)	14.4 (3.00)	0.806
	Delta	0.83 (3.11)	0.65 (2.50)	0.09 (3.56)	0.320
	MCID	2 (11.1%)	7 (20.6%)	19 (22.4%)	0.647
	Follow-up (days)	546 (345)	504 (182)	476 (168)	0.991

*Indicates statistical significance ($p<0.05$).

[1]MJOA: current smoker N=18, former smoker N=34, never smoker N=85

Abbreviations: Mental Health Component Score (MCS), Minimum Clinically Important Difference (MCID), Modified Japanese Orthopaedic Association (MJOA), Neck Disability Index (NDI), Physical Health Component Score (PCS), Visual Analog Scale (VAS)

E-POSTER #65 continued

Table 3. Patient reported outcome measurements comparisons by current smoking status

		Non-smoker (N=172)	*Current smoker (N=35)*	*P-value*
MCS-12	Preoperative	46.3 (11.6)	44.8 (12.0)	0.514
	Postoperative	52.7 (10.8)	46.8 (13.4)	**0.014***
	Delta	6.41 (10.7)	2.06 (14.7)	0.105
	MCID	94 (54.7%)	17 (48.6%)	0.637
	Follow-up (days)	695 (370)	650 (297)	0.868
PCS-12	Preoperative	31.1 (8.91)	30.9 (7.55)	0.933
	Postoperative	38.4 (10.6)	37.3 (10.8)	0.462
	Delta	7.28 (11.4)	6.42 (12.6)	0.452
	MCID	85 (49.4%)	14 (40.0%)	0.406
	Follow-up (days)	695 (370)	650 (297)	0.868
NDI	Preoperative	41.4 (21.5)	42.2 (19.1)	0.734
	Postoperative	32.5 (20.4)	39.7 (22.5)	0.073
	Delta	8.88 (19.1)	2.51 (21.8)	0.136
	MCID	46 (26.7%)	7 (20.0%)	0.535
	Follow-up (days)	648 (374)	675 (385)	0.882
VAS Neck	Preoperative	5.56 (3.25)	6.38 (2.82)	0.180
	Postoperative	2.96 (2.71)	3.57 (2.88)	0.288
	Delta	2.60 (3.22)	2.81 (3.70)	0.507
	MCID	86 (50.0%)	18 (51.4%)	1.000
	Follow-up (days)	675 (385)	695 (392)	0.453
VAS Arm	Preoperative	5.23 (3.10)	6.36 (3.01)	**0.033***
	Postoperative	2.40 (2.63)	3.26 (2.95)	0.100
	Delta	2.84 (3.13)	3.09 (3.59)	0.418
	MCID	54 (31.4%)	12 (34.3%)	0.892
	Follow-up (days)	648 (374)	675 (385)	0.882
MJOA[1]	Preoperative	13.9 (2.98)	12.7 (3.52)	0.122
	Postoperative	14.4 (3.04)	14.2 (2.65)	0.570
	Delta	0.25 (3.29)	0.83 (3.11)	0.233
	MCID	26 (21.8%)	2 (11.1%)	0.366
	Follow-up (days)	484 (172)	546 (345)	0.935

*Indicates statistical significance ($p<0.05$).

[1]MJOA: non-smoker N=119, current smoker N=18

Abbreviations: Mental Health Component Score (MCS), Minimum Clinically Important Difference (MCID), Modified Japanese Orthopaedic Association (MJOA), Neck Disability Index (NDI), Physical Health Component Score (PCS), Visual Analog Scale (VAS)

E-POSTER #66

Assessing the Efficacy of the mJOA in Myelopathic Patients: A Cervical QOD Study

Timothy Yee, MD[1], Paul Park, MD
University of Michigan[1]

Introduction: The modified Japanese Orthopedic Association (mJOA) score is a validated metric for assessing severity of myelopathy. However, its relationship to functional and quality-of-life outcomes after surgery is incompletely known.

Materials and Methods: The cervical module of the prospectively enrolled Quality Outcomes Database (QOD) was queried. Patients over age 18 who underwent single-stage surgery for cervical spondylotic myelopathy (CSM) were included. Revision and operations for infection, trauma, and tumor were excluded. Postoperative outcomes included the modified Japanese Orthopedic Association (mJOA) score, the Neck Disability Index (NDI), and Quality-Adjusted Life Year (QALY) by EQ-5D. Improvement in mJOA was used as the independent variable in univariate and multivariate linear and logistic regression.

Results: Across 14 surgical centers, 1,121 patients were identified. Mean age±SD was 60.6±11.8 years, and 52.5% were male. Anterior-only operations were performed in 772 patients (68.9%), and posterior-only operations in 349 patients (31.1%). Mean mJOA±SD scores at baseline, 3 months postoperatively, and 12 months postoperatively were 12.0±2.8 (n=1121), 13.9±2.6 (n=914), and 13.8±2.8 (n=801). Mean NDI±SD scores at baseline, 3 months postoperatively, and 12 months postoperatively were 38.3±20.8 (n=1117), 23.1±17.9 (n=942), and 20.4±19.4 (n=807). Mean QALY±SD scores at baseline, 3 months postoperatively, and 12 months postoperatively were 0.6±0.2 (n=1029), 0.7±0.2 (n=899), and 0.7±0.2 (n=761). By univariate analysis, improvements in mJOA were associated with improvements in NDI and QALY at 3 and 12 months postoperatively (all $p<0.0001$). These findings were similar in multivariate analysis.

Conclusion: In this large cohort of patients who underwent surgery for CSM, improvements in mJOA were associated with improvements in NDI and QALY. These findings suggest that changes in mJOA can serve as a proxy for functional and quality-of-life outcomes.

E-POSTER #66 continued

	n=1,121
Age in years (mean ± SD)	60.6 ± 11.8
Male	588 (52.5%)
BMI in kg/m2 (mean ± SD)	30.1 ± 6.4
ASA	
Class 1	22 (2.1%)
Class 2	488 (46.9%)
Class 3	510 (49%)
Class 4	20 (1.9%)
Diabetes	236 (21.1%)
CAD	105 (9.4%)
PVD	40 (3.6%)
CKD	47 (4.2%)
Osteoarthritis	317 (28.3%)
Anxiety	206 (18.4%)
Depression	244 (21.8%)
Parkinson Disease	5 (0.5%)
Multiple Sclerosis	18 (1.6%)
COPD	77 (6.9%)
Current Smoker	197 (17.9%)
White Race	860 (76.8%)
College Graduate	404 (37.5%)
Private Insurance	567 (50.6%)
Worker's Comp	21 (1.9%)
Employed and Working	433 (38.7%)
Outside Activities	909 (81.3%)
Home Activities	996 (90.4%)
Any Motor Deficit	692 (61.7%)
Radicular Motor Deficit	334 (29.8%)
Radicular Pain	501 (44.7%)
Radicular Numbness	657 (58.6%)
Neck Pain	707 (63.1%)
Independently Ambulatory	916 (81.7%)
Listhesis	256 (24.9%)

Table 1. Baseline characteristics of the cohort.

E-POSTER #66 continued

Anterior Approach (n=772)	
ACDF	745 (96.5%)
Corpectomy	92 (11.9%)
Arthroplasty	37 (4.8%)
Posterior Approach (n=349)	
Laminectomy	310 (88.8%)
Laminoplasty	45 (12.9%)
Dorsal arthrodesis	253 (72.5%)

Table 2. Operative details for the cohort. All patients underwent either anterior-only or posterior-only operations.

	Baseline	3 Months Postop	12 Months Postop
mJOA, mean±SD (n)	12±2.8 (n=1121)	13.9±2.6 (n=914)	13.8±2.8 (n=801)
NDI, mean±SD (n)	38.3±20.8 (n=1117)	23.1±17.9 (n=942)	20.4±19.4 (n=807)
QALY, mean±SD (n)	0.6±0.2 (n=1029)	0.7±0.2 (n=899)	0.7±0.2 (n=761)

Table 3. Mean mJOA, NDI, and QALY at baseline, 3 months postoperatively, and 12 months postoperatively.

E-POSTER #67

Preclinical study of directly reprogrammed human neural progenitor cells for cervical spinal cord injury.

Kazuya Yokota, MD, PhD, Mohamad Khazaei, PhD, Christopher Ahuja, MD, Michael G. Fehlings, MD, PhD, FRCSC, FACS

Introduction: While stem cell therapy could be a viable option to prevent devastating outcome of traumatic spinal cord injury and to reverse the neurological impairment brought about by the condition, its translation into clinical use is still hindered by limited availability, immunologic complications and ethical concerns.

Materials and Methods: Here we established directly-reprogrammed neural progenitor cells from human somatic cells which has a strong potency to differentiate into three neural lineages including oligodendrocytes, neurons, and astrocytes.

Results: Transplanting drNPCs into the injured spinal cord of immunodeficient rats showed the marked integration of host disrupted corticospinal tract as well as demyelinated axons that consequently promoted functional recovery following injury. Electrophysiological evaluation and also observation by electronic microscopy supported the findings of functional benefits by drNPC cell transplant.

Conclusion: Overall, we demonstrated that drNPCs could be a novel promising treatment option for injured spinal cord to restore the connectivity of neural networks.

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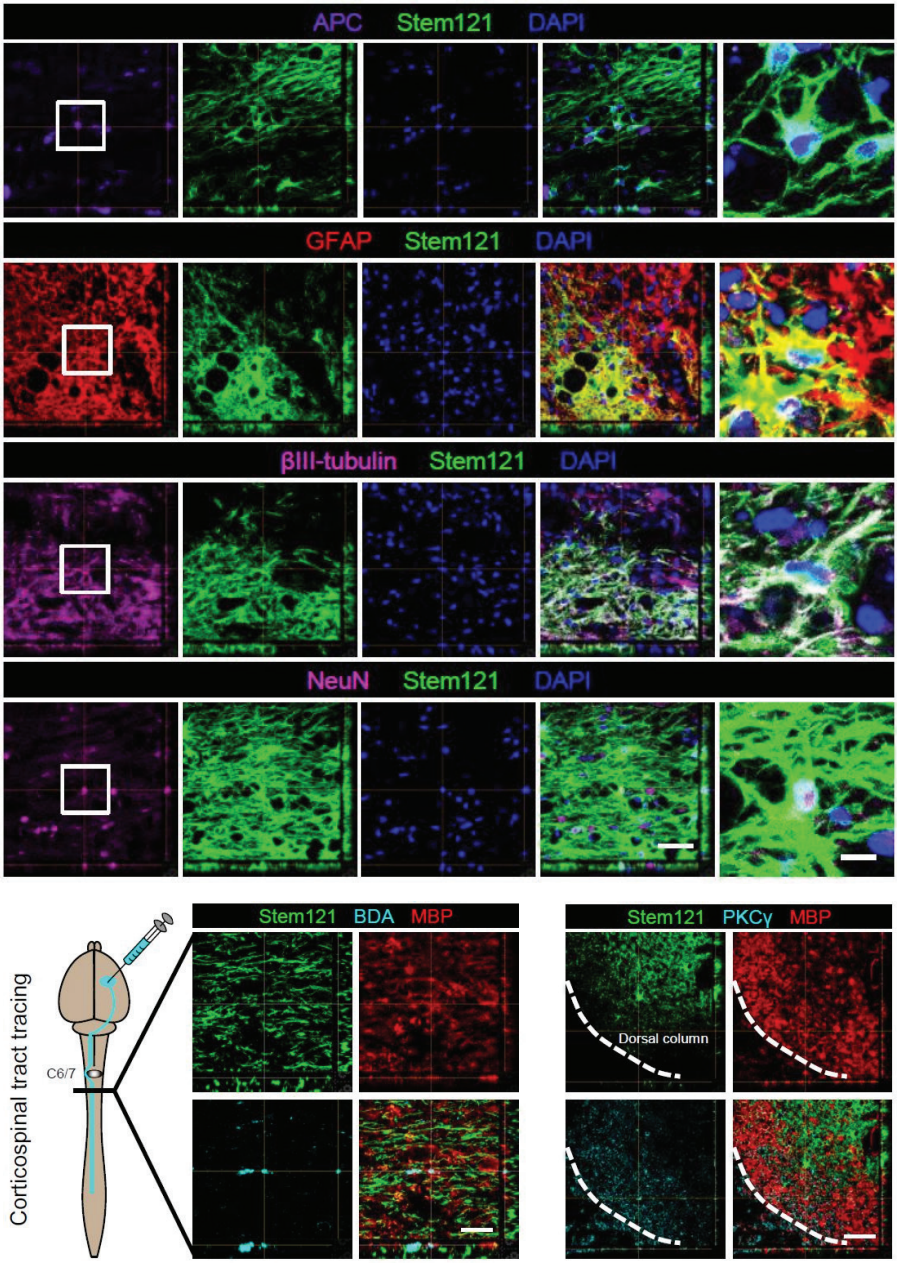
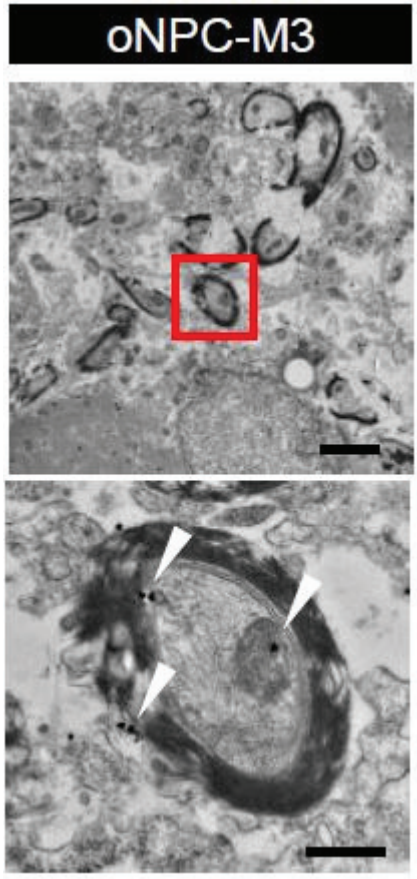


Individual Disclosures can be found in the Disclosure Index pages 34-48.
Presentations and e-posters are sorted numerically. Presentation times may be found in the program on pages 8-33.

E-POSTER #67 continued



E-POSTER #68

Effect of Autograft Utilization on Patient Reported Outcomes Following Anterior Cervical Discectomy and Fusion

Ivan Zapolsky, MD, Lauren Boden, MD, Amrit Khalsa, MD, Comron Saifi, MD

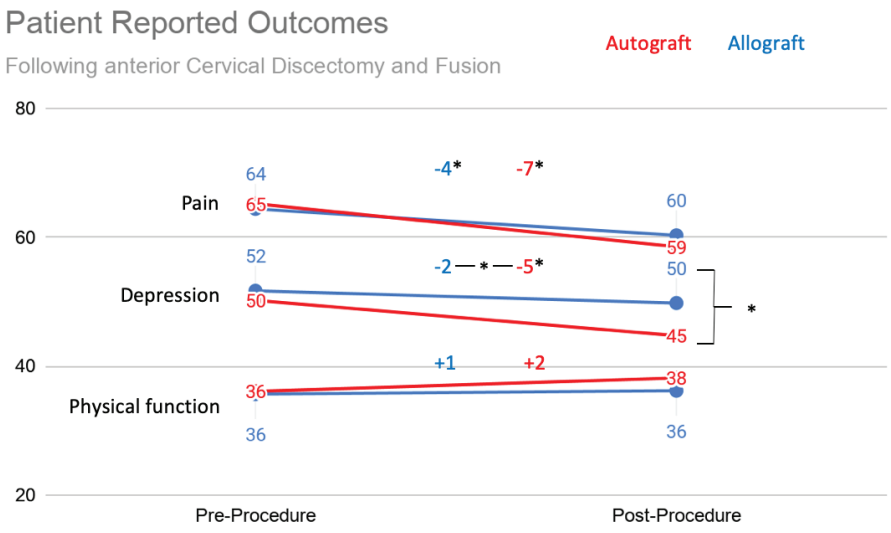
Introduction: Utilization of iliac crest autograft bone, cortical, morselized or marrow aspirate, to enhance fusion in anterior cervical discectomy and fusion (ACDF) is a well-established surgical technique. This practice has been associated with higher rates of fusion than those seen with allograft alone. It has been well documented that autograft harvest is associated with postoperative pain and harvest site wound complications. Despite this widespread utilization, there is a paucity of data regarding the effect of autograft harvest and utilization of autograft on patient reported outcome measures (PROMIS) following ACDF. The purpose of this study was to examine the short-term patient reported outcomes following ACDF with or without autograft harvest performed in conjunction with their procedure.

Materials and Methods: All ACDF procedures performed by neurosurgeons and orthopaedic spine surgeons at a single institution were collected during the calendar year of 2019. Of those, 123 had PROMIS scores obtained pre and post operatively, with postoperative scores obtained at an average of 8 weeks after surgery. This time point was chosen to isolate the effect of graft harvest on outcome scores in the acute postoperative period. Change in PROMIS scores for pain, physical function and depression were compared between the autograft and allograft groups.

Results: There was no significant difference between autograft and allograft groups in complication rate, number of levels fused or average time to follow up. Subgroup analysis demonstrated that both groups had a significant improvement in PROMIS pain scores from pre to postoperative assessment and that postoperative pain and physical function scores were not statistically different between groups. There was also no significant difference in the amount of improvement between groups. There was a significant improvement in post operative depression score in the autograft group, this effect was not seen in the allograft group. The average postoperative depression score in the autograft group was significantly better than that of the allograft group.

Conclusion: Our data suggests that while autograft donor site pain is a common complaint following ACDF, PROMIS scores do not reflect an advantage to the use of allograft with respect to reduction in patient reported post-operative pain. Beyond the known economic and clinical benefits of decreased cost and increased rates of fusion, this data further bolsters the usage of autograft in ACDF procedures.

E-POSTER #68 continued



E-POSTER #69

High Clinical No-Show Correlates with Worse Patient Reported Outcomes Following Anterior Cervical Discectomy and Fusion

Ivan Zapolsky, MD, Lauren Boden, MD, Comron Saifi, MD, Amrit Khalsa, MD

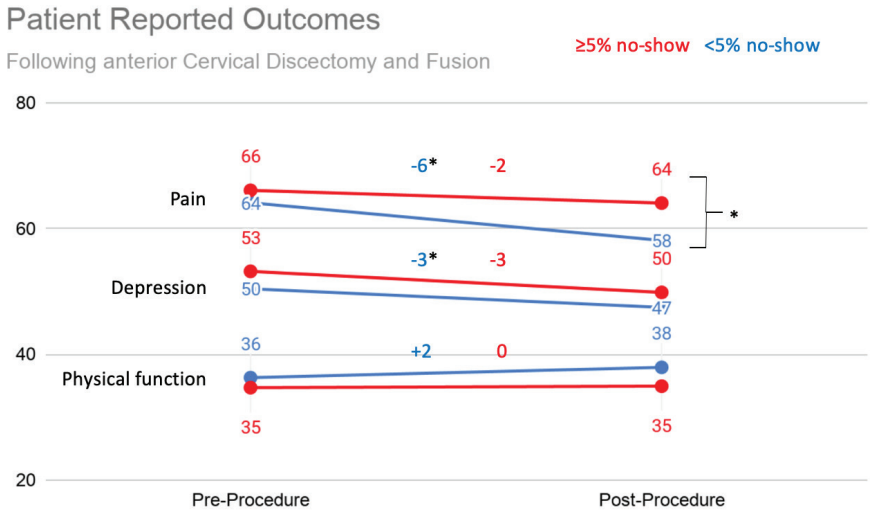
Introduction: Patient no-show rates have been shown to have effects on clinical outcomes in numerous healthcare settings. It has also been demonstrated that outreach mechanisms and special coordination of these patients can improve both individual outcomes and overall health status. This effect has rarely been described in an orthopedic or spine surgery population. In this study we investigated the effects of patient clinical no-show rate on post-operative patient reported outcome measures in a spine surgery population.

Materials and Methods: All ACDF procedures performed by neurosurgeons and orthopaedic spine surgeons at a single institution were collected over a 1-year period. Of those, 124 patients had Patient-Reported Outcomes Measurement Information System (PROMIS) scores obtained pre and post operatively. Clinical appointment no-show rate within the entire health system was collected for all patients and placed in the high no show group (HNG) if over 5% and Low no-show group (LNG) if under 5%. Patient reported outcomes scores and complication rates were then compared between patients with high or low clinical no-show rates. Post-operative PROMIS scores were recorded at a mean of 8 weeks postoperatively.

Results: On average patients had 66 clinic visits of any type in any department within our hospital system with an average of 3.7 missed visits each. On average patients missed 5.6% of their scheduled clinical appointments. Patients in the LNG missed an average of 1.3% of their appointments compared to 9.24% in the HNG.here was no difference in age, gender, prior cervical spine surgeries, number of intraoperative levels, or major complications between the HNG and LNG. The LNG had a higher estimated median household income than the HNG. The HNG also had a higher percentage of patients who self-identified as black. There was no difference in the pre-operative PROMIS scores for pain, physical function, or depression between groups. The postoperative pain score was higher in HNG compared to the LNG. There was no significant difference between pre and post-operative physical function scores between the two groups. For the LNG, the pain score improved, This difference was not seen in the HNG. Depression scores improved for the LNG, but there was no significant improvement in depression scores for the HNG.

Conclusion: Patients who regularly miss scheduled clinical appointments are an at-risk population. This study corroborates those in other fields, demonstrating worse clinical outcomes for pain, physical function and depression in the high no-show population. The effect of surgery on their scores was also less robust and did not demonstrate significant improvement with surgery. While these patients may still benefit from surgical intervention, their postoperative improvements are diminished as compared to their low no-show rate counterparts. The poor clinical attendance of these patients may cause them to miss vital clinical follow-up, including relevant instructions and post-operative care critical to surgical success. Surgeons may choose to consider clinical attendance rates in patient selection for surgical intervention. Efforts might also be made to improve patient outreach to at-risk individuals to mitigate the negative effects on surgical outcomes.

E-POSTER #69 continued



E-POSTER #70

The Use of Table Mounted Retraction Does Not Lead to Higher Incidence of Postoperative Dysphagia After Anterior Cervical Spine Surgery

Athan Zavras, BA[1], Ali Piracha, BS, Zakariah Siyaji, BS, Talha Qadri, BS, Arash Sayari, MD, Nicholas Shepard, MD, Daniel Caicedo, BS, Mubashir Ahmed, BS, Joana Dhivra, BS, Matthew Colman, MD
Rush University Medical Center[1]

Introduction: Retraction of prevertebral cervical structures during anterior cervical spine surgery (ACSS) is commonly implicated in postoperative dysphagia or dysphonia. Modes of retraction commonly used include non-fixed self-retaining retraction devices or fixed table-mounted retractor arms. Current literature describing postoperative dysphagia rates in patients after ACSS using table-mounted versus self-retaining retractor is sparse.

Materials and Methods: All patients who underwent ACSS with a single surgeon between the years of 2014 and 2020 with a minimum of 6-months follow-up were retrospectively evaluated. Patients were grouped based on the mode of retraction used: self-retaining retraction or table-mounted retraction. Stage of career for the senior author was the only determinant of table-mounted retractor use. Perioperative data such as operative time, retractor time, operative levels, side of approach, and others were recorded. Patient outcomes were quantified via retrospective collection of preoperative and final postoperative patient-reported outcome (PROs) questionnaires, including the SWAL-QOL survey for dysphagia. Rates of dysphagia were assessed using previously defined values for the minimum clinically important difference (MCID) on SWAL-QOL.

Results: A total of 117 and 75 patients receiving either self-retaining or table-mounted retraction were assessed. No differences were detected between self-retaining and table-mounted cohorts in swallowing function at around one year based on the SWAL-QOL assessment tool (81.6±22.3?vs?82.1±17.1,?p=.918). There were no differences in total operative time between the two groups (p=.436), although 3-level procedures were significantly shortened using a table-mounted retractor (162.5±28.0 min vs 122.5±41.1 min, p=.005). Average retraction time per operated level (p=.243) and longest retractor time at any level per case (p=.981) were similar irrespective of the retractor used. However, the total time of retraction was greater with table-mounted retractor (45.7±17.7 min vs 64.4±23.1 min, p<.001), commensurate with a greater number of levels operated in this group (1.7±0.8 vs 2.1±1.0, p=.002). Multivariate analysis showed a trend towards worse swallow function as the number of operative levels increased (ß: -24.05, p=.072) and with increasing total retraction time (ß: -1.09, p=.054), while the type of retractor used was not an independent predictor of worse swallowing function (ß: 4.43, p=.759). However, categorical rates of clinically significant postoperative dysphagia as defined by the MCID were 27.4% and 13.3% in self-retaining and table-mounted retractor cohorts, respectively (p=.033).

Conclusion: There was no significant difference observed in the severity of long-term swallowing dysfunction between patients who underwent ACSS with self-retaining and table-mounted retractors, although overall rates of any reported categorical dysphagia were lower with a table-mounted retractor, which may be related to the direct hand-tensioning of table-mounted blades as opposed to the ratcheting mechanism for self-retaining devices. Furthermore, although operative times were similar, the greater number of operated levels per

E-POSTER #70 continued

case in the table-mounted group suggests improved efficiency.

Physical Health Questionnaires	Self-Retaining	Table-Mounted	*p*
	n = 117	n = 75	
Preoperative			
SWAL-QOL	92.8 ± 5.3	92.0 ± 6.1	.790
SF12 Physical Health	32.5 ± 9.1	31.9 ± 9.9	.692
VR12 Physical Health	33.7 ± 9.9	33.4 ± 11.0	.858
NDI	46.3 ± 20.2	39.9 ± 23.3	.161
VAS Arm	6.3 ± 2.7	4.2 ± 3.2	**.001**
VAS Neck	6.5 ± 2.8	4.9 ± 3.6	**.018**
Postoperative			
SWAL-QOL	81.6 ± 22.3	82.1 ± 17.1	.918
SF12 Physical Health	34.0 ± 11.0	34.1 ± 9.9	.962
VR12 Physical Health	35.3 ± 11.7	35.8 ± 10.4	.822
NDI	27.6 ± 20.8	26.4 ± 22.9	.820
VAS Arm	3.0 ± 3.0	2.5 ± 2.6	.462
VAS Neck	3.6 ± 3.3	3.0 ± 2.8	.455

Bolding indicates statistical significance ($p < .05$)

E-POSTER #71

CT Osteoabsorbptiometry Assessment of Subchondral Bone Density Predicts Intervertebral Subsidence in a Human Cadaver Model

Alejandro Espinoza Orias, PhD, Evan Sheha, MD, Athan Zavras, BA[1], Paul John, BS, Ashlyn Fitch, BS, Howard An, MD, Nozomu Inoue, MD, PhD, Matthew Colman, MD
Rush University Medical Center[1]

Introduction: Subchondral bone mineral density (SBD) has been shown to reflect the long-term distribution of stress acting on the joints. SBD can be used to evaluate the onset and progression endplate degeneration. There are important advantages when using a 3-dimensional (3-D) method to evaluate SBD which can be achieved with computed tomography osteoabsorbptiometry (CT-OAM). CT-OAM can record the differences in the density distribution of certain regions, which usually focus on the subchondral bone. The purpose of this study was to measure the subchondral bone mineral density of the cervical endplates by using CT-OAM, and correlate it to subsidence in a cadaveric model.

Materials and Methods: Fourteen (7F, 7M, age range 27-89 y.o.) cadaveric cervical spines were used in this study. All specimens (n=8 C4-5, n=6 C6-7 motion segments) were potted in polymethylmethacrylate, instrumented with standalone PEEK interbody spacers, and were subjected to a dynamic testing regimen: five compressive ramp loading preconditioning cycles from 50 to 250 N at a frequency of 0.5 Hz, followed by a compressive sinusoidal load spanning the same load range at 2 Hz for 10,000 cycles. All specimens were imaged with clinical CT at 0.625 mm thickness slices (no spacing) three times: 1st) whole intact cervical spine, 2nd) before the test (potted and instrumented), and 3rd) immediately after completion of the mechanical testing (still instrumented). These images were used to assess the bone mineral density distributions using CT-OAM in a region of interest directly underneath the spacer (Figure 1). The CT-OAM analysis was carried out in 0.5 mm intervals down to a depth of 3.0 mm beneath the endplate surface. Subsidence was defined based on the displacement values at peak loads (both 250 N) on cycles no. 1 and no. 10,000; and the difference between these points in the displacement axis was the measured deformation of the endplate in mm (Figure 2). SBD data was presented in g/cc. Results are presented as mean±SD. Significance was set at p=0.05.

Results: The observed "failure mode" was consistently recorded as subsidence, where the interbody spacer indented itself into the endplates. Mean subsidence by level was registered as 0.45±0.36 mm and 0.40±0.18 mm, for C4-5 and C6-7, respectively, without differences by level. Deformation (subsidence) as s function of SBD: The experimental cyclic test showed that denser endplates experienced less deformation under the same load than less dense ones. (Figure 3).

Conclusion: This study showed that the regions with higher CT-OAM values did experience less subsidence, and validated the use of CT-OAM as a method to evaluate the endplate SBD. While subsidence is a multi-factorial event, and it is still poorly understood in relation to the endplate tissue structure-function relationships, work like this is providing new tools to the clinicians who treat spinal conditions that need augmentation and stabilization via interbody devices. The CT-OAM method is easily translated to the clinic, has been validated in many other joints, and does not require additional tests or cost to the patient.

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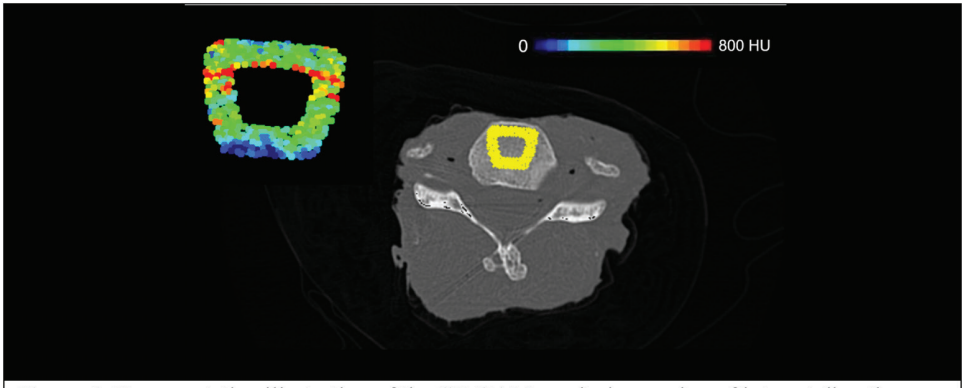

Figure 1. Representative illustration of the CT-OAM results in a region of interest directly underneath the footprint of the interbody device.

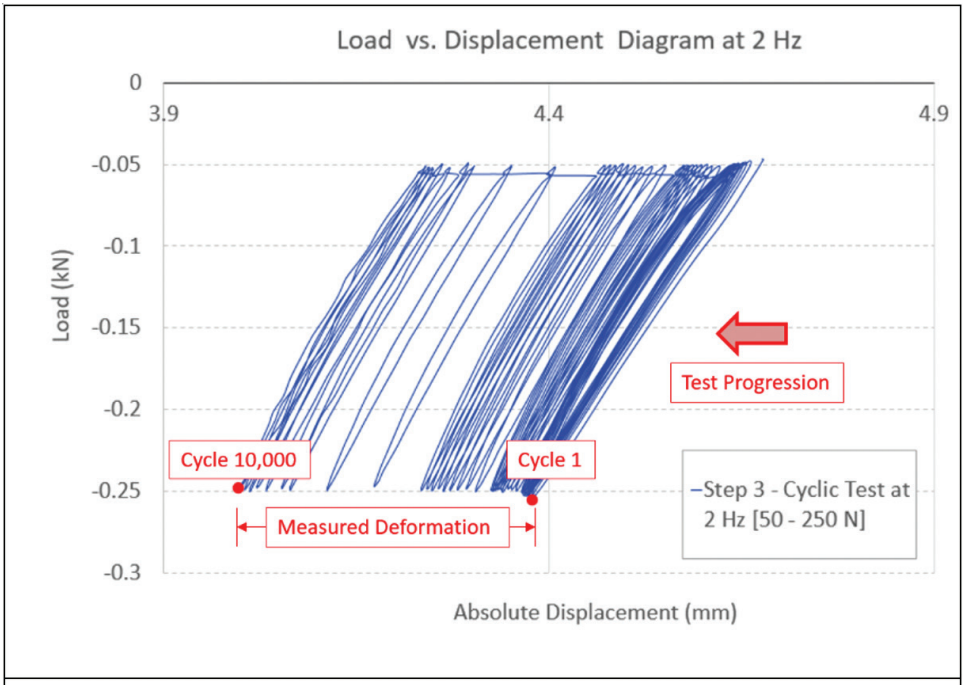

Figure 2. Graphical definition of the measured deformation, reported as *subsidence* of the interbody device.

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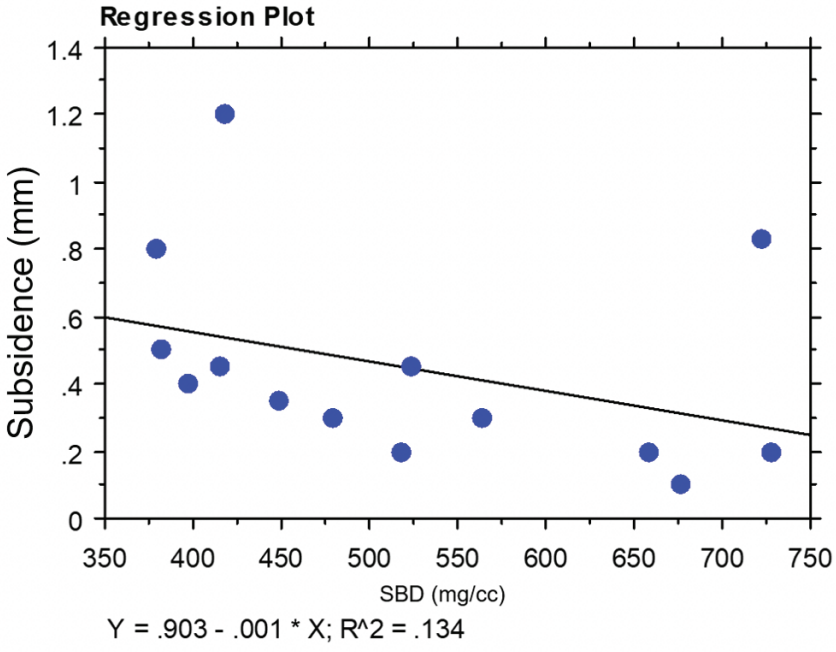

Figure 3. Deformation (mm) as a function of mean CTO-derived density measurements (SBD)

E-POSTER #72

A Longitudinal Assessment of Segmental Motion of the Cervical Spine Following Total Disc Arthroplasty: A Comparative Analysis of Devices

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Rush University Medical Center[1] Midwest Orthopedics at Rush[2]

Introduction: Total disc arthroplasty (TDA) has been shown to be an effective and safe treatment for cervical degenerative disc disease at short and mid-term follow-up. However, there remains a paucity of literature reporting the differences between individual prosthesis designs with regards to device performance. This study evaluated the long-term maintenance of segmental range of motion (ROM) at the operative cervical level across a diverse range of TDA devices.

Materials and Methods: This study retrospectively evaluated patients who underwent 1- or 2-level cervical TDA between 2005-2020 at a single institution. The criteria for inclusion were a minimum of 6 months follow-up and lateral flexion/extension radiographs at preoperative, 2-months postoperative, and final postoperative follow-up. Radiographic measurements included operative segment lordosis, segmental range of motion (ROM) on flexion/extension, global cervical (C2-C7) ROM on flexion/extension, and disc height. Paired t-test was used to evaluate improvement in radiographic parameters. Sub-analysis between devices was performed using one-way analysis of covariance (ANCOVA). Significance was determined at $p<.05$.

Results: A total of 85 patients (100 discs) were included with an average age of 46.01±8.82 years and follow-up of 40.16±39.72 months. There were 22 (22.00%) M6 devices implanted, 51 (51.00%) Mobi-C, 14 (14.00%) PCM, and 13 (13.00%) ProDisc-C (Table 1). On whole-group analysis, segmental lordosis at the operative level significantly improved from preoperatively to 2-months postoperatively (3.08±3.99º vs 4.74±5.95 º, p=.009) and was similarly maintained from 2-months postoperatively to final follow-up (4.74±5.95º vs 5.37±6.17º, p=.084). Similarly, disc height was significantly improved at 2-months (5.57±1.19mm vs 7.73±4.32mm, $p<.001$) with no significant deterioration at final follow-up (7.73±4.32mm vs 7.25±1.23mm, p=.252). There were no differences in segmental ROM or global cervical ROM between timepoints. Subgroup analysis was performed between devices looking at segmental ROM (Table 2). PCM demonstrated significantly less ROM at 2-months relative to M6, Mobi-C, and ProDisc-C after controlling for global cervical ROM ($F=5.32$, p=.003). At final follow-up, after controlling for both global cervical ROM and duration of follow-up, both PCM and ProDisc-C had less ROM than M6 and Mobi-C ($F=8.19$, $p<.001$). Additionally, from 2-months postoperatively to final follow-up, ROM declined significantly more with ProDisc-C relative to Mobi-C ($F=3.63$, p=.022). There were no differences in preoperative segmental ROM (p=.942) or in change from preoperative to 2-month postoperative ROM (p=.120). Motion-restriction heterotopic ossification (Grade 3/4 HO) was seen at 22 of 100 operative levels (22.00%) with no differences in frequency by device (p=.128). Device hyperflexion with resultant static segmental kyphosis was seen with 4 Mobi-C devices (7.84%).

Conclusion: Overall, TDA increases static segmental lordosis and disc height in a durable way at mean follow-up of 40 months. Subgroup analysis by device brand demonstrated that

E-POSTER #72 continued

motion preservation differs depending on disc design. Certain devices, including the M6 and Mobi-C, improve ROM on flexion/extension from pre-op to post-op and continue to increase slightly at final follow-up. On the other hand, devices such as the PCM and ProDisc-C contributed to greater segmental stiffness, with a gradual decline in ROM. Further studies are needed to understand how much segmental ROM is ideal following TDA for preservation of physiologic cervical kinematics.

Table 1. Patient demographics

Patients	n = 85 patients, 100 discs
Age	46.01 (8.82)
Sex	
Male	51 (60.00%)
Female	34 (40.00%)
Body Mass Index (BMI)	27.82 (4.25)
Number of Levels	
1-Level	70 (82.35%)
2-Level	15 (17.65%)
Operative Level	
C3-4	3 (3.53%)
C4-5	4 (4.71%)
C5-6	32 (37.65%)
C6-7	31 (36.47%)
C3-5	2 (2.35%)
C4-6	2 (2.35%)
C5-7	10 (11.76%)
C4-5, C6-7	1 (1.18%)

E-POSTER #72 continued

Table 2. Subgroup analysis of range of motion on flexion/extension by TDA device brand.

	All Discs (n = 100)	M6 (n = 22)	Mobi-C (n = 51)	PCM (n = 14)	ProDisc-C (n = 13)	*p-value*
Follow-Up (months)	40.16 ± 39.72	**31.10 ± 26.31**[a]	**19.15 ± 12.40**[a]	89.78 ± 48.10	67.69 ± 45.66	**< .001**
Pre-Op	7.16 ± 3.85	7.64 ± 4.63	6.93 ± 3.60	7.96 ± 4.86	6.81 ± 2.92	.942
2-Months	7.00 ± 3.53	8.45 ± 3.05	7.33 ± 4.06	**4.56 ± 2.07**[b]	7.41 ± 3.13	**.003**
Final	8.06 ± 4.63	9.10 ± 4.12	9.26 ± 4.77	**4.71 ± 3.29**[c]	**4.39 ± 3.83**[c]	**< .001**
Δ Pre-Op to 2-Months	-0.24 ± 4.52	1.37 ± 3.72	1.59 ± 4.22	-2.81 ± 5.22	-0.19 ± 3.94	.120
Δ 2-Months to Final	1.00 ± 4.38	1.17 ± 3.74	3.02 ± 4.71	-0.22 ± 3.69	**-3.08 ± 3.24**[d]	**.022**

Bolding denotes statistical significance

[a] Significantly shorter follow-up than PCM and ProDisc-C
[b] Significantly less ROM than M6, Mobi-C, and ProDisc-C
[c] Significantly less ROM than M6 and Mobi-C
[d] Significantly greater loss of ROM than Mobi-C

E-POSTER #73

Complications and Reoperation following Carpal Tunnel Release and Anterior Cervical Discectomy and Fusion in Patients with Double Crush Syndrome

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Introduction: Patients with cervical radiculopathy (CR) and carpal tunnel syndrome (CTS) may have double crush syndrome (DCS) and require carpal tunnel release (CTR) or anterior discectomy and fusion (ACDF). This study sought to evaluate patients with DCS and compare differences in complications and reoperation for patients with and without DCS undergoing ACDF and CTR.

Materials and Methods: Pearldiver database was used to identify patients with ICD-9-CM and ICD-10-CM diagnosis codes of CTS and CR within 6 months of each diagnosis. Those undergoing CTR or ACDF were identified by CPT code. DCS patients undergoing CTR or ACDF were matched and compared against non-DCS patients by multivariable logistic regressions to determine differences in procedure-specific complications and reoperation within 1 year. Patient comorbidities and presence of opioid use were evaluated with multivariable logistic regression to determine risk factors for patients undergoing both ACDF and CTR compared to a single procedure.

Results: In total, 110,379 patients with double crush syndrome were identified, of which 28,463(25.8%) underwent surgery. CTR was initially performed in 19,188(17.4%) DCS patients followed by ACDF for 1,072(0.97%) patients. ACDF was performed initially in 9,275(8.40%) DCS patients followed by CTR in 1,354(1.23%) of patients. DCS patients who underwent CTR were at greater risk for reoperation, surgical site infection, and CRPS compared to non-DCS patients. DCS patients who underwent ACDF were at greater risk for reoperation within one-year, surgical site infection, instrumentation failure, as well as reintubation compared to non-DCS patients. Obesity and tobacco use were significant risk factors in DCS patients who underwent CTR and ACDF rather than a single surgery.

Conclusion: This examination of over 100,000 patients with double crush syndrome found that 26% of patients underwent surgery with either CTR or ACDF. Subsequently, DCS patients were more likely to undergo reoperation and experience more complications after both CTR and ACDF compared to those without DCS. Obesity and tobacco use increased risk of undergoing both procedures. DCS patients that undergo surgery may be considered a high-risk population and should be counseled and optimized accordingly to prevent against complication and reoperation.

E-POSTER #74

Does grip strength improve after cervical spine surgery? A study of objective hand dynamometer readings

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Introduction: Patients with cervical spine pathology often present with an assortment of hand symptoms, including numbness, pain, and/or weakness. Due to multiple nerve root innervations and anatomical variations, hand function can be difficult to objectively assess preoperatively and postoperatively. In a cohort of patients undergoing cervical spine surgery, we sought to: 1) use a hand dynamometer to report preoperative and postoperative grip strength, 2) distinguish grip strength changes in patients with radiculopathy-only versus myelopathy, and 3) assess predictors of postoperative grip strength improvement.

Materials and Methods: A retrospective, single-surgeon, cohort study was performed. Demographic and operative data were collected. Hand dynamometer data was obtained from all patients preoperatively and postoperatively at three follow-up time periods (0-3m, 3-6m, 6-12m). For each visit, the average of three dynamometer readings from each hand was calculated. A significantly improved dynamometer reading was considered a 10-lbs. change. T-tests, chi-square, and logistic regression was performed.

Results: A total of 262 patients with a mean age of 59±14 years and 37% female underwent the following operations: ACDF (80%), corpectomy (25%), laminoplasty (19%), and posterior cervical fusion (7%). Radiculopathy-only was seen in 128 (49%) patients, and myelopathy was seen 134 (51%) patients. Of all 262 patients, 110 (42%) had improved grip strength by at least 10lbs, including 69/128 (54%) in the radiculopathy-only group, and 41/134 (31%) in the myelopathy group (p=0.035, 95%CI 0.01-0.25). After multivariate logistic regression, those most likely to have improved grip strength were those undergoing ACDF (OR 2.53, 95%CI 1.32, 4.85, p=0.005). Those less likely to have improved grip strength were older patients (OR=0.97, 95%CI 0.95, 0.99, p=0.003) and those undergoing laminoplasty (OR=0.44, 95%CI 0.23, 0.85, p=0.014). Interestingly, patients undergoing surgery at the C2-5 levels and the C6-T2 levels both significantly improved grip strength by 3 months postoperative: C2-5 57.2lbs. to 60.3lbs, p=0.035; C6-T2: 55.7lbs. to 60.0lbs, p=0.0153. Correspondingly, a similar percent of improvement was seen in the C2-5 group (45/108, 42%) versus the C6-T2 group (65/154, 42%) (p=1.00).

Conclusion: In a large cohort of patients undergoing cervical spine surgery, grip strength improved in 42% of all patients and more commonly occurred in patients with radiculopathy-only (54%) versus myelopathy (31%). Patients undergoing surgery in the C2-5 region and the C6-T2 region both significantly improved their grip strength at 3-months postoperatively, and similar rates of improvement were seen in both groups (42%). Younger patients and those undergoing ACDF were significantly more likely to improve grip strength, whereas those undergoing laminoplasty were less likely to improve grip strength, likely reflecting differences in surgical indication. While the presence of myelopathy, age, and operation impacted postoperative grip strength improvement, levels of surgery appeared to be less important, as patients undergoing surgery in the C2-5 region had similar rates of grip strength improvement

E-POSTER #74 continued

compared to patients undergoing surgery in the C6-T2 region. These results may aid in patient counseling and help set expectations of motor improvement postoperatively.

Table 1. Demographics and presenting information.

	Entire Cohort N=262	Radiculopathy-Only N=128	Myelopathy and/or myeloradiculopathy N=134
Age, mean±SD	57.9±14.0	52.4±12.6	63.2±13.2
Female, n (%)	97 (37.0)	49 (38.3)	48 (49.5)
BMI, mean±SD	26.8±4.8	25.9±4.5	27.6±5.0
Duration preop symptoms (days), mean±SD	690.6±1091.4	625.5±1024.4	755.1±1154.8
Pain, n (%)	25/72 (34.7)	3/72	22/72
Numbness, n (%)	47/72 (65.3)	2/72	45/72
Weakness, n (%)	26/67 (38.8)	3/67	23/67
Operation, n (%)			
ACDF	210 (80.2)	128 (100.0)	82 (39.1)
Corpectomy	62 (24.8)	17 (13.3)	48 (73.9)
Laminoplasty	49 (18.7)	1 (0.8)	48 (98.0)
PCLF	19 (7.3)	1 (0.8)	18 (94.7)

Table 2. Dynamometer readings at each time point in right and left hand.

	0-3 months				3-6 months				6-12 months			
Dynamometer Readings RIGHT	**N**	**Preop**	**Postop**	**P**	**N**	**preop**	**Postop**	**P**	**N**	**Preop**	**Postop**	**P**
Entire cohort	244	56.30±26.00	60.05±25.75	0.0015	73	52.20±27.35	58.63±29.46	0.0267	128	52.20±27.35	58.63±29.46	0.2226
Radiculopathy-only	115	60.18±30.78	66.82±27.63	0.0029	35	52.53±30.47	62.44±29.76	0.0647	57	63.42±29.87	66.19±25.87	0.3796
Myelopathy and/or myeloradiculoatphy	128	52.92±23.05	54.11±22.43	0.2461	38	51.90±24.55	55.22±29.15	0.2409	70	53.27±22.66	54.56±22.74	0.2409
ACDF												
Involved C2-5	100	57.15±24.29	60.28±22.01	0.0348	32	51.06±29.54	53.75±25.18	0.6045	54	56.46±22.58	58.77±20.98	0.2529
Involves C6-T2	144	55.70±28.79	59.88±28.13	0.0153	40	53.14±25.74	62.53±32.25	0.0298	74	55.61±29.07	60.26±27.29	0.4769
Corpectomies	63	52.79±23.40	54.69±20.83	0.2087	23	56.16±28.67	59.74±24.84	0.1521	32	50.63±19.81	52.06±17.76	0.4131
Laminoplasty	45	48.68±17.42	48.92±18.53	0.8985	11	45.73±15.62	50.12±39.77	0.5975	25	51.23±20.45	52.40±20.97	0.6892
PCF	19	53.00±21.09	52.80±20.91	0.9499	6	57.61±19.86	55.30±22.70	0.9378	15	54.18±21.30	55.77±21.46	0.6934
Dynamometer Readings Left	**N**	**Preop**	**Postop**	**P**	**N**	**preop**	**Postop**	**P**	**N**	**Preop**	**Postop**	**P**
Entire cohort	242	56.06±30.24	57.98±26.06	0.1889	74	57.11±40.20	57.74±31.63	0.8850	127	54.51±24.53	55.63±23.98	0.3171
Radiculopathy-only	114	60.96±35.15	65.04±26.90	0.1686	36	62.21±49.90	61.15±29.61	0.9014	58	57.29±24.67	60.77±24.83	0.1494
Myelopathy and/or myeloradiculoatphy	127	51.78±24.96	51.83±23.71	0.9507	38	52.28±27.99	54.50±33.52	0.3884	70	52.47±24.51	51.82±22.73	0.6287
ACDF												
Involved C2-5	99	57.84±35.01	57.72±24.41	0.0936	33	59.48±53.81	53.07±29.81	0.4412	54	53.84±22.01	54.93±21.30	0.4222
Involves C6-T2	143	54.82±26.49	58.16±27.22	0.0248	41	55.20±24.97	61.50±32.91	0.1206	75	54.98±26.32	56.13±25.87	0.4797
Corpectomies	63	57.13±40.95	54.66±23.93	0.5802	23	70.84±60.13	61.30±29.87	0.4265	32	50.61±23.57	52.48±21.63	0.3369
Laminoplasty	45	45.00±18.83	43.80±19.05	0.4945	11	42.24±17.94	44.06±43.83	0.8351	25	47.03±23.85	46.51±22.22	0.8400
PCF	19	50.49±21.21	47.23±21.72	0.2761	6	52.61±22.74	46.42±28.46	0.2495	15	55.17±21.70	52.52±19.81	0.8439

E-POSTER #74 continued

Table 3. Predictors of patients with improved dynamometer readings.

10 lbs improvement	IMPROVED (improved vs. all else)	
Dynamometer Readings	OR (95%CI)	p-value
Age, mean±SD	**0.967 (0.950, 0.985)**	**0.0003**
Female, n (%)	0.716 (0.443, 1.158)	0.1737
BMI, mean±SD	1.021 (0.973, 1.070)	0.3968
Operation, n (%)		
ACDF	**2.533 (1.322, 4.854)**	**0.0051**
Corpectomy	0.658 (0.383, 1.132)	0.1307
Laminoplasty	**0.440 (0.228, 0.848)**	**0.0141**
PCF	0.397 (0.139, 1.132)	0.0839
ACDF		
Involved C2-5	0.909 (0.568, 1.456)	0.6923
Involves C6-T2	ref	

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