51ST

Fifty-First Annual Meeting

OF THE

CERVICAL SPINE RESEARCH SOCIETY ®

FOUNDED 1973

ABSTRACT BOOK

51st Annual Meeting

November 29 – December 2, 2023

On-Demand recordings of scientific sessions available
January 22, 2024

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Physicians may claim credit for sessions he or she attended in the attendee portal or meeting mobile app. Please clink on the meeting link sent by CSRS in the "Know Before You Go" email to access the attendee portal. Credit claiming and evaluations may be completed in the meeting mobile app or in the attendee portal under "Session/On-Demand." Certificates will be available after the completion of the Annual Meeting on Saturday, December 2 and may only be accessed through the attendee portal.

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About CSRS

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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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November 29 - December 2, 2023

The Cosmopolitan *of* Las Vegas in Las Vegas, Nevada

On-Demand recordings of scientific sessions available
November 22, 2022 – January 31, 2023

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Scientific Program Co-Chairs: Brandon D. Lawrence, MD • Thomas E. Mroz, MD • Michael P. Steinmetz, MD

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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 Instructional Course, Annual Meeting Scientific Program, Virtual Poster Hall, Industry Workshops, or Technical Exhibits.

Thursday, November 30, 2023

Abstract Session 1: Techniques

Time: 8:05 am - 9:20 am
Location: Gracia Ballroom
Moderators: Michael D. Daubs, MD; James S. Harrop, MD, MSHQS

8:05 am **Introduction**

8:10 am **1ST PLACE CLINICAL RESEARCH AWARD**
1. Surgical Outcomes of Extensive Dome-like Laminoplasty Using En Bloc Resection of the C2 Inner Lamina for Patients With Severe Cord Compression Behind the C2 Body
Kyung-Chung Kang, MD

8:15 am **2. Open-Door Cervical Laminoplasty with Skip-fixation is Not Inferior to that of All-fixation: A Multicenter Randomized Controlled Trial**
Koji Tamai, MD

8:20 am **3. How to Choose the Open Side for Unilateral Open-door Laminoplasty in the Treatment of Cervical Ossification of the Posterior Longitudinal Ligament?**
Yifan Tang, MD

8:25 am **4. Different Patterns in Postoperative Sagittal Parameter Change After Laminoplasty According to the Preoperative T1 Slope**
Sehan Park, MD

8:30 am **5. C4-C6 Laminoplasty with and without C3 Laminectomy, the Fate of the C2-C3 level: A Cadaveric Biomechanical Study**
Orlando M. Martinez, BS

8:35 am **Discussion**

8:45 am **6. What Effect Does T1 Slope Have on Sagittal Balance and the Relationship with Caudal End of Three or More Level Posterior Cervical Fusions?**
Eeric Truumees, MD

8:50 am **7. Comparison of Outcomes Between Anterior Cervical Ossified Posterior Longitudinal Ligament En Bloc Resection and Posterior Total Laminectomy and Fusion in Patients with Cervical Ossification of the Posterior Longitudinal Ligament: A Prospective Randomized Controlled Trial**
Xiongsheng Chen, MD

8:55 am **8. The Impact of C2 Screw Placement Technique on Radiographic and Clinical Outcomes after C2-T2 Posterior Cervical Fusion**
Hannah A. Levy, MD

9:00 am **9. The Effect of C2 Muscular Exposure Technique on Radiographic and Clinical Outcomes after C2-T2 Posterior Cervical Fusion**
Hannah A. Levy, MD

9:05 am **10. Cervical Pedicle Screw Insertion in Degenerative Vertebrae Using a Robot System**
Masashi Neo, MD, PhD

9:10 am **Discussion**

Thursday, November 30, 2023

Abstract Session 2: Deformity

Time: 10:40 am - 11:55 am
Location: Gracia Ballroom
Moderators: Han Jo Kim, MD; Christopher Shaffrey, MD

10:40 am **Introduction**

10:45 am **11. The Evolution of ERAS: Assessing the Clinical Benefits of Developments within Enhanced Recovery After Surgery Protocols in Adult Cervical Deformity Surgery**
Robert Eastlack, MD

10:50 am **12. Are we Getting Better at Treating Adult Cervical Deformity? Complication Rate Trends Analysis in Adult Cervical Deformity Over 10 Years**
M. Burhan Janjua, MD

10:55 am **13. Working Towards Personalized Realignments in Adult Cervical Deformity Surgery: Consideration of Upper Cervical Region Reserve and Deformity Morphology in the Application of the Cervical Lordosis Distribution Index**
Thomas J. Buell, MD

11:00 am **14. Incorporation of Frailty Based Realignment Target Goals for Cervical Deformity Surgery in Adults Can Mitigate Mechanical Complications and Improve Perioperative Course**
M. Burhan Janjua, MD

11:05 am **15. Preoperative Optimization of Modifiable Patient-Related Factors Reduces the Risk of Distal Junctional Kyphosis (DJK): A Virtual Analysis of a Novel Multicenter Complex Adult Cervical Deformity Database**
Thomas J. Buell, MD

11:10 am **Discussion**

11:20 am **16. Radiographic Parameter Analysis of Positive Sagittal Decompensation After Long-level Posterior Cervical Fusion**
Hyunwook Nam, MD

11:25 am **17. Identifying Intra-operative C2 Slope Thresholds for Optimal Functional and Clinical Outcomes in Cervical Deformity Correction**
Peter G. Passias, MD

11:30 am **18. Influence of Upper Cervical Malalignment and Negative Sagittal Imbalance on Clinical Outcomes in Patients with Craniovertebral Junction Kyphosis**
Jae Taek Hong, MD, PhD

11:35 am **19. Evolution of Osteotomy Techniques over Time in Adult Cervical Deformity Surgery: Impact of New Technologies and Techniques on Patient Outcomes**
Robert Eastlack, MD

11:40am **20. Longer Screws Decrease the Risk of Radiographic Pseudarthrosis Following Elective Anterior Cervical Discectomy and Fusion**
Byron F. Stephens, MD, MSCI

11:45 am **Discussion**

Thursday, November 30, 2023

Abstract Session 3: Trauma and the Elderly

Time: 1:05 pm - 2:25 pm
Location: Gracia Ballroom
Moderators: Brian A. Karamian, MD; Chris Kepler, MD, MBA

1:05 pm **Introduction**

1:10 pm **21. Is Routine Use of External Spinal Orthoses Necessary After Operative Stabilization of Cervical Spine Injuries?**
Mark Prasarn, MD

1:15 pm **22. The Effect of Mean Arterial Pressure (MAP) Augmentation on Intraparenchymal Hemorrhage Progression in Cervical Spinal Cord Injury (SCI)**
Toluyemi A. Malomo, MD, MSc, FWACS

1:20 pm **23. The Effect of Early Surgical Decompression on Segmental Neurological Recovery in Acute Traumatic Spinal Cord Injury: A Pooled Analysis of Individual Participant Data from Prospective, Multicenter Trials**
Michael Fehlings, MD, PhD, FRCSC, FACS

1:25 pm **24. Mortality Following Operative and Nonoperative Treatment of Odontoid Fracture Among Medicare Beneficiaries and the Influence of Dementia: A Matched Cohort Analysis**
Darrel Brodke, MD

1:30 pm **25. Can Generative Artificial Intelligence Provide Accurate Medical Advice?: A Case of ChatGPT vs. Congress of Neurological Surgeons Management of Acute Cervical Spine and Spinal Cord Injuries Clinical Guideline**
Michael Saturno, BA

1:35 pm **1ST PLACE BASIC SCIENCE AWARD**
26. Ex Vivo Gene Therapy Using Human-induced Pluripotent Stem Cell-derived Neural Stem/Progenitor Cells to Deliver Synaptic Organizer CPTX for Spinal Cord Injury
Yusuke Saijo, MD

1:40 pm **Discussion**

1:50 pm **27. The Effects of Cervical Orthoses on Multiplanar Intervertebral Range of Motion**
Anthony A. Oyekan, MD

1:55 pm **28. Does Approach Matter? Comparison of Early Postoperative Life-threatening Complications in Elderly Patients with Multilevel Cervical Stenosis**
Tomoyuki TA. Asada, MD

2:00 pm **29. Similar Post-operative Complications but Increased Rates of Prolonged Hospitalization and Non-home Discharge in Octogenarians Undergoing Anterior Cervical Decompression and Fusion Compared to Matched Younger Patients**
Alexander Upfill-Brown, MD

2:05 pm **30. Investigation of Risk Factors of C5 Palsy After Anterior Cervical Spine Surgery**
Yu Matsukura, MD, PhD

2:10 pm **31. Comparison of CTA and MRI for C1 Instrumentation Presurgical Planning**
Artine Arzani, BS

2:15 pm **Discussion**

Thursday, November 30, 2023

Abstract Session 4: Anterior Cervical Disc

Time: 5:00 pm - 6:15 pm
Location: Gracia Ballroom
Moderators: Regis W. Haid, Jr., MD; Langston Holly, MD, FAANS

5:00 pm **Introduction**

5:05 pm **32. Do Tracheal Traction Exercises Help Prevent Dysphagia Following Anterior Cervical Spine Surgery: A Randomized Double Blind Placebo Controlled Trial**
Addisu Mesfin, MD

5:10 pm **33. The Surgical Learning Curve for Cervical Disc Replacement**
Andrea M. Roca, MA

5:15 pm **34. Determining Minimum Clinically Important Difference for PROMIS Domains in Patients Undergoing Cervical Disc Replacement**
Andrea M. Roca, MA

5:20 pm **4TH PLACE RESIDENT/FELLOW RESEARCH AWARD**
35. Anterior Cervical Disc Replacement (ACDR) versus Minimally Invasive Posterior Cervical Foraminotomy (MI-PCF) in the Treatment of Cervical Radiculopathy: A 5-Year Retrospective Analysis
Stuart Changoor, MD

5:25 pm **Discussion**

5:35 pm **1ST PLACE RESIDENT/FELLOW RESEARCH AWARD**
37. Opioid-free Analgesia is Safe and Effective in Anterior Cervical Spine Surgery: A Randomized Controlled Trial
Michael Schallmo, MD

5:40 pm **38. 20 Year Radiographic Outcomes of BRYAN Cervical Disc Arthroplasty: A Prospective, Randomized, Controlled Trial**
David P. Foley, MD, MBA

5:45 pm **39. Five-year Follow-up of a Prospective FDA IDE Trial Evaluating Single-level PEEK-on-Ceramic Cervical Disc Replacement**
Richard D. Guyer, MD

5:50 pm **40. Obesity Does Not Negatively Affect Patient-Perceived Outcomes Following Cervical Disc Replacement for Disc Herniation**
Fatima N. Anwar, BA

5:55 pm **41. The Impact of Smoking on Outcomes Following Cervical Disk Arthroplasty: A Quality Outcomes Database Study**
Byron F. Stephens, MD, MSCI

6:00 pm **Discussion**

Friday, December 1, 2023

Abstract Session 5: CSM

Time: 8:05 am - 9:20 am
Location: Gracia Ballroom
Moderators: Don Moore, MD; Ahmad Nassr, MD

8:05 am **Introduction**

8:10 am **42. Is Upper Extremity or Lower Extremity Function More Important for Patient Satisfaction? An Analysis of 24-Month Outcomes from the QOD Cervical Myelopathy Cohort**
Eunice Yang, BS

8:15 am **43. Quantitative Romberg on a Force Plate: Objective Assessment After Surgery for Patients with Cervical Spondylotic Myelopathy**
Kyle Kesler, MD

8:20 am **44. Anterior Cervical Discectomy and Fusion Versus Laminectomy and Posterior Cervical Fusion Across 3 Interspaces Using the QOD CSM Module: Are There Differences in Outcomes?**
Praveen Mummaneni, MD

8:25 am **45. Clinical Predicting Models for Diagnosis the Patients with Degenerative Cervical Myelopathy: An Analysis of 180 Cases of Degenerative Cervical Myelopathy Comparison with 1211 Asymptomatic Subjects**
Masahiro M. Funaba, MD, PhD

8:30 am **46. Development of the Cervical Myelopathy Severity Index: A New Myelopathy Specific Patient Reported Outcome Measure to Facilitate Clinical Care and Research**
Armaan K. Malhotra, MD

8:35 am **Discussion**

8:45 am **47. The Degenerative Cervical Myelopathy Subjective and Objective Score (DCM-SOS): A Novel Outcome Measure**
Khadija H. Soufi, BS

8:50 am **48. Impact of Cervical Spondylotic Myelopathy on Preoperative and Postoperative Care Dependency: A Quality Outcomes Database (QOD) Study**
Raj S. Lavadi, MBBS

8:55 am **49. Selective Modified K-line Interval on T2-weighted MRI can Predict JOA Recovery Rate After Posterior Decompression Surgery in Patients with Cervical Spondylotic Myelopathy**
Naoki N. Yamaguchi, MD

9:00 am **50. Which Social Determinants of Health Affect the Odds of Readmission Following Surgical Treatment of CSM?**
Mohamed Macki, MD, MPH

9:05 am **51. The Comparison Between Ossification of Posterior Longitudinal Ligament and Cervical Spondylotic Myelopathy Patients in Health-related Quality of Life: A Multicenter Cross-sectional Study**
Go Uesugi, MD

9:10 am **Discussion**

Friday, December 1, 2023

Abstract Session 6: OPLL

Time: 10:40 am - 11:55 am
Location: Gracia Ballroom
Moderators: James D. Kang, MD; Samuel Overley, MD

10:40 am **Introduction**

10:45 am **3RD PLACE CLINICAL RESEARCH AWARD**
52. Factors Associated with Repeat Surgery in Cervical Ossification of the Posterior Longitudinal Ligament: An 8-year Follow-up Study
Hyun Jun Jang, MD

10:50 am **53. The Incidence and Alert Timing of Spontaneous Electromyogram in Surgery for Ossification of the Posterior Longitudinal Ligament**
Jun Hashimoto, MD, PhD

10:55 am **54. Evaluating Changes to The Modified K-line Using Kinematic MRIs**
Andy Ton, BS

11:00 am **55. Investigation of Orthopaedic Surgery Resident Education Regarding the Management of Unintentional Durotomies**
Austin H. Carroll, MD

11:05 am **56. Indications and Limitations of Laminoplasty for Cervical Spondylotic Myelopathy Using Modified K-line –Importance of Dynamic Factor-**
Takuya Tamaoka, MD

11:10 am **Discussion**

11:20 am **57. "Adjacent-Level Ossification Development" and Clinical Implications for Adjacent Segment Pathology Following ACDF**
Micahel Raad, MD

11:25 am **58. Predictors of Ligamentum Flavum Buckling in Patients with Congenital Cervical Stenosis**
Ryan Palmer, BS

11:30 am **59. Predictive Risk Factors for the Incidence of Cervical Spine Instabilities in Rheumatoid Arthritis: A Multicenter Prospective Study During Over 10 years**
Yutaro Kanda, MD, PhD

11:35 am **60. Fifty Percent of Patients with Chronic Renal Failure Experience Major Medical Complication with a Third Requiring ICU admission for Anterior Cervical Discectomy and Fusion Surgery**
Spencer Smith, MD

11:40 am **61. Neck Pain Does NOT Contraindicate Cervical Laminoplasty**
Nathaniel L. Rawicki, MD

11:45 am **Discussion**

Saturday, December 2, 2023

Abstract Session 7: Fun Facts

Time: 10:55 am - 12:10 pm
Location: Gracia Ballroom
Moderators: Matthew W. Colman, MD; Ryan Spiker, MD

10:55 am **Introduction**

11:00 am **3RD PLACE RESIDENT/FELLOW RESEARCH AWARD**
62. Cervical Spine Surgery following COVID-19 Infection: When is it Safe to Proceed?
Justin P. Chan, MD

11:05 am **63. Anatomic Study of Cervical Neuroforaminal Dimensions, Interpedicular Distance, and Disc Space Height from C2-T1 Using Computed Tomography of 1,000 Patients**
Jacob Razzouk, BS

11:10 am **64. Dynamic Radiographs are Unreliable to Assess Arthrodesis following Cervical Fusion: A Modeled Radiostereometric Analysis of Cervical Motion**
Zachariah W. Pinter, MD

11:15 am **2ND PLACE CLINICAL RESEARCH AWARD**
65. Adjunctive Use of Bone Growth Stimulation Increases Cervical Spine Fusion Rates in Patients at Risk for Pseudarthrosis
Vikas V. Patel, MD

11:20 am **2ND PLACE RESIDENT/FELLOW RESEARCH AWARD**
66. MRI Vertebral Bone Quality Correlates with Interbody Cage Subsidence After Anterior Cervical Discectomy and Fusion
James Bernatz, MD

11:25 am **Discussion**

11:35 am **67. Pulsed Electromagnetic Fields (PEMF) Used as an Adjunct to Cervical Spine Fusion**
Vikas V. Patel, MD

11:40 am **68. Decreased Opioid Use After Anterior Cervical Discectomy and Fusion during 2014-15 to 2018-19: The Influence of State Policies**
Spencer Smith, MD

11:45 am **69. How Much Money Do You Actually Save Your Hospital When You Choose a Posterior Foraminotomy Instead of an ACDF for Cervical Radiculopathy?**
Ahilan Sivaganesan, MD

11:50 am **70. How Does the Cervical Spinal Cord Run After Cervical Laminoplasty? Additional Risk Factor Analysis for Spinal Cord Alignment Deterioration After Cervical Laminoplasty**
Nam Yeop Kim, MD

11:55 am **71. Impact of Frailty and Cervical Radiographic Parameters on Postoperative Dysphagia Following Anterior Cervical Spine Surgery: mFI-11, T1 slope, Change in Cervical Lordosis and C3/4 Surgery**
Tomoyuki TA. Asada, MD

12:00 pm **Discussion**

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Alphabetical Participant Disclosure List

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Podium and Virtual Poster Abstracts

PAPER 1

Surgical Outcomes of Extensive Dome-like Laminoplasty Using En Bloc Resection of the C2 Inner Lamina for Patients With Severe Cord Compression Behind the C2 Body

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Introduction: Severe cord compression behind the C2 body is rare, but it is a prominent concern for spinal surgeons. Owing to the importance of the paraspinal muscles around the C2 spinous process, laminectomy or laminoplasty of C2 is not preferred. To date, there has been no established solution for severe cord compression behind the C2 body. This study aimed to evaluate the efficacy and safety of a newly developed extensive dome-like laminoplasty using en bloc resection of the C2 inner lamina in patients with severe cord compression behind the C2 body.

Materials and Methods: Patients with severe cord compression behind the C2 body who underwent posterior surgery were reviewed retrospectively. For sufficient decompression, "extensive" dome-like laminoplasty has been developed and performed. To minimize neural tissue damage, en bloc removal of the C2 inner lamina and decompression up to the upper border of the C2 were performed. Pre and postoperative canal diameters behind the C2 and the mean removed area of the C2 inner lamina were measured using MRI and three-dimensional CT scan. With lateral plain radiographs, the pre and postoperative sagittal vertical axis (SVA) at C2–C7 and segmental angle at C2–C3 were checked. Clinical scores, including the neck visual analog scale (VAS), arm VAS, Japanese Orthopaedic Association (JOA) score, and neck disability index (NDI), were also assessed pre and postoperative periods. In addition, perioperative complications were analyzed.

Results: A total of 36 patients had severe cord compression behind the C2 body and underwent extensive dome-like laminoplasty. The patients were diagnosed with ossification of the posterior longitudinal ligament (OPLL) (24, 66.7%) and cervical spondylotic myelopathy (12, 33.3%). In the preoperative midsagittal CT scan, the mean canal diameter behind the C2 increased from 9.85 ± 2.28 (6.59–14.03) mm preoperatively to 19.91 ± 3.93 (12.14–30.65) mm at the last follow-up ($P < 0.001$). Preoperative SVA (23.34 ± 15.16) and C2–C3 angle (0.34 ± 5.27) were significantly different from the postoperative SVA (22.16 ± 14.50) mm and C2–C3 angle (-0.83 ± 5.18) at the last follow-up ($P < 0.05$). Clinically, neck and arm VAS, JOA, and NDI significantly improved at postoperative 1 month ($P < 0.05$), and the scores were maintained until the last follow-up. During the procedures, there were no particular complications, but one patient showed deteriorated spinal cord compression at C1–C2 and underwent additional decompressive surgery.

Conclusion: To date, this study is the largest series regarding the treatment of severe cord compression behind the C2 body without laminectomy or laminoplasty. OPLL is the main pathology in this area, followed by congenital stenosis with spondylosis. After extensive dome-like laminoplasty, surgical outcomes are satisfactory, and complications are rare. Therefore, this technique may be a viable option for patients with severe cord compression behind the C2 body.

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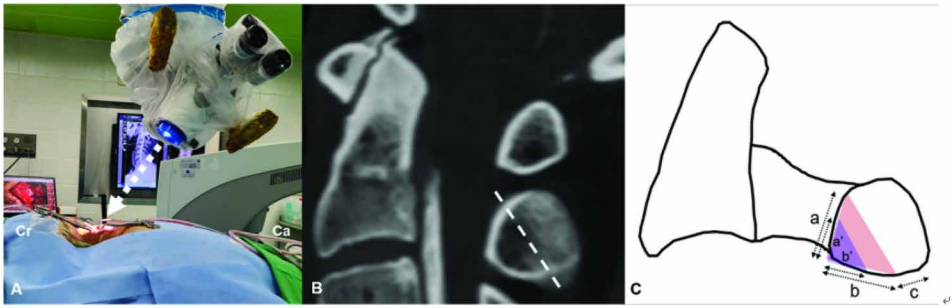

Figure 1. Intraoperative microscope position (A) and preoperative radiography and images (B, C) A. The microscope is tilted to a caudal direction (angle: 40–50°) and used at three times magnification. The right-handed operator stands on the left side of the patient and perform a procedure (Cr: cranial, Ca: caudal). B. The white dotted line indicates the inner part of the C2 lamina to be removed. C. The schematic image shows the comparison between the existing dome-like laminoplasty (triangle area of a–b) and "extensive" dome-like laminoplasty (triangle area of a–b) and remaining C2 lamina (c).

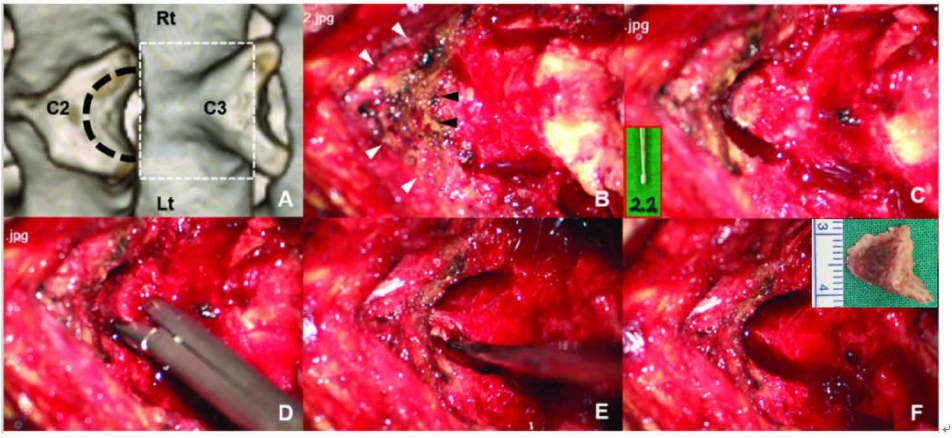

Figure 2. A. Areas scheduled to be removed in preoperative 3D CT scan (black dotted line: inner lamina of C2, white dotted box: total lamina of C3). B. Total exposure of the C2 inner lamina (blackheads) below a low border of the C2 lamina (white arrowheads) without significant muscle damage after C3 total laminectomy. C. A groove is started just below the inner border of the C2 lamina and deepened using a high-speed burr with a 2.2 mm match-stick head. D and E. Cut-off "en bloc" bone is removed, and the remaining border is trimmed. F. Complete decompression behind the C2 body is done (small box: part of the C2 lamina resected by "en bloc").

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PAPER 2

Open-Door Cervical Laminoplasty with Skip-fixation is Not Inferior to that of All-fixation: A Multicenter Randomized Controlled Trial

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Introduction: Degenerative cervical myelopathy (DCM) is the leading cause of spinal cord impairment [(1)]. Surgical decompression, including cervical laminoplasty, is the standard treatment to improve the neurological function and quality of life (QOL) of most patients [(2)]. In patients with DCM undergoing cervical laminoplasty, it is well-accepted that a multilevel laminar should be expanded to attain adequate spinal cord decompression [(3)]. However, whether all the expanded lamina should be fixed or not have not been validated enough. We postulated that the surgical outcomes of open-door laminoplasty with every other expanded laminar fixation (skip-fixation) may not be inferior to those of surgery with an all-expanded laminar fixation (all-fixation) (figure). Therefore, this study aimed to test the non-inferiority of myelopathy improvement one year after open-door cervical laminoplasty with skip-fixation compared to all-fixation in patients with DCM. Additionally, in the sub-analysis, we compared other 1-year surgical outcomes, including patient-reported outcomes, between the two types of surgeries.

Materials and Methods: This prospective, multicenter, non-blinded randomized controlled trial was performed in four sites in Japan. Patients at least 60 years old and who underwent C3-C6 open-door cervical laminoplasty for DCM were included in this study. In total, consecutive 217 patients were assessed for eligibility, and 213 were randomized to undergo laminoplasty with skip-fixation (n=112) or all-fixation (n=101) using the permuted block strategy. The primary outcome was the difference in the one-year Japanese Orthopaedic Association (JOA) score between the groups. The non-inferiority margin was set as 2.0, the minimum clinically significant difference in the JOA score. Secondary outcomes included surgical data, surgical complications, one-year changes in the Neck Disability Index, EuroQol 5 Dimensions (EQ5D) score, and visual analog scale (VAS) score for neck pain, arm pain, arm numbness, and radiographic outcomes.

Results: Among the 213 patients, 178 completed the trial after one year (skip-fixation, n=92; all-fixation, n=86; follow-up rate, 83.6%). The difference in the JOA score after one year was -0.101 (95% confidence interval: -0.799 to 0.596), which was significantly within the non-inferiority margin ($p<0.0001$, non-inferior test). In the sub-analysis, laminoplasty with skip-fixation demonstrated a significantly shorter surgical time ($p=0.019$), better improvement in neck pain VAS ($p=0.007$), and better improvement in EQ5D score ($p=0.048$) than laminoplasty with all-fixation. There were no significant differences in radiographic outcomes, including C2-7 angle and range of motion, between the surgical types.

Conclusion: Because skip-fixation requires half the number of implants compared to all-fixation, laminoplasty with skip-fixation can reduce medical costs. Current results indicates that among patients with DCM who underwent C3-C6 open-door cervical laminoplasty, skip-fixation was not inferior to all-fixation in terms of myelopathy improvement. Additionally,

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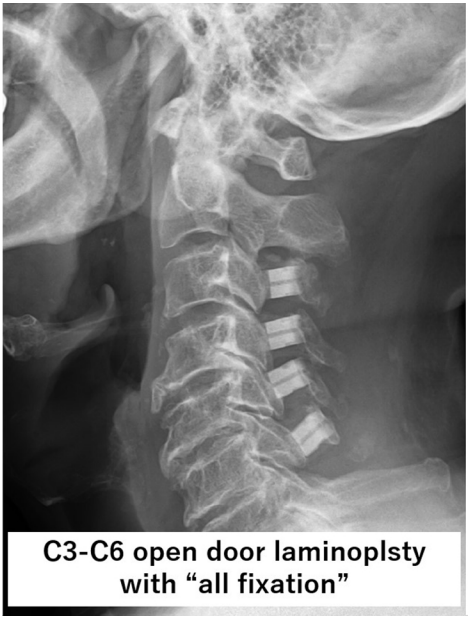
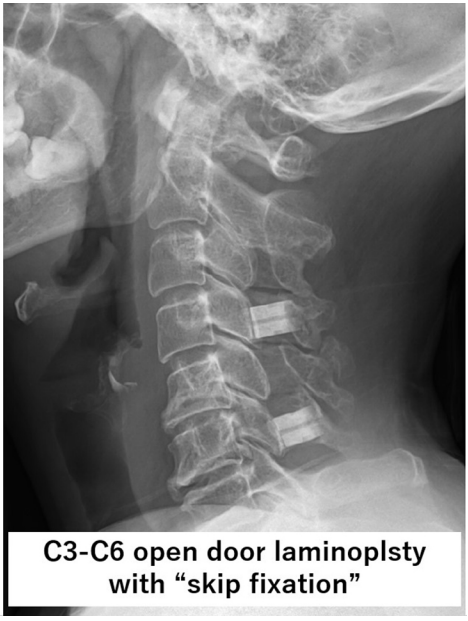
laminoplasty with skip-fixation can potentially improve neck pain and QOL more than that with all-fixation. As the incremental cost-effectiveness ratio was calculated by "medical cost/gained QOL", cervical laminoplasty with skip-fixation can be considered a cost-effective procedure.



C3-C6 open door laminoplsty with "all fixation"



C3-C6 open door laminoplsty with "skip fixation"

PAPER 3

How to Choose the Open Side for Unilateral Open-door Laminoplasty in the Treatment of Cervical Ossification of the Posterior Longitudinal Ligament?

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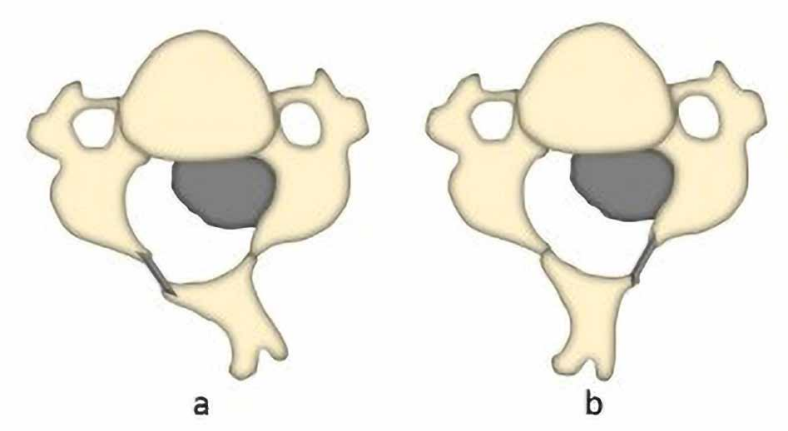
Introduction: To provide a more optimized strategy for choosing the open side for unilateral open-door laminoplasty in the treatment of cervical ossification of the posterior longitudinal ligament (OPLL).

Materials and Methods: We retrospectively analyzed the data of patients with cervical OPLL who underwent unilateral open-door laminoplasty in our department from January 2015 to December 2019. All patients had myelopathy preoperatively, with symmetrical symptoms on left and right limbs, and CT or MRI showed ossification leaning toward one side. The data of patients who completed a 3-year follow-up period were analyzed. According to the direction of the open side, all patients were divided into two groups: the contralateral group and the ipsilateral group. Clinical efficacy evaluation indicators included the Japanese Orthopaedic Association (JOA) score, JOA recovery rate, and neck pain visual analog scale (VAS) score. Imaging evaluation parameters included spinal canal expansion rate, cervical spine range of motion, and spinal cord cross-sectional area. The independent sample t-test was used for intergroup comparisons, and repeated measures analysis of variance was used for intragroup comparisons. $P<0.05$ was considered statistically significant.

Results: A total of 148 patients were included in this study, with 85 in the contralateral group and 63 in the ipsilateral group. There were no statistically significant differences in the baseline data between the two groups ($P>0.05$). The incidence of postoperative complications in the two groups was not significantly different ($P>0.05$). The JOA score and JOA recovery rate of the contralateral group were significantly higher than those of the ipsilateral group after surgery ($P<0.05$). There were no significant differences in cervical spine range of motion and spinal canal expansion rate between the two groups during the 3-year follow-up period ($P>0.05$). However, magnetic resonance imaging measurements of the cross-sectional area of the most severely compressed level of the spinal cord after surgery showed that the degree of increase in the cross-sectional area was significantly higher in the contralateral group than in the ipsilateral group ($P<0.05$).

Conclusion: When performing unilateral open-door laminoplasty in patients with cervical OPLL who present with myelopathy, choosing the contralateral side of the ossified mass as the open side can achieve better clinical outcomes.

PAPER 3 continued



PAPER 4

Different Patterns in Postoperative Sagittal Parameter Change After Laminoplasty According to the Preoperative T1 Slope

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Introduction: Since laminoplasty achieves cord decompression by inducing a dorsal shift of the spinal cord, postoperative kyphotic deformity and sagittal imbalance are factors that could adversely affect surgical outcomes. Therefore, the risk of postoperative kyphosis or sagittal imbalance should be identified preoperatively, and considered when selecting a surgical strategy. Previous studies have reported an association between T1S and the risk of kyphotic deformities after laminoplasty. Therefore, the present study was conducted to demonstrate whether there is a difference in the postoperative pattern of sagittal parameter change between patients with high T1S/cervical lordosis and low T1S/cervical lordosis preoperatively.

Materials and Methods: A total of 108 patients who underwent laminoplasty for cervical myelopathy and were followed-up for ≥24 months were retrospectively reviewed. Patients with preoperative kyphosis were excluded. Demographic and operative factors, C0-C2 lordosis, C2-C7 lordosis, T1S, C2-C7 sagittal vertical axis (SVA), K-line tilt, cervical range of motion (ROM), neck pain visual analog scale (VAS), arm pain VAS, neck disability index (NDI), and the Japanese Orthopedic Association (JOA) score were assessed. Patients with T1S≥20° and T1S<20° were compared.

Results: Thirty-five patients(32.4%) were included in the T1S<20° group and 73(67.6%) were included in the T1S≥20° group. Loss of lordosis occurred in 22 patients(62.8%) in the T1S<20° group and 41 (56.2%) in the T1S≥20° group (p=0.539). Correlation analysis demonstrated that preoperative C2-C7 lordosis (r=0.480, p<0.001) and T1 slope (r=0.251, p=0.009) were associated with loss of C2-C7 lordosis signifying that patients with greater preoperative lordosis lost more lordosis postoperatively. C2-C7 lordosis at the final follow-up was significantly lower in the T1S<20° group (p<0.001), and kyphotic deformity (C2-C7 lordosis <0°) occurred significantly more frequently in the T1S<20° group (12/33 [34.3%] vs. 5/73 [6.8%], p<0.001). Although the SVA significantly increased after the operation in both groups (p=0.035 and p <0.001, respectively), the SVA at the final follow-up was significantly greater in the T1S≥20° group (p=0.006). Furthermore, sagittal imbalance defined by an SVA >40 mm occurred only in the T1S≥20° group (14/73, 19.2%), with no cases in the T1S<20° group (p=0.004) (Table). However, there was no significant intergroup difference in the patient-reported outcome measures at the final follow-up.

Conclusion: The present study demonstrates that patients with greater preoperative C2-C7 lordosis suffer greater lordosis loss after laminoplasty. Greater neck muscle strength would be needed to maintain greater lordosis, and injury of the posterior tension band due to the operation would have resulted in more significant lordosis loss. However, loss of lordosis resulted in different consequences according to the preoperative T1S. In the T1S<20° group, since the preoperative C2-C7 lordosis was already small, lordosis loss more frequently resulted in kyphotic deformity. However, in the T1S≥20° group, lordosis loss caused an increase in SVA, and more often caused sagittal imbalance because the base of the cervical spine was tilted.

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While there is no need to avoid laminoplasty according to high or low T1S because clinical results were not significantly affected, different patterns of sagittal parameter change and the risk of kyphotic deformity or sagittal imbalance should be carefully considered during operative planning.

Table. Postoperative radiographic results

	T1S<20° (n= 35)	T1S >20° (n = 73)	p value
Postoperative 3 months			
C0-C2 lordosis (°)	30.0 ± 6.8	29.6 ± 8.3	0.792
C2-C7 lordosis (°)	6.7 ± 8.6	16.2 ± 8.9	<0.001*
C2-C7SVA (mm)	14.3 ± 9.2	22.5 ± 14.5	0.003*
T1 slope (°)	15.3 ± 5.3	25.3 ± 8.0	<0.001*
K line tilt (°)	9.0 ± 3.8	13.0 ± 8.5	0.010*
Cervical ROM (°)	26.9 ± 11.2	22.9 ± 10.6	0.074
Postoperative 2 years			
C0-C2 lordosis (°)	30.3 ± 7.5	30.1 ± 7.7	0.897
C2-C7 lordosis (°)	4.7 ± 6.7	13.9 ± 9.8	<0.001*
C2-C7 SVA (mm)	15.6 ± 9.1	23.2 ± 14.5	0.006*
T1 slope (°)	15.4 ± 5.7	24.6 ± 9.7	<0.001*
K line tilt (°)	9.6. ± 4.9	13.4 ± 8.4	0.013*
Cervical ROM (°)	27.3 ± 14.3	20.8 ± 12.8	0.019*
Cervical lordosis loss (°)	3.9 ± 8.0	6.7 ± 9.6	0.145
Kyphosis progression >10	7 (20.0%)	25 (34.2%)	0.177
Kyphotic alignment (Lordosis <0°)	12 (34.3%)	5 (6.8%)	0.001*
Sagittal imbalance (SVA >40mm)	0 (0.0%)	14 (19.2%)	0.004*
K line state change to (-)	2 (5.7%)	4 (5.5%)	1.000

T1S, T1 slope; SVA, sagittal vertical axis; ROM, range of motion

Categorical variables were analyzed using a chi-square test

Continuous variables were analyzed using student's t-test

* P<0.05

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PAPER 5

C4-C6 Laminoplasty with and without C3 Laminectomy, the Fate of the C2-C3 level: A Cadaveric Biomechanical Study

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Introduction: Posterior cervical laminoplasty is a common decompressive procedure used in the treatment of cervical spondylotic myelopathy. While it has been established that preservation of the semispinalis cervicis at C2 needs to be secured to maintain the posterior tension band, many providers feel that preservation of at least some of the C3 spinous process contributes to stability at the C2-C3 level. To our knowledge, there has been no work assessing the efficacy of C4-C6 laminoplasty with and without a C3 complete laminectomy and its consequence on the stability of the C2-C3 level.

Materials and Methods: Four human cadaveric spines (C1-T2) were mounted to a six degree-of-freedom robot (simVITRO®) and underwent preconditioning with pure moment loading of ±1.5 Nm in flexion/extension (FE), axial rotation (AR), and lateral bending (LB) to minimize viscoelastic effects. For testing, a 30 N head compressive force was maintained as a head load while ±1.5 Nm moments were applied to the native spine in FE, LB, AR, and in the coupled directions of flexion with axial rotation (FE±AR) and extension with axial rotation (E±AR). After testing, left sided open door laminoplasties were performed at C4, C5, and C6 (Stryker). The specimens were tested again with the above approach. After the second round of testing, a complete C3 laminectomy was performed and testing was repeated. Primary axes of rotation were compared at the C2-C3 level for each loading trajectory. Subsequent quaternion angles were calculated to quantify total changes in motion between specimens in the two surgical states and the native state.

Results: Our measurements focused on the change in motion between the standard C4-C6 laminoplasty and the C4-C6 laminoplasty with an additional C3 laminectomy, treating the native as the control. The C4-C6 laminoplasty construct showed a primary increase in the flexion motion at the C2-C3 level (Figure 1). The addition of a C3 laminectomy to this construct further increased instability in overall flexion and flexion with left axial rotation. Surprisingly, there appeared to be a reduction in motion with flexion and right axial motion with the additional C3 laminectomy. Laminoplasty alone demonstrated reduced motion at the C2-C3 level with extension. The addition of a C3 laminectomy demonstrated a trend towards baseline extension motion at the C2-C3 level, as supported through analysis of the Quaternion difference (Figure 2).

Conclusion: Augmenting the standard C4-C6 laminoplasty with a C3 laminectomy altered the biomechanics at C2-C3 level. Our biomechanical measurements suggest a trend towards increased instability in the standard laminoplasty group at C2-C3 level, and the addition of a C3 laminectomy further increased this instability overall primarily in flexion. Interestingly, the loss of extension and gain of flexion motion at C2-C3 can predispose patients to rest in increased kyphosis at this level. The increased instability in the lab has an unknown clinical significance,

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but disruption of the C2-C3 posterior tension band along with increased instability at the C2-C3 level might possibly explain increasing rates of kyphosis seen after a laminoplasty with laminectomy. Further studies are necessary to validate these trends and explore the clinical correlation of these findings.

Figure 1: C2-C3 Primary Axis Differences

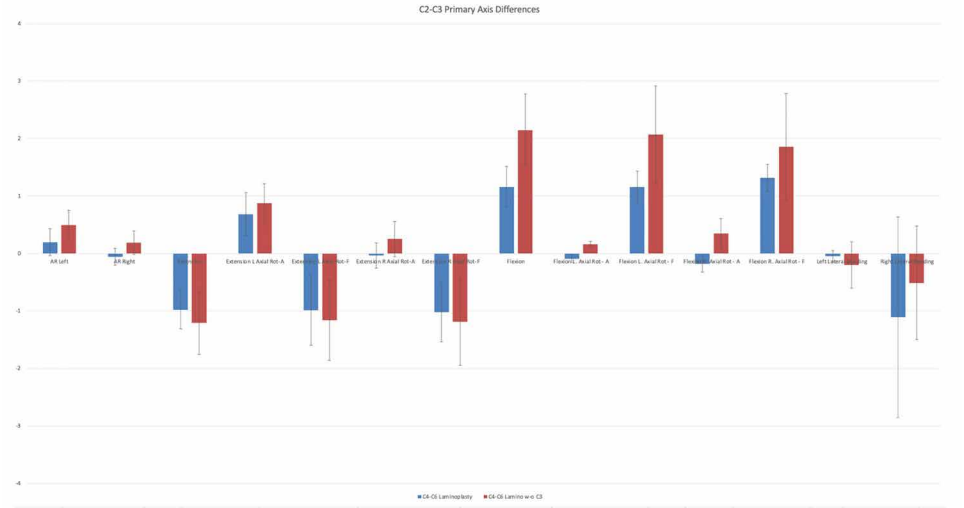
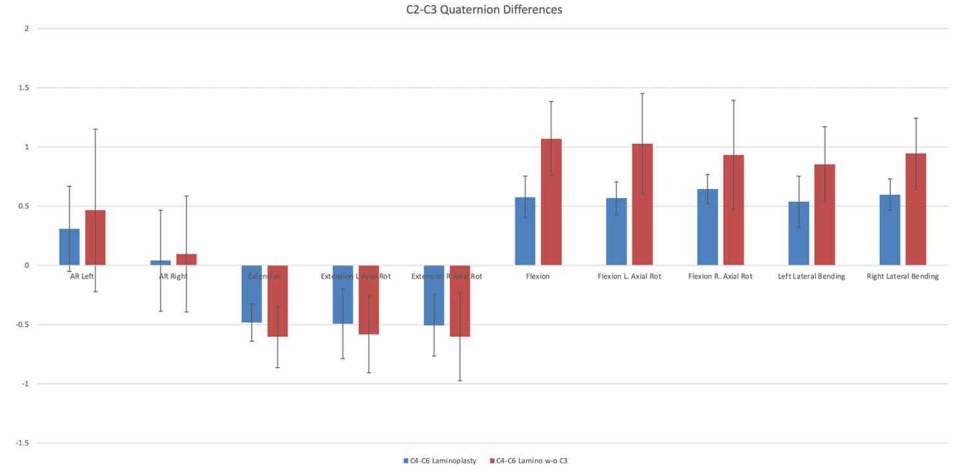


Figure 2: C2-C3 Quaternion Difference



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PAPER 6

What Effect Does T1 Slope Have on Sagittal Balance and the Relationship with Caudal End of Three or More Level Posterior Cervical Fusions?

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Introduction: The study investigated the effect of T1 slope on post-operative Sagittal Vertical Axis (SVA) and whether extension of posterior cervical fusions into the upper thoracic spine provides improved sagittal balance in comparison to C7 caudal level. Our hypothesis was does extension of posterior cervical fusions across the cervicothoracic junction lead improved sagittal balance in comparison to C7 caudal level.

Materials and Methods: A database of 327 patients who underwent a three or more level posterior cervical fusion with two years follow up was created. Two cohorts were created based on fusion caudal level, those whose fusion terminated at C7 and those whose fusions extended to T1 or T2. The cohorts were then divided again into two subgroups, high T1 slope (>25°) and low T1 slope (≤25°) and subject to comparative analysis.

Results: 224 patients were included in the C7 caudal cohort and 103 were included in the T1/T2 caudal cohort. The mean age of C7 and T1/T2 groups were 61±12 yrs and 63.1±12.6 yrs, respectively. Mean BMI of the C7 cohort was 28.9±6.8, and 29.1±5.8 in the T1/T2 cohort. Mean SVA was significantly higher in patients with high T1 slopes (mean range 34.2-44.1mm) as compared to patients with Low T1 slopes (mean range 21-28.9mm) across all time intervals (pre-op to 24 months post-op). Additionally, the 25th percentile SVA of High T1 slopes were greater than the median SVA values of Low T1 slopes at all intervals. For both the high and low T1 slope cohorts, patients with a caudal T1/T2 had comparatively higher SVA values than their C7 counterparts at all intervals despite maintenance of cervical lordosis, however these differences were not statistically significant.

Conclusion: Increased sagittal imbalance was comparatively higher in patients with >25° T1 slope ranging across preoperative to 24 months postoperative radiographic measurements. Extension of the posterior cervical fusion to T1 or T2 did not improve sagittal balance in patients with high T1 slopes. In fact, extension of posterior cervical fusions across the junction lead to increased positive sagittal imbalance. The results of this study do not support routinely extending posterior cervical fusions into T1 or T2 to improve post-operative sagittal balance. Longer thoracic extension or other intra-operative measures must be sought in patients at high risk for sagittal decompensation.

PAPER 7

Comparison of Outcomes Between Anterior Cervical Ossified Posterior Longitudinal Ligament En Bloc Resection and Posterior Total Laminectomy and Fusion in Patients with Cervical Ossification of the Posterior Longitudinal Ligament: A Prospective Randomized Controlled Trial

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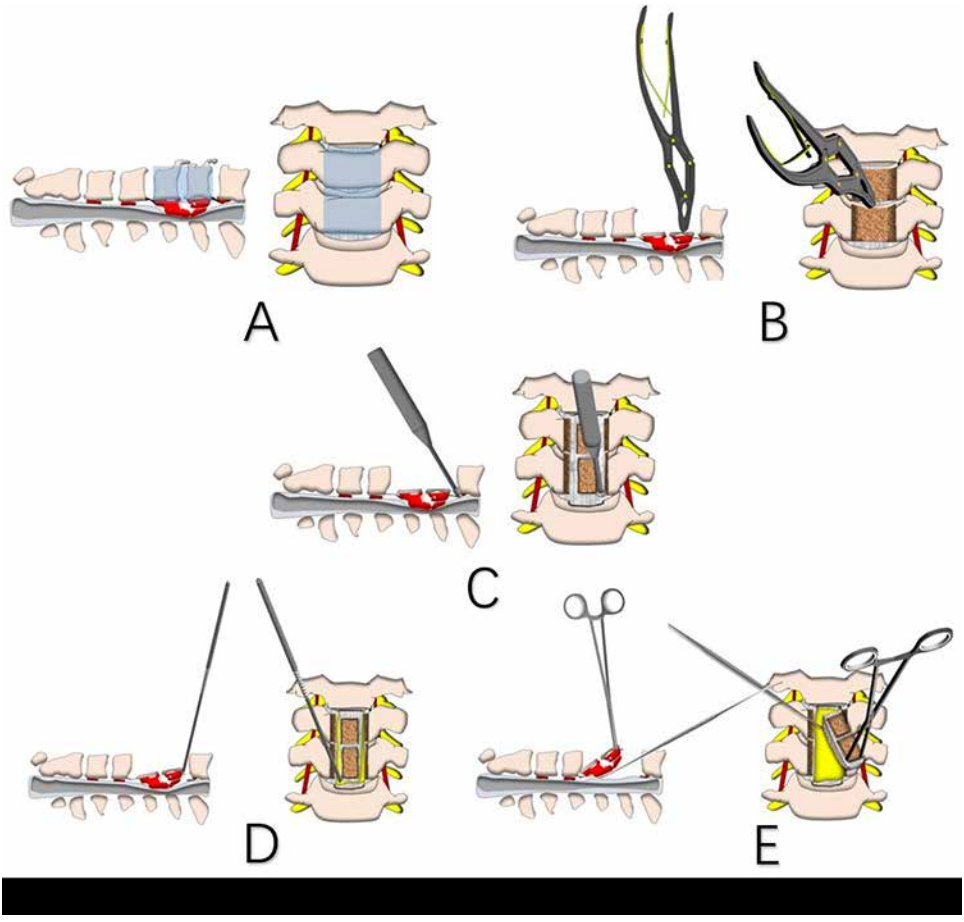
Introduction: The optimal surgical approach for treating ossification of the posterior longitudinal ligament (OPLL) remains controversial. This study aimed to compare the outcomes of anterior cervical ossified posterior longitudinal ligament en bloc resection (ACOE) with posterior laminectomy and fusion with bone graft and internal fixation (PTLF) in patients with cervical OPLL.

Materials and Methods: Between July 2017 and July 2019, 40 patients with cervical OPLL were randomized equally to undergo ACOE or PTLF surgery. Clinical and radiological results were compared between the two groups.

Results: The Japanese Orthopaedic Association (JOA) score and recovery rate were significantly higher in the ACOE group than in the PTLF group during the two-year postoperative period when the canal occupying ratio (COR) was > 50% or the K-line was negative. No significant differences in JOA scores and rate of recovery were observed between the two groups when the COR was < 50% or the K-line was positive. No significant differences were observed in the Cobb angle between C2 and C7, sagittal vertical axis, cervical range of motion (ROM), or complications between the two groups.

Conclusion: ACOE is a preferred surgical approach for the management of cervical OPLL over PTLF when the COR is > 50% or the K-line is negative because it offers a better therapeutic outcome and preserves better cervical curvature and sagittal balance. The prognosis of ACOE is similar to that of PTLF when the COR is < 50% or the K-line is positive.

PAPER 7 continued



PAPER 8

The Impact of C2 Screw Placement Technique on Radiographic and Clinical Outcomes after C2-T2 Posterior Cervical Fusion

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Introduction: In posterior cervical fusions (PCF) involving the upper cervical spine, the utilization of C2 pedicle versus C2 pars interarticularis screws varies by surgeon preference and patient anatomic considerations. When comparing both C2 screw placement techniques, there is a theoretical safety versus mechanical stability tradeoff, where C2 pedicle screws are associated with a higher load failures but may be technically challenging and risk malpositioning [hl1] in patients with narrow pedicles, inconsistent transverse foramen location, or high-riding vertebral arteries. While limited evidence suggests that there are no significant differences in complications comparing C2 pedicle and pars screws in atlantoaxial fusion, the impact of C2 screw placement technique as the upper instrumented level of a long-segment PCF is yet to be established. This study aimed to determine if C2 screw placement predicted change in cervical alignment and patient reported outcomes measures (PROMs) after C2-T2 PCF for degenerative indications.

Materials and Methods: All adult patients who underwent C2-T2 PCF for myelopathy or myeloradiculopathy at a multi-institutional academic center between 2013-2020 were retrospectively identified. Patients were dichotomized by C2 screw placement technique into bilateral pedicle or bilateral pars screw groups determined through the operative note or postoperative CT scan. Patients with traumatic injury, infection, malignancy, a combined anterior/posterior surgical approach, or incomplete medical records, less than one year of radiographic follow-up, a combination of C2 unilateral pars and pedicle screws, or C2 laminar screws were excluded. Preoperative and short- and long-term postoperative radiographic outcomes (upper cervical alignment, global alignment, fusion status) and PROMs (VAS Neck, Neck Disability Index, Short Form-12) were collected. Univariate and multivariate analysis compared patient demographics, surgical factors, change in radiographic measures, and change in PROMs across C2 screw placement groups.

Results: A total of 87 patients met the inclusion/exclusion criteria (47 pars, 40 pedicle). Patients in the pars screw group relative to the pedicle screw group were more likely to be female (p=0.015) and have a larger rod diameter utilized (p=0.039) (Table 1). Preoperative bone mineral density, Hounsfield units, medical comorbidities, operative indication, and bone graft use did not differ significantly between groups (all p>0.05, Table 1). There were no significant differences in fusion status, C2-3 pseudoarthrosis, C2 screw loosening, proximal junctional kyphosis, complications, and revision rate between C2 screw placement groups (all p>0.05, Table 1). Similarly, preoperative to postoperative changes in upper cervical alignment (C2 slope, C2 tilt, C2-3 segmental lordosis, C2-3 listhesis, C0-2 cobb angle in neutral, flexion, and extension, ADI, distance between C1 lamina and occiput) and global cervical alignment (C2 SVA, C2-7 lordosis, T1 slope-cervical lordosis mismatch) and PROMs at immediate, > six months, and final postoperative follow-up did not vary significantly by C2 pars versus pedicle screw

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groups (all p>0.05, Table 1).

Conclusion: There were no significant differences in upper cervical alignment, C2 screw loosening, and proximal junctional kyphosis or failure based on C2 screw placement technique in C2-T2 PCF. C2 pars screws, a technically less demanding option given variable patient anatomy, can be utilized in the upper instrumented level of long-segment PCFs without compromising outcomes.

Variable	C2 Bilateral Pars Screws (N=47)	C2 Bilateral Pedicle Screws (N=40)	P value
Demographics			
Age	63.9 (9.8)	65.6 (9.4)	0.418
Sex (Female)	25 (53.2%)	11 (27.5%)	**0.015**
BMI <25 25-35 >35	14 (29.8%) 24 (51.1%) 9 (19.1%)	9 (22.5%) 25 (62.5%) 6 (15.0%)	0.562
Smoking	8 (17.0%)	4 (10.0%)	0.344
Diabetes	10 (21.3%)	11 (27.5%)	0.499
Chronic steroid use	2 (4.3%)	5 (12.5%)	0.159
Chronic kidney disease	6 (12.8%)	1 (2.5%)	0.079
Inflammatory arthritis	3 (6.4%)	6 (15.0%)	0.188
Neurodegenerative disease	1 (2.1%)	1 (2.5%)	0.908
Indication			
Myelopathy Myeloradiculopathy	41 (87.2%) 6 (12.8%)	33 (82.5%) 7 (17.5%)	0.537
Preop BMD + Muscle			
Lowest BMD	1.0 (0.2)	1.0 (0.2)	0.797
Lowest BMD t-score	-0.7 (1.2)	-0.7 (1.5)	0.915
Prior BMD Treatment	5 (8.3%)	7 (9.6%)	0.801
Average HU at C2	328.5 (82.3)	317.3 (115.5)	0.635
Average HU at C6	364.3 (131.3)	321.7 (107.9)	0.154
Average HU at T2	220.0 (65.6)	212.1 (67.1)	0.620
Longus Colli Area at C5/6	62.4 (23.0)	70.7 (25.2)	0.157
Longus Colli AP Diameter at C5/6	8.8 (10.4)	7.5 (2.2)	0.500
Longus Collis HU at C5/6	49.3 (20.9)	50.5 (15.9)	0.788
Surgical Factors			

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Rod Diameter	3.8 (0.4)	3.6 (0.4)	**0.039**
BMP Use	14 (29.8%)	6 (15.0%)	0.102
Bone Graft Material Allograft ICBG local auto only	21 (44.7%) 2 (4.3%) 24 (51.1%)	17 (42.5%) 1 (2.5%) 22 (55.0%)	0.869
Upper Cervical Alignment			
C2 Slope Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	1.6 (14.3) 2.6 (13.6) 7.6 (12.3)	3.2 (13.0) 4.8 (10.1) 5.7 (10.3)	0.594 0.385 0.679
C2 Tilt Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	2.9 (14.3) 7.1 (13.8) 9.1 (11.5)	4.7 (15.2) 7.2 (10.5) 10.7 (10.3)	0.594 0.974 0.735
C2-3 Segmental Lordosis Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	-0.5 (4.5) -0.3 (4.7) 0.6 (3.8)	0.6 (4.4) -0.5 (4.9) -0.7 (6.6)	0.288 0.873 0.561
C2-3 Listhesis Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	-0.1 (2.4) -0.0 (3.3) -0.3 (1.0)	-0.4 (2.2) -0.3 (2.4) 0.1 (1.6)	0.591 0.709 0.534
C0-2 Cobb Angle in Neutral Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	0.3 (10.6) 2.1 (9.4) 4.5 (11.5)	0.6 (11.5) 2.2 (10.4) 3.5 (13.8)	0.922 0.957 0.840
Atlantodens Interval (ADI) Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	0.1 (0.5) 0.0 (0.5) 0.3 (0.5)	-0.0 (1.0) -0.2 (1.0) -0.3 (0.7)	0.551 0.232 0.787

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

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O-C2 Cobb Angle in Flexion Δ (>6 months– Pre) Δ (Final– Pre)	-1.6 (8.3) 0.7 (7.7)	-4.8 (8.9) 3.6 (7.9)	0.367 0.642
O-C2 Cobb Angle in Extension Δ (>6 months– Pre) Δ (Final– Pre)	-0.1 (7.6) 5.5 (11.7)	-1.6 (12.1) 3.6 (0.7)	0.684 0.827
Distance Between C1 Lamina and Occiput Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	-0.2 (3.4) -1.5 (3.6) -1.0 (3.1)	-0.1 (3.8) -1.1 (3.5) -1.5 (3.9)	0.911 0.571 0.742
Global Cervical Alignment			
C2 SVA (mm) Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	3.6 (14.1) 7.2 (13.1) 9.8 (14.4)	3.9 (13.3) 6.6 (15.2) 4.5 (11.6)	0.915 0.844 0.336
C2-C7 Lordosis Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	1.5 (15.6) 1.4 (15.1) -5.7 (23.2)	-0.9 (10.8) -1.8 (10.7) -0.1 (8.7)	0.402 0.272 0.453
T1 Slope- Cervical Lordosis Mismatch Δ (Immediate – Pre) Δ (>6 months– Pre) Δ (Final– Pre)	10.1 (24.4) 1.8 (11.8) 6.8 (14.6)	4.7 (11.6) 4.0 (8.6) 1.6 (9.9)	0.513 0.353 0.343
Fusion and Screw Status			
Final f/u Evidence of screw loosening at C2	0.0 (0.2)	0.0 (0.2)	0.659
Final f/u Evidence of screw loosening at T2	0.1 (0.3)	0.1 (0.3)	0.619
Fusion	34 (91.9%)	24 (96.0%)	0.518
Pseudoarthrosis involving C2-3	3 (8.1%)	1 (4.0%)	0.518

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Pseudoarthrosis involving T1-2	1 (2.7%)	0 (0.0%)	0.407
PROMs			
NDI: Δ (<3months – Pre) Δ (>3months – Pre)	 -5.9 (6.5) -3.9 (4.6)	 -3.1 (6.4) -2.9 (7.2)	0.208 0.729
VAS Neck: Δ (<3months – Pre) Δ (>3months – Pre)	 -5.7 (3.1) -4.8 (2.4)	 -4.9 (2.8) -3.6 (3.2)	0.322 0.122
SF Physical Health: Δ (<3months – Pre) Δ (>3months – Pre)	 1.6 (6.7) 2.1 (3.9)	 0.6 (3.7) 2.2 (6.2)	0.647 0.964
SF Mental Health: Δ (<3months – Pre) Δ (>3months – Pre)	 -1.7 (6.6) -1.7 (6.6)	 -0.3 (7.1) -0.3 (7.1)	0.604 -1.1 (4.0)
Complications			
Proximal Junctional Kyphosis	2 (14.3%)	3 (27.3%)	0.420
New or Progressive Neuro Deficit	3 (6.4%)	7 (17.5%)	0.105
Postop Hematoma requiring Drainage?	0 (0.0%)	3 (7.5%)	0.056
Evidence of C2-3 stenosis?	1 (2.4%)	2 (5.6%)	0.481

PAPER 9

The Effect of C2 Muscular Exposure Technique on Radiographic and Clinical Outcomes after C2-T2 Posterior Cervical Fusion

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Introduction: In long-segment posterior cervical fusions (PCF), handling of the C2 posterior paraspinal musculature during the operative approach varies by surgeon technique. To date, no studies have investigated if maintenance of the upper cervical semispinalis cervicis attachments and decreased disruption of the posterior tension band as compared to complete reflection of upper cervical paraspinal musculature from the posterior bony elements is associated with superior radiographic and clinical outcomes after PCF. This study aimed to determine if C2 exposure technique was a predictor of change in cervical alignment and patient reported outcomes measures (PROMs) after C2-T2 PCF for degenerative indications.

Materials and Methods: All adult patients who underwent C2-T2 PCF for myelopathy or myeloradiculopathy at a multi-institutional academic center between 2013-2020 were retrospectively identified. Patients with traumatic injury, infection, malignancy, a combined anterior/posterior surgical approach, or incomplete medical records, or less than one year of radiographic follow-up were excluded. Patients were dichotomized by C2 exposure technique into semispinalis preservation or midline muscular reflection groups determined through the operative note or contacting the lead surgeons. Preoperative and short- and long-term postoperative radiographic outcomes (upper cervical alignment, global alignment, fusion status) and PROMs (VAS Neck, Neck Disability Index, Short Form-12) were collected. Univariate and multivariate analysis [hl1] compared patient demographics, surgical factors, change in radiographic measures, and change in PROMs across C2 exposure groups.

Results: A total of 133 patients met the inclusion/exclusion criteria (73 muscle preservation, 60 muscle reflection). Patients in the muscular attachments preservation group were on average younger ($p=0.006$) and more likely to have bone morphogenic protein used during surgery ($p<0.001$) (Table 1). Preoperative bone mineral density, Hounsfield units, medical comorbidities, operative indication, and rod diameter did not differ significantly between groups (all $p>0.05$, Table 1). Preoperative to postoperative changes in upper cervical alignment (C2 slope, C2 tilt, C2-3 segmental lordosis, C2-3 listhesis, C0-2 cobb angle in neutral, flexion, and extension, proximal junctional kyphosis, ADI, distance between C1 lamina and occiput) and global cervical alignment (C2 SVA, C2-7 lordosis, T1 slope-cervical lordosis mismatch) and PROMs at immediate, > six months, and final postoperative follow-up did not vary significantly by C2 exposure technique (all $p>0.05$, Table 1). Likewise, there were no significant differences in fusion status, C2-3 pseudoarthrosis, C2 screw loosening, complication rate, and revision rate between C2 exposure groups (all $p>0.05$, Table 1).

Conclusion: Preservation of C2 semispinalis attachments as compared to complete posterior muscular reflection did not significantly impact cervical alignment, clinical outcomes, or proximal junction complications in long-segment PCF. Furthermore, reflection of C2

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musculature may increase operative efficiency and visualization without compromising outcomes.

Variable	Complete C2 Paraspinal Muscular Dissection Off Posterior Bony Elements (N=60)	Maintenance of C2 Posterior Midline Paraspinal Attachments (N=73)	P value
Demographics			
Age	66.2 (8.2)	61.8 (9.8)	**0.006**
Sex (Female)	22 (36.7%)	35 (47.9%)	0.191
BMI <25 25-35 >35	14 (23.3%) 37 (61.7%) 9 (15.0%)	12 (16.4%) 47 (64.4%) 14 (19.2%)	0.557
Smoking	8 (13.3%)	10 (13.7%)	0.951
Diabetes	4 (6.7%)	5 (6.8%)	0.967
Chronic steroid use	11 (18.3%)	18 (24.7%)	0.379
Chronic kidney disease	8 (13.3%)	4 (5.5%)	0.116
Inflammatory arthritis	10 (16.7%)	5 (6.8%)	0.075
Neurodegenerative disease	4 (6.7%)	3 (4.1%)	0.511
Indication			
Myelopathy Myeloradiculopathy	51 (85.0%) 9 (15.0%)	64 (87.7%) 9 (12.3%)	0.654
Preop BMD + Muscle			
Lowest BMD	1.0 (0.2)	0.9 (0.2)	0.345
Lowest BMD t-score	-0.5 (1.5)	-0.9 (1.3)	0.152
Prior BMD Treatment	5 (8.3%)	7 (9.6%)	0.801
Average HU at C2	322.2 (111.5)	329.8 (103.4)	0.709
Average HU at C6	337.4 (120.8)	350.1 (118.6)	0.601
Average HU at T2	220.7 (76.4)	221.9 (71.3)	0.935
Longus Colli Area at C5/6	71.1 (24.0)	61.9 (26.5)	0.058
Longus Colli AP Diameter at C5/6	8.9 (8.8)	7.1 (2.0)	0.135
Longus Collis HU at C5/6	48.2 (25.3)	48.7 (16.7)	0.895

PAPER 10

Cervical Pedicle Screw Insertion in Degenerative Vertebrae Using a Robot System

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Introduction: Cervical pedicle screws (CPSs) give us strong cervical fixation, which contributes to higher fusion rates, earlier rehabilitation, and shorter fusion range, compared to other fixation methods. This technique, however, has the potential risk of vertebral artery (VA) injury, which is not accepted because it may be catastrophic or fatal. To avoid this complication, preoperative precise examination of the VA course, and accurate placement of CPS as planned is mandatory. The latter, however, is very difficult particularly in the degenerative vertebrae, because the trajectory of CPS cannot be determined with only anatomical landmarks due to the vertebral deformity and rotation caused by the degenerative change. Recently we introduced an intraoperative real CT (iCT), a navigation system, and a robot system. With the iCT-navigation system, an intraoperative C-arm and time-consuming point registration are ideally unnecessary. The robot system helps us to insert screws without intracerebral conversion from 2-dimensional information (navigation monitor) to 3-dimensional practice (screw insertion). These characteristics of the advanced systems may offer us accurate CPS insertion and a less stressful operation environment.

Materials and Methods: CPSs were inserted into C2-6 vertebrae, where VAs exist in the transverse foramen, using the iCT-navigation-robot system from May 2022 to March 2023. C-arm was not used during surgery. After surgery, the positions of the screws were evaluated using a CT, according to Neo's classification[1], that is Grade 0: no pedicle perforation, Grade 1: perforation < 2mm, Grade 2: perforation 2-4mm, and Grade 3: perforation >4mm.

Results: Ninety-five screws were inserted in 22 patients (18 men and 4 women, mean age: 69 years, range of age: 49-93 years) with more or less degenerative cervical spine. In one case, the insertion of bilateral C2 CPSs was impossible, and MagerI screws were inserted bilaterally using the iCT-navigation-robot system. Original morbidity included 8 OPLL, 5 CSM, 2 dropped head syndrome, and so on. Four patients with cervical kyphosis of > 10 degrees, 8 with segmental anterolisthesis of > 2mm, and 4 with translational instability of > 3mm were included. No neurological or vascular complications were encountered.

Ninety-one screws (96%) were classified as acceptable (Grade 0: 85%, and Grade 1: 11%). Four screws were classified as Grade 2 and there was no Grade 3 perforation. Among the 4 screws of Grade 2, no screw perforated laterally (toward the VA) or cranially (toward the nerve root). Compared with our historical control of CPS insertion using only a C-arm, the unacceptable perforation rate decreased from 15% to 4%. Further, among unacceptable screws (Grade 2 or 3), the rate of Grade 3 decreased from 54% to 0%, and that of lateral perforation decreased from 69% to 0%.

Conclusion: CPS insertion using the iCT-navi-robot system increases insertion safety in a stressless environment. The accurate placement of the screws also enables us to obtain more rigid anchors, which would bring about better clinical results.

PAPER 11

The Evolution of ERAS: Assessing the Clinical Benefits of Developments within Enhanced Recovery After Surgery Protocols in Adult Cervical Deformity Surgery

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Introduction: Enhanced Recovery After Surgery (ERAS) can help accelerate patient recovery and assist hospitals in maximizing the incentives of bundled payment models while maintaining high-quality patient care. However, there remains a paucity of literature assessing how developments have impacted outcomes after adult cervical deformity (CD) surgery.

Materials and Methods: Operative CD patients ≥18yrs with pre-(BL) and 2-year(2Y) postop data who underwent ERAS protocols were stratified by increasing implantation of ERAS component: Early (multimodal pain program), Intermediate (Early protocol + paraspinal blocks, early ambulation), and Late (Early/Intermediate protocols + comprehensive prehabilitation). Differences in demographics, clinical outcomes, radiographic alignment targets, peri-operative factors and complication rates were assessed via Bonferroni-adjusted means comparison analysis.

Results: 131 patients were included (59.4±11.7 years, 45% female, 28.8±6.0 kg/m^2). Of these patients, 38.9% were considered Early, 36.6% were Intermediate, and 24.4% were Late. Peri-operatively, rates of intraoperative complications were lower in the Late group ($p=.036$). Post-operatively, discharge disposition differed significantly between cohorts, with Late patients more likely to be discharged to home versus Early or Intermediate cohorts ($\chi^2(2)=37.973$, $p<.001$). In terms of post-operative disability recovery, Intermediate and Late patients demonstrated incrementally improved 6W mJOA scores ($p=.004$), and Late patients maintained significantly higher mean EQ5D and mJOA scores by 1Y ($p<.001$, $p=.026$). By 2Y, cohorts demonstrated incrementally increasing SWAL-QOL scores (all domains $p<.028$) domain scores versus Early or Intermediate cohorts. By 2Y, incrementally decreasing reoperation were observed in Early vs Intermediate vs Late cohorts ($p=.034$).

Conclusion: The present study demonstrates that patients enrolled in an evolving ERAS programs demonstrate incremental improvement in pre-operative optimization and candidate selection, greater likelihood of discharge to home, decreased post-operative disability and dysphasia burden, and decreased likelihood of intra-operative complications and reoperation rates.

PAPER 12

Are we Getting Better at Treating Adult Cervical Deformity? Complication Rate Trends Analysis in Adult Cervical Deformity Over 10 Years

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Introduction: Adult cervical deformity patients can have significant impact on quality of life. Realignment surgery has proven to be effective in a select group of these patients, however despite advancements in the field, complications are not uncommon. Evaluation of outcomes overtime can be insightful on aspects that surgeons have been improving on and those that remain to be a nuance.

Materials and Methods: Patients with Adult Cervical Deformity with a minimum 2-year follow-up and less than 10 levels fused were included. Patients were stratified into quartiles by date of surgery, with the middle two quartiles being merged to form three categories: Early (E), Middle (M), Recent (R). Descriptive analysis of demographic data, preoperative data, surgical information, and complications was conducted. ANCOVA was used to assess complication rates and PROMs amongst tertiles controlling for age, gender, osteoporosis, CCI, mFI, TS-CL, cSVA, and levels fused. Multivariate analyses were used to assess differences in surgical, radiographic, and clinical outcomes over time.

Results: 570 patients were included with enrollment from 2011-2021. Baseline demographics details: Age: 59.6±12.4, 65% female, BMI 28.6±7.1kg/m^2, CCI 0.9±1.3, mFI 2.7±1.7. Age, CCI, and mFI were highest in R cohort. No difference at baseline in Ames modifiers amongst cohorts. Controlled analysis depicted lowest rates of complications in R (E: 62.5%, M: 72.7%, R: 45.5%). Major complication rates decreased from 59.8% in E to 15.0% in last cohort. Rates of DJK decreased from M to R (39.6% to 12.7%, p=.011), with rate of DJF being lowest in R and highest in M (20% in M, 12% in E, 6.7% in R, p=0.046). Reoperation rates decreased from 18.8% in E to 12.4% in R. Neurological complications decreased as well from 38.5% in E to 2.1% in R (p=0.044). Cardiopulmonary complication rates decreased from 24.8% in M to 3.5% in R.

Conclusion: Complication rates significantly decreased over a 10 year period amongst cases, despite having higher age, frailty, comorbidities, mJOA, and no difference in baseline deformity between early and recent cases.

PAPER 13

Working Towards Personalized Realignments in Adult Cervical Deformity Surgery: Consideration of Upper Cervical Region Reserve and Deformity Morphology in the Application of the Cervical Lordosis Distribution Index

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Introduction: The cervical lordosis distribution index tailored correction to patient. However, impact of morphologic differences and upper cervical segments has not been characterized.

Materials and Methods: Cervical deformity patients with baseline and 2Y data included. Caudal (CaLDI) and cranial lordosis distribution index thresholds (CrLDI) developed by dividing each cervical arch by total segment (C0-T2) and multiplying by 100. Conditional inference tree analysis developed thresholds for (Cranial 70-100, Caudal -10-30). Patients were stratified by Ames et al classification then assessed against thresholds. Patients were further divided into those meeting thresholds with upper cervical compensation (defined by C0C2 angle, C0 slope, McGregor's Slope [MGS]) vs those without compensation. Good clinical outcome (GCO) is defined by no DJF (DJK >15.3°) and meeting ***Virk*** et al Criteria: [Meeting 2 of 3: 1. NDI>20 or meeting MCID, 2. mJOA ≥14, 3. NRS-Neck≤5 or improved 2+points]. Multivariate regression analysis controlling for T1 slope assessed differences in classification and impact of upper cervical region.

Results: 82 met inclusion (Age: 61.4 yrs, BMI: 29.1kg/m^2, 64%F, CCI: 1.06). Distribution of cervical apex at 3 months was 1% C3, 42% C4, 30% C5, 27% C6. Mean cranial lordosis was 22.97±12.0°, caudal lordosis 1.7±12.5°. Those meeting cranial threshold had 93% more likely to be classified into primarily cervical deformity by Ames criteria (OR: .07, [1.15,1.59], p<.05) followed by cervico-thoracic (OR: .29, [1.08, 1.41], p=.057). For caudal threshold, patients were 51% more likely to be classified as cervical (OR:.49, [.22,.53], p>.05) and 39% more likely as cervico-thoracic (OR: .61, [.32, .68], p>.05).Meeting CrLDI threshold significantly predicted a decrease in C0-C2 angle (OR: -3.7 [1.80, 2.70], p=.009) and in C0 slope (OR:-6.1 [1.19, 1.72], p<.001). Similarly, meeting CaLDI threshold had a decrease in C0-C2 angle (OR: -1.5, [1.12,2 .33], p=.03) and C0 slope (OR: -4.7, [.85,1.23],p=.045), although by a lesser degree. Patients with

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upper cervical compensation meeting CrLDI thresholds had lower DJK (10% vs. 23%, p=.03). Meeting CaLDI threshold while compensating in upper cervical region generated similar results with lower DJK (11% vs. 29%, p=.042). Overall, CrLDI threshold with compensation had higher odds of meeting GCO compared to CaLDI (2.71 vs. 2.23, p<.05), indicating importance of upper cervical compensation in more cranial lordosis.

Conclusion: Further development of cervical lordosis distribution index takes into account impact of upper cervical and differences in classification, with greater degree of cervical only deformity in those meeting index thresholds. While differences based on morphology exists, upper cervical region functions as a reserve in all deformity types. Consideration of regional and global factors allows for a comprehensive assessment and individualization of realignment surgery.

PAPER 14

Incorporation of Frailty Based Realignment Target Goals for Cervical Deformity Surgery in Adults Can Mitigate Mechanical Complications and Improve Perioperative Course

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Introduction: Given the high prevalence of frailty in adults undergoing cervical deformity surgery, along with frailty drastically influencing recovery patterns, adjusting realignment goals can be of value. Assessing patient specific goals accounting for frailty, can lead to greater rates of optimal outcomes in ACD.

Materials and Methods: Operative adult cervical deformity (ACD) patients with 2 year data were included. Cervical deformity defined as: patients that met radiographic evidence of cervical deformity, defined previously as meeting at least one of the following radiographic parameters: C2-C7 lordosis <-15°, TS-CL >35°, segmental cervical kyphosis >15° across any 3 vertebrae between C2-T1, C2-C7 SVA >4cm, McGregor's slope >20°, or CBVA > 25°, measured with preoperative radiographs were included. Patients were stratified based on mFI into not frail (NF), frail (F), and severely frail (SF). Good outcomes (GO) was defined as meeting all of the following parameters at 1Y and 2Y: 1) no DJF or mechanical failure, 2) met Virk et al. good clinical outcome, NRS-Neck ≤5 or improvement ≥2 points from BL], 3) improved in ≥1 Ames modifier, and 4) no worsening in Ames modifier. Those that did not meet GO were PO. ANCOVA used to control for baseline deformity, levels corrected, and age to assess radiographic alignment on earliest postoperative imaging. Logistic regression analysis followed by conditional inference tree (CIT) run forest analysis generated categorical thresholds. Multivariate analysis controlling for age, baseline deformity, and history of revision.

Results: 343 ACD patients were included (Age 59.6±12.4yrs, 46% females, BMI 28.6 ± 7.1kg/m^2). Baseline HRQL's were NDI 53±19, ODI 48.5±17.5, mJOA 13.2 ± 2.6, Swal 89 ± 22, EQ-5D 0.54 ± 0.21. Baseline frailty categories: 21% Not Frail, 67% Frail, and 12% severely frail. Baseline deformity: TS-CL 36.1°±18.9°, cSVA 4.5±2.4cm, C2-C7 -3.9°±22.2°, C2-T3 -15.5°±21.5°, C2S 35.8°±19.9°, MGS 2.3°±13.0°, with greater deformity present as frailty increased. BL mJOA was worse in SF and in PO cohort (both p<0.001). Overall by 2Y, 18.9% developed DJK, 7.9% DJF, 6.3% mechanical failure, 11% neurological complications, and 16.5% underwent reoperation, with 43.3% meeting GO. 52% of NF met GO, 42% of F, and 33% of SF. Analysis adjusted for baseline deformity depicted GO had increased correction relative to GO in NF and F, however for SF decreased correction in TS-CL (-6° vs -17°, p=0.047), C2S (-9° vs -19°, p=0.108), and MGS (-12° vs -13.5°, p=0.2). When assessing the cohort as a whole, improvement in Ames modifiers had correlation with development of DJK, DJF, good outcomes, but not reoperation. GO rates decreased as frailty increased. Cohort with good outcomes had mean baseline TSCL of 40.7 degrees ± 19.2 with correction by 16.1 ± 18.4 degrees. Frail cohort with good outcomes had mean baseline TSCL of 39.6 degrees ± 17.4 with correction by 7.2 ± 18.6 degrees.

Conclusion: Consideration of chronological age, in addition to physiological age, may be beneficial in management of operative goals to maximize clinical outcomes while minimizing

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junctional failure. This combination enables the spine surgeon to fortify a surgical plan for even the most challenging patients undergoing adult cervical deformity corrective surgery.

PAPER 15

Preoperative Optimization of Modifiable Patient-Related Factors Reduces the Risk of Distal Junctional Kyphosis (DJK): A Virtual Analysis of a Novel Multicenter Complex Adult Cervical Deformity Database

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Introduction: Potentially modifiable patient-related factors may play a significant role in predicting post-operative complications. However, such effects have not been well studied in complex adult cervical deformity (ACD) surgery, especially in the context of distal junctional kyphosis (DJK).

Materials and Methods: Complex ACD patients with baseline (BL) data were included, excluding those indicated for index DJK revision. Virtual risk of DJK was assessed based upon Passias et al. baseline-only factors: 1) prior diagnosis of diabetes, hypertension, or depression 2) presence of baseline neurological impairment 3) Baseline C2-T3 angle >31°). Pre-operative laboratory and comorbidity data correlating to a virtual risk was developed via backstep logistic regression. Conditional Inference Tree (CIT) determined thresholds for significant factors. A count score based on number of optimized variables was then created (Opt Count), with CIT determining threshold associated with DJK risk. Means comparison analysis assessed groups differences in BL patient-reported outcomes and frailty indices [Edmonton, Adult Cervical Frailty Index (ACFI)] in patients considered Optimized (Opt) vs not optimized (nOpt).

Results: 52 ACD patients were included (mean age: 60.4±15.4, sex: 68.8% female, BMI: 27.5±5.8, CCI: 0.95± 1.4). Based upon Passias et al. criteria, 30.8% of patients were predicted to suffer DJK by 2Y post-operatively. Logistic regression revealed significant modifiable

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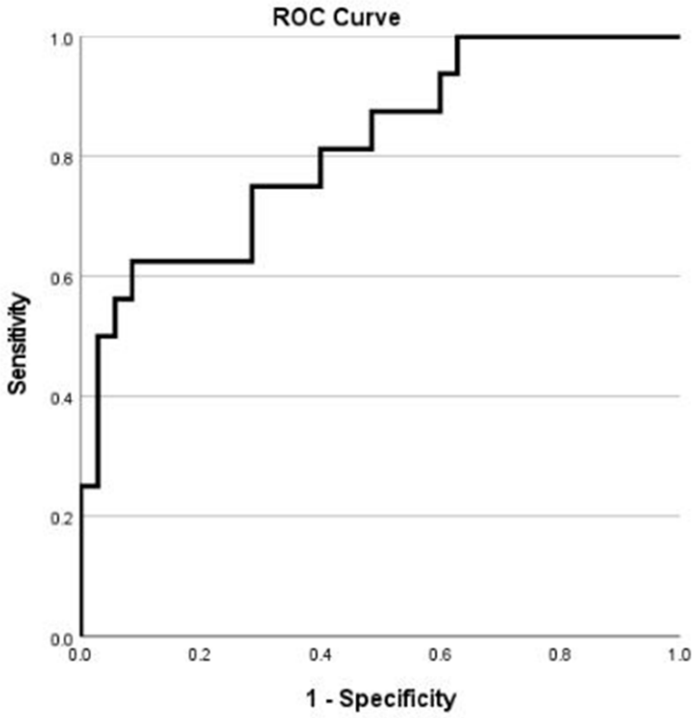
demographic, nutritional and metabolic factors predictive of DJK were: BMI <18.5 or >30, total spine DEXA T-score < 1.1, HgA1C > 7.0%, ESR > 15.7, INR > 0.9, Albumin > 4.2, Hematocrit > 41.7 (model p=.010). After calculation of Opt Count, CIT analysis revealed that optimization of a minimum of 3 variables was associated was protective against development of DJK [.727 (.591-.895), p=.003]. Of the total cohort, 73.1% were therefore considered Opt. Baseline analysis of demographic factors revealed that Opt patients were comparable in age, gender, prior history of spine surgery, nor indication for surgery (all p>.05). However, Opt patients with history of thoracolumbar surgery were more likely to have a significantly higher UIV (mean: T4) compare to nOpt patients (p=.036). In terms of HRQLs, though comparable in NDI, PROMIS, VR12, EAT-10, and NRS (all p>.05). Radiographically, Opt and nOpt patients did not differ in global deformity per C7-S1 SVA (p>.05), though nOpt patients did present with significantly greater C2-7 lordosis than Opt patients in standing static imaging (p=.031).

Conclusion: Through virtual risk analysis, the present study demonstrates that empiric and potentially modifiable metabolic and nutritional factors, as well as pre-operative bone health, are significantly associated with predicted risk of distal junctional kyphosis by 2Y. As such, surgeons should consider reduction of >3 risk factors pre-operatively to expedite recovery, enhance peri-operative course, and reduce complications in complex adult cervical deformity patients.



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Area Under the Curve

Test Result Variable(s): Predicted probability

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.816	.065	.000	.689	.943

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

PAPER 16

Radiographic Parameter Analysis of Positive Sagittal Decompensation After Long-level Posterior Cervical Fusion

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Introduction: After introduction of spinopelvic parameters in the thoracolumbar spine, studies have reported several concepts about cervical sagittal imbalance and highlighted the importance of T1S–CL and PI–LL mismatch in sagittal imbalance of the thoracolumbar spine. However, research on positive sagittal decompensation after cervical fusion is lacking, particularly studies with long-term follow-up. We therefore analyzed and compared the preoperative, postoperative, and final follow-up radiographic parameters of the cervical spines of patients who underwent long-level cervical posterior fusion with positive sagittal decompensation and associated risk factors.

Materials and Methods: From 2006 to 2020, 81 patients who underwent posterior cervical long-level fusion for spondylotic myelopathy, radiculopathy, cervical stenosis by ossification of the posterior longitudinal ligament, degenerative disc disorder, and deformities were evaluated. Patients who were followed up for less than 2 years were excluded. Group 1 comprised 51 patients with positive sagittal decompensation after long-level posterior cervical fusion, while group 2 comprised 30 patients without positive sagittal decompensation. All radiographic parameters were obtained in neutral standing whole spine lateral view, and compared at preoperative, postoperative, and final follow-up. Evaluated parameters included: C2–C7 lordosis, C2–C7 sagittal vertical axis (SVA), T1 slope, and T1S–CL (Figure 1).

Results: Preoperative C2–C7 lordosis was significantly higher in Group 1 compared with Group 2 (10.44±10.88 vs. 4.75±12.89, P=0.042) (Table 1), while postoperative C2–C7 SVA was significantly higher in Group 2 (26.19±12.81 vs. 32.95±13.25, P=0.030). At final follow-up, T1S and T1S–CL were higher in Group 1 (31.72±8.64 vs. 26.86±10.91, P=0.033; 23.04±11.37 vs. 17.07±9.95, P=0.023, respectively). C2–C7 SVA was also higher in Group 1 at final follow-up (34.78±14.12 vs. 25.60 ± 11.85, P=0.005). $\Delta T1S_{Post-Pre}$ was negative on average in Group 1, whereas $\Delta T1S_{Post-Pre}$ was positive on average in Group 2 (-1.34±8.31 vs. 3.50±9.61, respectively; P=0.022). T1S at final follow-up in Group 1 was higher than in the postoperative state (postoperative: 28.28 ± 7.81, final follow-up: 31.72±8.64, P=0.000) and T1S–CL was also higher at final follow-up in Group 1 (postoperative: 18.82±10.70, final follow-up: 23.04±11.37, P=0.004) (Table 2). In contrast, T1S and T1S–CL at final follow-up were lower than in the postoperative state in Group 2 (T1S postoperative: 29.86±10.28, final follow-up: 26.86±10.91, P=0.047) (T1S–CL: postoperative: 21.43±13.50, final follow-up: 17.07±9.95, P=0.023). Linear regression analysis was performed to evaluate Δ C2–C7 $SVA_{F/U-Post}$ and preoperative C2–C7 lordosis, and a positive relationship was observed (modified $R^2 = 0.264$).

Conclusion: Positive sagittal decompensation after long-level posterior cervical fusion is associated with high preoperative C2–C7 lordosis. Patients with positive decompensation had higher T1S at final follow-up than in the postoperative state, and tended to have increased T1S–CL mismatch. Group 1 had increased T1S on average , whereas Group 2 had decreased T1S before and after the operation . Patients with decreased T1S after the operation tended to

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have increased T1S and a higher risk of positive sagittal imbalance. To prevent positive sagittal decompensation after long-level posterior cervical fusion, surgeons should be cautious of decreasing T1S after the operation and high preoperative C2–C7 lordosis.

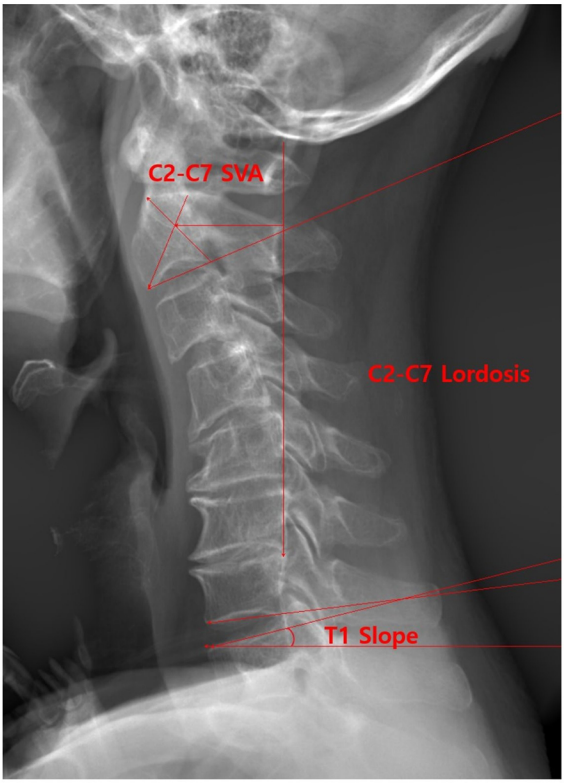

Fig 1. Measured cervical radiographic parameters, including C2–C7 lordosis, the T1 slope, and the C2–C7 sagittal vertical axis (C2–C7 SVA).

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Table a. Comparison of radiographic parameters between Groups 1 and 2. Group 1 was defined as the positive sagittal decompensation group, with ΔC2-7SVA$_{F/U\text{-}Post}$ >0 whereas the ΔC2-7SVA$_{F/U\text{-}Post}$ of Group 2 was negative.

Variables	Group 1 (ΔC2-7SVA$_{F/U\text{-}Post}$ >0, N=51)	Group 2 (ΔC2-7SVA$_{F/U\text{-}Post}$ <0, N=30)	P-value
Preoperative radiographic parameters			
T1S$_{Pre}$	29.62±9.40	26.36±7.28	0.116
CL$_{Pre}$	10.44±10.88	4.75±12.89	0.042
T1S-CL$_{Pre}$	19.18±11.18	21.61±10.74	0.354
C2-7 SVA$_{Pre}$	24.42±12.90	22.52±8.64	0.441
Postoperative radiographic parameters			
T1S$_{Post}$	28.28±7.81	29.86±10.28	0.449
CL$_{Post}$	9.46±9.91	8.43±11.44	0.678
T1S-CL$_{Post}$	18.82±10.71	21.43±13.50	0.351
C2-7 SVA$_{Post}$	26.19±12.81	32.95±13.25	0.030
Final follow-up radiographic parameters			
T1S$_{F/U}$	31.72±8.64	26.86±10.91	0.033
CL$_{F/U}$	8.68±10.02	9.79±13.81	0.685
T1S-CL$_{F/U}$	23.04±11.37	17.07±9.95	0.023
C2-7 SVA$_{F/U}$	34.78±14.12	25.60±11.85	0.005
Change value of radiographic parameters			
ΔT1S$_{Post\text{-}Pre}$	-1.34±8.31	3.50±9.61	0.022
ΔCL$_{Post\text{-}Pre}$	-0.98±13.07	3.68±16.43	0.173
ΔT1S-CL$_{Post\text{-}Pre}$	-0.36±10.99	-0.18±14.79	0.951
ΔC2-7SVA$_{Post\text{-}Pre}$	1.77±9.82	10.43±10.28	0.000
ΔT1S$_{F/U\text{-}Post}$	3.44±5.07	-3.00±7.62	0.000
ΔCL$_{F/U\text{-}Post}$	-0.78±8.51	1.36±6.09	0.246
ΔT1S-CL$_{F/U\text{-}Post}$	4..22±9.81	-4.36±9.60	0.000
ΔC2-7SVA$_{F/U\text{-}Post}$	8.59±7.58	-7.35±6.70	0.000
ΔT1S$_{F/U\text{-}Pre}$	2.10±8.33	0.50±10.20	0.456
ΔCL$_{F/U\text{-}Pre}$	-1.76±11.85	5.04±17.01	0.042
ΔT1S-CL$_{F/U\text{-}Pre}$	3.86±10.01	-4.54±14.33	0.003
ΔC2-7SVA$_{F/U\text{-}Pre}$	10.36±10.98	3.08±9.99	0.005

T1S = T1 slope, CL = C2–C7 lordosis, T1S–CL = T1 slope minus C2–C7 lordosis.

Pre = preoperative data; post = postoperative data; F/U = final follow-up data.

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Table b. Comparison of radiographic parameters between two periods in the same group.

Pre = preoperative data, Post = postoperative data, F/U = final follow-up data.

Variables	Group 1 (ΔC2-7SVA$_{F/U-Post}$ >0, N=51)			Group 2 (ΔC2-7SVA$_{F/U-Post}$ <0, N=30)		
Preoperative period and postoperative period						
	Pre	Post	P-value	Pre	Post	P-value
T1S	29.62±9.39	28.28±7.81	0.260	26.36±7.28	29.86±10.28	0.065
CL	10.44±10.88	9.46±9.91	0.598	4.75±12.89	8.43±11.45	0.246
C2–7 SVA	24.42±12.90	26.19±12.81	0.208	22.52±8.64	32.95±13.25	0.000
T1S–CL	19.18±11.18	18.82±10.71	0.818	21.61±10.74	21.43±13.50	0.950
Preoperative period and final follow-up period						
	Pre	F/U	P-value	Pre	F/U	P-value
T1S	29.62±9.40	31.72±8.64	0.081	26.36±7.28	26.86±10.91	0.797
CL	10.44±10.88	8.68±10.02	0.299	4.75±12.89	9.79±13.81	0.129
C2–7 SVA	24.42±12.90	34.78±14.12	0.000	22.52±8.64	25.60±11.85	0.114
T1S–CL	19.18±11.18	23.04±11.37	0.009	21.61±10.74	17.07±9.95	0.106
Postoperative period and final follow-up period						
	Post	F/U	P-value	Post	F/U	P-value
T1S	28.28±7.81	31.72±8.64	0.000	29.86±10.28	26.86±10.91	0.047
CL	9.46±9.91	8.68±10.01	0.520	8.43±11.45	9.79±13.81	0.248
C2–7 SVA	26.19±12.81	34.78±14.12	0.000	32.95±13.25	25.60±11.85	0.000
T1S–CL	18.82±10.70	23.04±11.37	0.004	21.43±13.50	17.07±9.95	0.023

PAPER 17

Identifying Intra-operative C2 Slope Thresholds for Optimal Functional and Clinical Outcomes in Cervical Deformity Correction

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Introduction: It has not yet been determined whether intraoperative or immediate post-operative C2 slope and the magnitude of change from baseline correlate with postoperative health-related quality of life (HRQL) metrics and radiographic complications.

Materials and Methods: Included: operative CD patients with pre-(BL) and 2-year(2Y) data. Paired means comparison analysis and linear regression analysis assessed the impact of absolute intraoperative/immediate postoperative (intra-op) radiographic measures or BL-normalized changes in radiographic measures on post-op outcomes. Univariate and multivariate (MVA) regression and conditional inference tree (CIT) determine radiographic thresholds. Optimal outcome defined as: 1) 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 2) for developing DJK or DJF by 2Y.

Results: 178 CD patients met inclusion criteria (61.2±10.5yrs, 63%F, BMI 29.0±7.5kg/m^2, CCI: 1.00±1.31) and underwent surgery (mean 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: C2S: 31.18° C2-C7 lordosis 0.91°, T1S 29.03°, TS-CL 25.81°, cSVA 27.07mm. Between BL and intra-op, paired analysis revealed significant mean decrease in C2S (Δ-9.30°) and TS-CL (Δ-12.03°), as well as mean increase in CL (Δ+14.06°) (all p<.001). Between 1Y and 2Y, however, there was notable decrease in C2S (Δ-3.01°, p=.001), T1S (Δ-3.15°, p=.001), CL (Δ-7.18°, p=.015), and TS-CL (Δ-3.99°, p=.001). Between BL and intra-op, absolute reduction in C2S of >13.70° (43.94%) was associated with a decrease in DJF risk (p=.041). Lastly, patients who had improvement in cSVA at 6M were significantly more likely to achieve optimal outcome by 2Y (p=.013).

Conclusion: This study demonstrates that intra-operative reduction in C2 slope of 44% or more from baseline BL is significantly associated with reduced risk of distal junctional failure at 2Y, though other post-operative radiographic parameters also play a crucial role in predicting catastrophic outcomes and should be assessed in tandem.

PAPER 18

Influence of Upper Cervical Malalignment and Negative Sagittal Imbalance on Clinical Outcomes in Patients with Craniovertebral Junction Kyphosis

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Introduction: Many studies have shown the relationship between the positive sagittal imbalance of the subaxial cervical spine, and clinical scores in the literature. However, the effect of negative sagittal imbalance and malalignment on the clinical outcome has not been studied in patients with craniovertebral junction (CVJ) kyphosis.

This study aims to identify the possible prognostic factors for the craniocervical realignment procedure for CVJ kyphosis combined with negative sagittal imbalance, to determine the critical value of radiological parameters for predicting good surgical outcome.

Materials and Methods: This retrospective study underwent a craniocervical realignment procedure in patients with CVJ kyphosis and negative sagittal imbalance between January 2014 and March 2022.

The inclusion criteria were as follows:

1. C0-C2 angle less than 0 degree
2. The C2-C7 sagittal vertical axis (SVA) is less than 0mm.
3. Minimum of one-year follow-up after surgery

The C0-C2 angle, C0-2 ROM, C2-C7 angle, C2-7 ROM, the C7 sagittal vertical axis, C2-7 SVA, C2-slope, C7-slope, thoracic kyphosis (TK), pelvic incidence (PI), and lumbar lordosis (LL) were measured before and after surgery.

The Japanese Orthopaedic Association (JOA) score was used to determine the neurological outcome. Axial symptom severity was quantified by Neck Disability Index (NDI).

Patients were divided into two groups according to their neurological recovery rate (RR). Patients with JOA RR of >50% and <50% were designated as having good and poor outcomes, respectively.

We also divided patients into two groups based on the improvement of NDI; good (postoperative NDI < 10) and poor (postoperative NDI > 10).

The relationship between prognostic factors and clinical outcomes was assessed.

Results: Twenty-five patients with CVJ kyphosis and negative imbalance were enrolled (M/F=13/12, Age = 56.8 ± 17.8 years).

The patient age, gender, radiological and clinical parameters were similar between the two groups, respectively. Follow-up data analysis showed significant differences ($P < 0.001$) in the C02 angle, C27 angle, C2 slope, and C27 SVA, whereas no significant differences in C7 SVA, TK, LL, and PI.

The good NDI group significantly increased C0-C2 ($p = 0.042$) and C2-C7 SVA ($p=0.000$). NDI improvement significantly correlated with the correction of CVJ Kyphosis (ΔC0-C2 angle,

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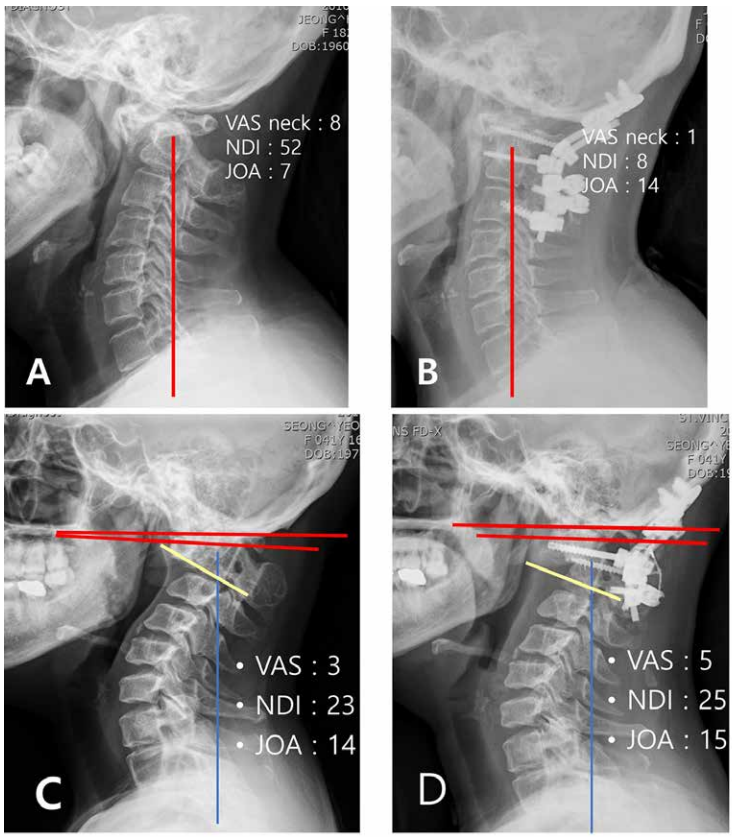
p=0.002) & negative imbalance (ΔC2-7 SVA, p=0.003).

The C02 angle change (12.7 vs. 7.5, p=0.042) and the C27 SVA change (18.8 vs. 5.1, p=0.000) had significant differences between the two JOA RR groups. JOA RR significantly correlated with the correction of negative sagittal imbalance (ΔC2-7 SVA, p=0.001) after surgery.

Multivariate regression analysis showed that C02 angle change was independently associated with NDI improvement (p<0.01). C0-2 angle change significantly correlated with the correction of negative sagittal imbalance (ΔC2-7 SVA, p=0.037) after surgery.

Conclusion: Craniocervical realignment surgery improved the neurological function and quality of life of patients with CVJ kyphosis. The most critical radiological parameter for predicting good outcomes is the postoperative improvement of the C02 angle and C27 SVA. The C02 angle is the most significant independent parameter to predict the improvement of axial neck pain.

Our findings suggest that it is essential for clinical recovery to restore CVJ alignment and sagittal balance in CVJ kyphosis patients.



PAPER 19

Evolution of Osteotomy Techniques over Time in Adult Cervical Deformity Surgery: Impact of New Technologies and Techniques on Patient Outcomes

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Introduction: The field of corrective spine surgery, specifically **c**ervical deformity (CD), is ever-evolving. Although new technologies and methods of measuring malalignment contribute to increase in surgical corrective procedures, the impact on postoperative impact remains unclear. The goal of this study was to examine whether surgical advancements over the years have changed outcomes and the overall way we approach CD surgery.

Materials and Methods: CD patients (≥18 yrs) with complete BL and 2Y HRQL data were included. Descriptive analysis included demographics, radiographic, and surgical details. Patients were stratified into 3 groups based on Ames ISSG Osteotomy Classification System: Grade 1 and 2 classified as Low Grade Osteotomies (LGO); Grades 3 through 5 considered Mid Grade Osteotomies (MGO); Grade 6 and 7, considered major osteotomies by Ames et al, were classified as High Grade Osteotomies (HGO). For any combination procedure where two different grades of osteotomies were done, the highest grade was taken for classification into our stratification system. Patient outcomes were measured by surgical complication rates, HRQL score difference across 2 years, and postoperative length of stay. ANCOVA and multivariable logistic regression analyses were used to evaluate the clinical, radiographic, and complications outcomes between the three cohorts.

Results: 136 CD patients met inclusion (57.1±9.5yrs, 60%F, BMI 28.6±6.7kg/m2, CCI: .58±1.0). 22 patients (16.2%) received MGO, while 9 patients (6.6%) had HGO and 74 patients (54.4%) received LGO. At baseline, graded osteotomies showed no statistically significant differences in age, Charlson Comorbidity Index, degree of deformity or radiographic parameters. Surgically, osteotomies had comparable levels fused, estimated blood loss, operative time, and surgical approach. Overall complication rate was the lowest for patients undergoing HGO compared to LGO and MGO, with the greatest being for LGO (22% vs 11% vs 0%, p = .16). 2 year difference in HRQL mJOA was highest for HGO as compared to LGO and MGO, with only HGO experiencing a negative difference (.29 vs .63 vs -1, p = .55). However, EQ5D difference over the same years showed significant rates of changes in LGO compared to MGO and HGO (-.61 vs .14 vs -.11, p<.001). LGO had the greatest degree of improvement in 1 year difference in ODI, followed by HGO, compared to the other two groups (-13.6 vs -8.5 vs -10.4, p= .2), indicating short term improvement with lower invasive surgeries despite no significant long term benefit compared to surgery with greater complexity. The longest length of stay postoperatively was seen by HGO (4.4 vs 3 vs 10.25, p <.001), indicating increasingly invasive surgery requires greater postoperative recovery by patients.

Conclusion: Overtime, patients undergoing cervical deformity surgery received less high-grade osteotomies, even with high grade deformities. Despite operating on a cohort with a greater degree of comorbidity, there was no deterioration in clinical and radiographic

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outcomes with more complex surgeries. Compared to lower invasive techniques, high grade osteotomies maintained patient outcomes in longer term follow-up. These findings reflect an improved understanding of surgical management and utility of invasive osteotomies in adult cervical deformity.

PAPER 20

Longer Screws Decrease the Risk of Radiographic Pseudarthrosis Following Elective Anterior Cervical Discectomy and Fusion

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Introduction: The importance of screw length in elective anterior cervical discectomy and fusion (ACDF) is understudied. In a cohort of patients undergoing elective, primary ACDF, we sought to determine the impact of screw length on: 1) radiographic pseudarthrosis, 2) pseudarthrosis requiring reoperation, and 3) patient-reported outcome measures (PROMs).

Materials and Methods: A single-institution, retrospective cohort study was undertaken for patients undergoing ACDF for degenerative disease from 2010-2021 among 12 surgeons. The primary independent variables were: screw length (mm), screw length divided by the anterior-posterior vertebral body diameter (VB%), and the presence of any screw with VB%<75% versus all screws with VB%≥75%. The primary outcome was pseudarthrosis, defined as interspinous motion>1mm on flexion-extension x-ray or a lack of intra/extra-graft bridging bone on imaging. PROMs included Numeric Rating Scale-Arm/Neck and Neck Disability Index. Minimal clinically important difference (MCID) of PROMs was set at 30% improvement at 1-year postoperatively. Univariate and multivariable logistic regression controlled for age, BMI, gender, smoking, American Society of Anesthesiology grade (ASA) grade, number of levels fused, and whether a corpectomy was performed.

Results: A total of 406 patients underwent elective ACDF with available imaging at 1-year. The mean age was 52.3±10.7years, 196 (48.3%) were males, and levels fused were: 1-level (39.4%), 2-level (42.9%), 3-level (16.7%), and 4-level (1.0%). Mean screw length was 14.3±2.3mm, and mean VB% was 74.4±11.2. Of 406 patients, 293 (72.1%) had at least one screw with VB%<75% and 113 (27.8%) had all screws with VB%≥75%. A total of 141 (34.7%) patients had radiographic pseudarthrosis at 1-year postoperatively diagnosed by the following imaging modalities: flexion-extension x-ray (56.4%), CT scan (3.4%), MRI (3.2%), and static x-ray (36.9%). Patients who had any screw with VB%<75% had a higher rate of radiographic pseudarthrosis compared to those had all screws with VB%≥75% (39.6% vs. 22.1%, p<0.001). Moreover, patients who had all screws with VB%<75% had a higher rate of radiographic pseudarthrosis compared to those who had any screw with VB%≥75% (44.1% vs. 29.1%, p=0.002). Multivariable logistic regression revealed that a higher VB% (OR=0.97, 95%CI=0.95-0.99, p=0.035) and having all screws with VB%≥75% (OR=0.51, 95%CI=0.27-0.95, p=0.037) significantly decreased the odds of radiographic pseudarthrosis at 1-year. However, although pseudarthrosis requiring reoperation was higher in patients with VB%<75% (4.1% vs. 2.7%, p=0.769), statistical significance was not attained. Similarly, no significant difference was found in PROMs (all p>0.05).

Conclusion: In a cohort of patients undergoing elective, primary ACDF, longer screws taking up ≥75% of the vertebral body protected against radiographic pseudarthrosis at 1-year, yet no difference was found in pseudarthrosis requiring reoperation. Maximizing screw length in elective ACDF is an easily modifiable factor directly under the surgeon's control that may mitigate the risk of pseudarthrosis.

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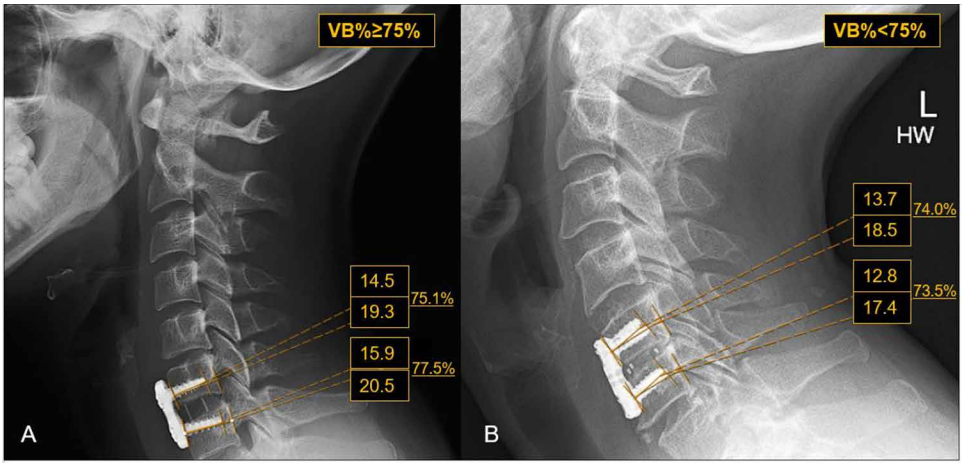

PAPER 21

Is Routine Use of External Spinal Orthoses Necessary After Operative Stabilization of Cervical Spine Injuries?

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University of Texas[1]

Introduction: There is no consensus in the literature regarding the use of post-operative cervical spine orthoses in spine trauma patients. While cervical orthoses are generally well tolerated, it is not clear that post-operative bracing is effective at reducing the rate of fixation failure or non-union in this patient population[1–4]. Furthermore, the use of spine orthoses adds expense, may delay or prohibit rehabilitation, increases risk of dysphagia and aspiration, and can contribute to skin and wound breakdown[5–10]. The purpose of this study is to evaluate the efficacy of post-operative cervical orthoses to prevent fixation failure and loss of reduction after operative treatment of unstable cervical spine injuries.

Materials and Methods: All patients that underwent surgical stabilization involving anterior cervical discectomy and fusion (ACDF) and posterior spinal instrumented fusion (PSIF) for cervical spine injuries at a single institution between January 2015 and August 2019 were identified through the institutional Research Electronic Data Capture (REDcap) database[11,12]. Patient data including cervical spine injury, surgery, post-operative orthosis use, and secondary surgeries for loss of reduction were recorded for all patients meeting the inclusion criteria. The primary outcome was loss of reduction or failure of fixation requiring revision surgery. Statistical analysis was performed using Jamovi (Version 1.1) statistical software[13].

Results: 201 patients meeting inclusion and exclusion criteria were identified within the study period. 133 (66.2%) patients were treated with a cervical orthosis post-operatively and 68(33.8%) patients were allowed to mobilize as tolerated without a cervical orthosis. 99 (49.3%) patients were treated with anterior cervical discectomy and fusion, 72 (35.8%) were treated with posterior spinal instrumentation and fusion, and 30 (14.9%) underwent both anterior and posterior instrumented fusion at the index surgery. Fixation failure and loss of reduction occurred in four (1.99%) patients. Of these four, three patients were treated with a cervical orthosis post-operatively. There was no significant difference in risk of instrumentation failure between patients in the post-operative orthosis and no orthosis groups (p=0.706). There was no significant difference in loss of reduction and fixation failure between patients that underwent ACDF, PSIF, or both (p=0.136). Subgroup analysis of surgical approach demonstrated no significant difference in risk of failure of fixation between post-op orthosis and no orthosis groups. Additionally, the number of vertebral levels instrumented did not correlate with fixation failure (p=.328).

Conclusion: The use of cervical orthoses after operative stabilization of cervical spine injuries remains controversial. There was no statistically significant difference in hardware failure or loss of fixation/reduction between patients treated in cervical orthoses post-operatively and those that were not. Given the challenges to self-care and rehabilitation as well as the risks and added cost with the use of post-operative cervical orthoses, surgeons should be judicious in their indications for post-operative bracing.

PAPER 22

The Effect of Mean Arterial Pressure (MAP) Augmentation on Intra-parenchymal Hemorrhage Progression in Cervical Spinal Cord Injury (SCI)

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Introduction: Current practice guidelines for clinicians working with people with traumatic spinal cord injuries (t***SCI***) recommend augmenting mean arterial blood pressure (MAP) at 85–90mm Hg for the first 7 days post-injury in acute SCI patients. In an attempt to maintain perfusion to the injured and ischemic spinal cord. MAP augmentation with vasopressors may improve blood flow and reduce ischemia in the injured cord. However, it may also induce undesirable increases in hemorrhage within the injured spinal cord. Intraparenchymal hemorrhage (IPH) may be deleterious by causing direct compression of adjacent tissue and generating regions of hypoperfusion with worsened ischemia. Furthermore, blood and its breakdown products can damage neural tissue. Understanding how MAP augmentation affects IPH is important for optimizing the hemodynamic management of SCI. Therefore, in the present MRI-based clinical study, we aimed to determine whether IPH within the injured spinal cord is influenced by mean arterial pressure (MAP) augmentation with vasopressors in the first two weeks following tSCI.

Materials and Methods: This study is performed with approvals of the *Clinical Research Ethics Board* (CREB) and institutional review board (IRB) of the Vancouver General Hospital, Vancouver, Canada (ClinicalTrials.gov Identifier: NCT04758377). Informed consent was obtained from each patient. Per institutional protocol, target MAP was set at 85-90 mmHg using intravenous norepinephrine, vasopressin and midodrine infusion as required. MRI data were collected at baseline (within 24 hours after tSCI) and at 2, 4, 7 and 14 days post-tSCI, acquired on a 1.5T MRI scanner. Axial and sagittal T2WI sequences were evaluated to determine the extent of IPH, defined as a hypointense area with a surrounding hyperintense rim (Fig.1). IPH progression (delta hemorrhage) was calculated between the first MRI scan and the subsequent MRI scan on Day 2, then from day 2 to day 4, from day 4 to day 7, and finally from day 7 to day 14 post-SCI. Using simple linear regression and linear mixed effect models, we evaluated the associations between IPH progression and both time-weighted average MAP (TWA-MAP) and measures of MAP.

Results: To date, we have obtained data from 7 cervical tSCI patients. At the baseline time point, all patients demonstrated IPH. On days 2 and 4, the extent of IPH progressed, followed by a reduction in the area on days 7 and 14. During the first 48 hours after injury, TWA-MAP

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significantly correlated with delta IPH (p=<0.0001; Fig.2). Subsequent analysis revealed a threshold-driving association. In starting at a MAP of 85 mmHg and increasing the binary cut-off by 5 mmHg increments, TWA-MAP became a predictor of IPH progression in the first 2 days after SCI at a MAP upper threshold >90 mmHg (p=0.035; Fig. 3).

Conclusion: These results represent an important finding that with efforts to improve blood flow and reduce ischemia in the injured cord by augmenting MAP via vasopressors, clinicians may inadvertently promote undesirable bleeding within the spinal cord, thereby increasing the size of IP hemorrhage at the injury site.

Fig.1

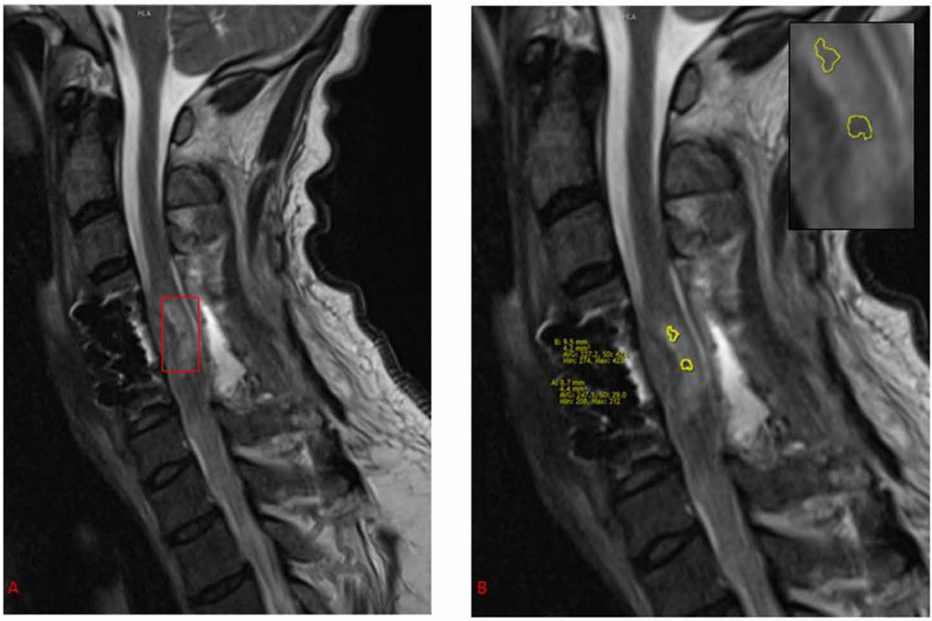

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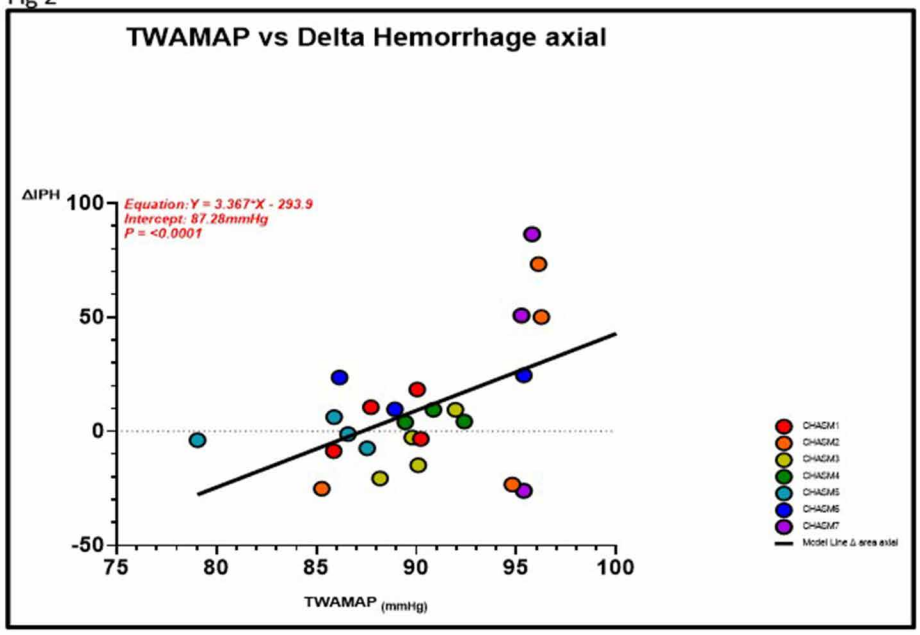
Fig 2



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.

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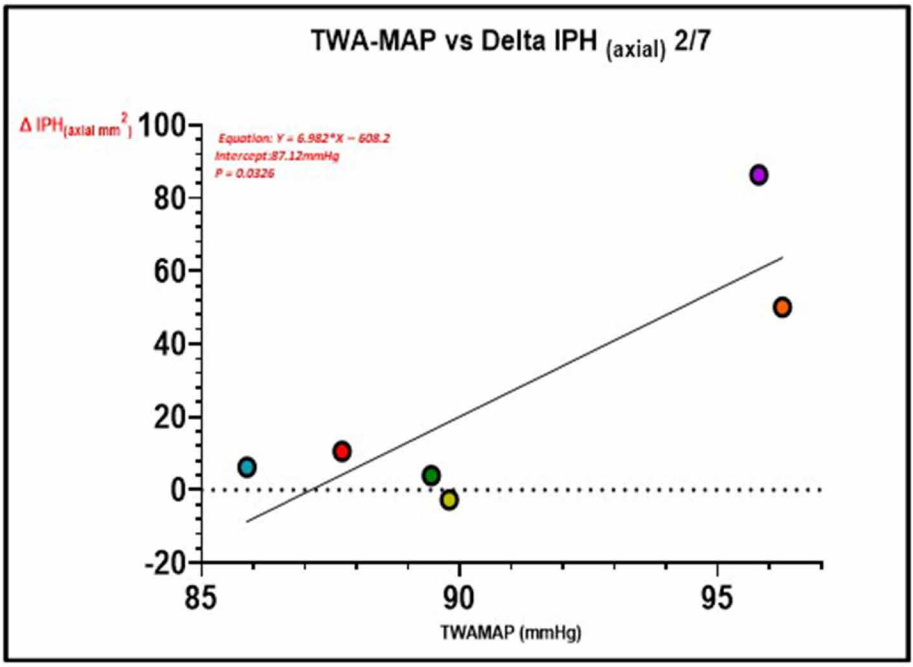
Fig 3



PAPER 23

The Effect of Early Surgical Decompression on Segmental Neurological Recovery in Acute Traumatic Spinal Cord Injury: A Pooled Analysis of Individual Participant Data from Prospective, Multicenter Trials

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Introduction: Burgeoning evidence shows the association of early (<24 hours after spinal injury) surgical decompression after acute traumatic spinal cord injury (SCI) and improved neurological outcomes. However, the impact of early surgery on recovery of injured spinal cord levels is unclear. In the current absence of established minimum clinically important differences of sensorimotor scores, recovery of even one sensorimotor-intact neurological level may mean the difference of regaining ability to perform activities of daily living.

Materials and Methods: Individual participant data from three independent, prospective, multicenter trials (NACTN, STASCIS, NASCIS III) from December 1991 to March 2017 were analyzed. [MF1] All participants that underwent decompressive surgery for SCI were included. Participants were stratified into early (<24 hr after spinal injury) and late (≥24 hr after spinal injury) decompression cohorts. Neurological outcomes were assessed using the ASIA or ISNCSCI examination. The primary endpoint was change in neurological level of injury from baseline to 1 yr after spinal trauma. Two-stage meta-analysis was performed using hierarchical mixed-effects regression adjusting for age, sex, mechanism of injury, baseline ASIA grade, total motor score, pin prick score, light touch score, baseline neurological level of injury, Glasgow Coma Scale, and administration of methylprednisolone. Effect size was estimated with adjusted mean difference (MD), with corresponding 95% confidence intervals (CI) and Pvalues. Subgroup analysis was conducted in cervical SCI with the same methodology as primary analysis.

Results: A total of 1328 eligible subjects were identified from the datasets (77.3% cervical, 14.9% thoracic, 7.8% lumbar). Patients who underwent early surgical decompression (n=439, 40.3%) experienced greater recovery of injured spinal levels than those who underwent delayed surgical decompression (MD: 1.08 levels, 95% CI [0.06 to 2.10], p=0.037). In patients with cervical SCI (n=1026, 77.3%), the effect size was greater in patients that underwent early surgical decompression with a greater recovery of 1.25 levels than those with delayed decompression (95% CI [0.04 to 2.46], p=0.043).

Conclusion: Surgical decompression within 24 hours of acute spinal cord injury is associated with improved recovery of neurological spinal levels. These data add further to the growing evidence in support of early surgical intervention in acute spinal cord injury, including ASIA A patients.

PAPER 24

Mortality Following Operative and Nonoperative Treatment of Odontoid Fracture Among Medicare Beneficiaries and the Influence of Dementia: A Matched Cohort Analysis

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University of Utah[1]

Introduction: Type-II odontoid fractures are common among elderly patients due to the increased fragility of the upper cervical spine coupled with the greater incidence of low energy trauma. These fractures increase morbidity and limit physiologic reserve, leading to greater mortality. Current literature suggests lower mortality rates following surgical fixation of odontoid fractures within this population. However, it is unclear whether this reduction in mortality is confounded by the selection of healthier patients for surgery. Dementia represents age-related cognitive impairment that crosses a threshold of deterioration greater than what would be expected for a patient's functional status. Pre-operative dementia has been shown to increase the complication profile following elective spine surgery. However, no previous studies have evaluated the association of dementia on outcomes following operative versus non-operative management of type-II odontoid fracture.

Materials and Methods: The number of days from fracture to date of death was derived by linking claims to the Master Beneficiary Summary File. Comorbidity, including dementia, was calculated with a 90-day lookback prior to Type II odontoid fracture. The Average Treatment Effect among operatively treated patients was reported in comparison to non-operatively treated patients using a 1:2 nearest-neighbor Mahalanobis matching by age, sex, race, and comorbidity. Robust logistic regressions were used to report the association of dementia on mortality, controlling for age, sex, race, and comorbidity.

Results: Unadjusted mortality was significantly lower among operative patients compared to non-operative patients: 10.8% vs. 19.0% within 90 days, 17.9% vs. 30.9% at 1 year, 25.9 vs. 41.7 at 2 years, and 35.5% vs. 50.3% at 3 years ($p<0.001$ at all time points). From the matched analysis, mortality remained significantly lower among operative patients with an average treatment effect of 5.9 percentage points lower than non-operative patients at 90 days (95%CI -7.5; -4.3), 8.5 percentage points lower at 1 year (95%CI -10.5; -6.4), 8.9 percentage points lower at 2 years (95%CI -11.7; -6.2), and 9.4 percentage points lower at 3 years (95%CI -13.6; -5.3). Dementia was strongly associated with mortality (OR 1.96; 95%CI 1.69 - 2.27; $p<0.001$).

Conclusion: While the risk of mortality is greater in patients with dementia, operatively treated Medicare beneficiaries with Type II odontoid fractures still have a lower mortality rate through four years compared to non-operative patients in a matched analysis.

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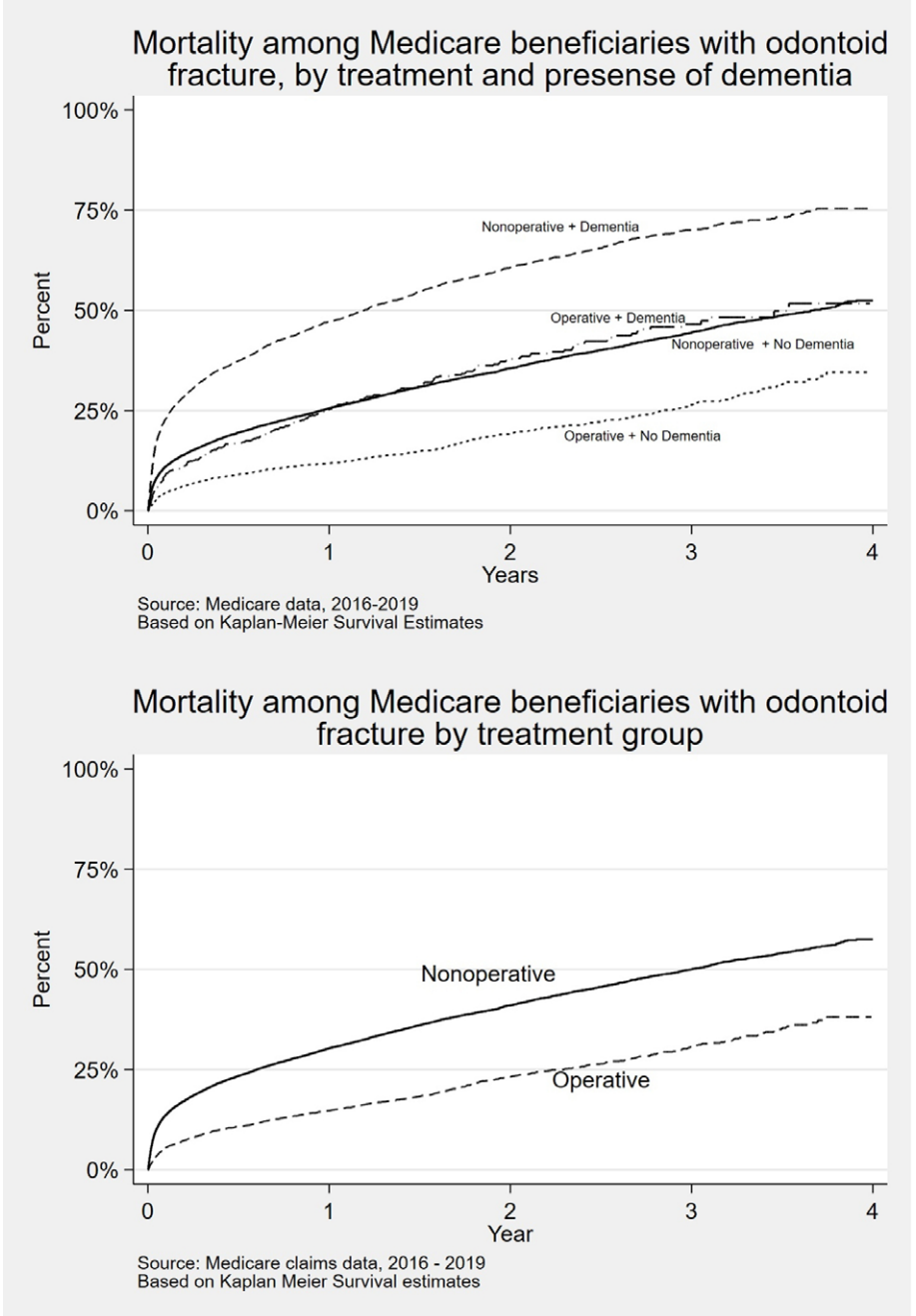

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

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Table 1: Demographic characteristics of operative and non-operative treatment of Medicare beneficiaries with odontoid fractures.

Characteristic		Nonoperatively treated (n = 18,979)	Operatively treated (n=3,166)	p-value
Age, mean (sd)		84.0 (8.2)	79.2 (7.2)	<0.001
Female, %		59.7	52.0	<0.001
Race, %	White	96.2	95.4	0.078
	Black	1.7	2.0	
	Other	2.1	2.6	
Charlson Comorbidity Index, %	None	26.6	23.0	<0.001
	1	22.8	23.1	
	2+	50.6	53.9	
Osteoporosis, %		9.4%	10.8%	0.016
Dementia, %		21.8%	22.3%	0.528
Cardiovascular disease, %		14.2%	14.5%	0.125

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Table 2: Mortality of operative and non-operative treatment of Medicare beneficiaries with odontoid fractures.

	Mortality
90 days	
Crude rate nonoperative, %	19.0
Crude rate operative, %	10.8
Operative vs. non-operative, ppt (95%CI) p-value	-5.9 (-7.5; -4.3) p<0.001
1 year	
Crude rate nonoperative, %	30.9
Crude rate operative, %	17.9
Operative vs. non-operative, ppt (95%CI) p-value	-8.5 (10.5; -6.4) p<0.001
2 years	
Crude rate nonoperative, %	41.7
Crude rate operative, %	25.9
Operative vs. non-operative, ppt (95%CI) p-value	-8.9 (-11.7; -6.2) p<0.001

ppt = percentage point difference.

Relative effect based on average treatment effect among the surgically treatment patients from propensity matched analysis of surgical cohort matched 1:2 to non-surgical cohort on age, sex, race, comorbidity, and dementia.

PAPER 25

Can Generative Artificial Intelligence Provide Accurate Medical Advice?: A Case of ChatGPT vs. Congress of Neurological Surgeons Management of Acute Cervical Spine and Spinal Cord Injuries Clinical Guideline

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Icahn School of Medicine at Mount Sinai[1]

Introduction: Artificial intelligence (AI) such as large language models have been successfully utilized in many sectors. However, their potential within the medical field remains largely unexplored. A notable exception is the study by Kung et al.showing ChatGPT's ability to score near or above passing for all of the USMLE Step Exams1, which includes Step 1, Step 2CK, and Step 3. As such, we investigated the feasibility of integrating ChatGPT beyond medical education and into clinical settings as a tool for patient care. Specifically, we explored ChatGPT's concordance with the published guidelines from The Congress of Neurological Surgeons (CNS) on the Management of Acute Cervical Spine and Spinal Cord Injuries2. The findings from this study may have significant and enduring consequences for how large language models are utilized in medical decision-making and patient care.

Materials and Methods: We developed a series of questions to address all subjects evaluated in the official guidelines on the Management of Acute Cervical Spine and Spinal Cord Injuries published by the CNS in 2013. These questions were stratified into a therapeutic, diagnostic, or clinical assessment category as defined by the guideline methodology. A total of 36 questions across 21 subjects were generated. We prompted ChatGPT-4 with each question and recorded its responses. These responses were scored as "concordant" or "not concordant" with the accepted CNS clinical guidelines. A literature review was performed for each subject to more accurately contextualize the answers provided by ChatGPT with additional evidence published since 2013.

Results: We judged 23 (63.89%) of ChatGPT's responses to be concordant with the CNS guidelines (Table 1). ChatGPT more frequently aligned with the guidelines when answering therapeutic and diagnostic questions, providing 16 (76.19%) and 6 (60%) answers, respectively, that aligned with guidelines. The model demonstrated an inferior performance on questions targeting clinical assessments, aligning with the guidelines on only 1 of the 5 questions posed. Of note, the recommendations deemed as being supported by the highest quality of evidence (Level I) by the CNS working group were the least likely to be replicated by ChatGPT (20%). Conversely, ChatGPT's responses agreed with 80% of the recommendations supported exclusively by lower quality Level II/III evidence such as case series and suboptimal randomized clinical trials.

Conclusion: When asked clinical questions relating to acute cervical spine and spinal cord injuries, ChatGPT-4 impressively generated answers that were similar to the standing clinical guidelines. This is notable, considering the model was not trained on a dedicated medical training set. It clearly understood the prompts provided and identified key search phrases upon which it developed its answers. ChatGPT-4 supersedes the previous ChatGPT-3.5 in that it has internet connectivity and can cite supporting sources, thus bolstering its evidence-based credibility. However, the extent to which it matched guideline recommendations varied greatly

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depending on the subject criteria of question and the supporting literature. Thus, while these results suggest ChatGPT may offer a promising clinical support tool, medical practitioners should scrupulously monitor its usage until further models can be rigorously trained on medical data.

Table 1: ChatGPT Response Concordance with Clinical Guidelines

	Concordant	Not Concordant
All Subjects, n (%)	23 (63.89%)	12 (36.11%)
Subjects Containing Level I Evidence, n (%)	2 (20%)	8 (80%)
Subjects Containing Only Level II/III Evidence, n (%)	21 (80.77%)	5 (19.23%)
Therapeutic Subjects, n (%)	16 (76.19%)	5 (23.81%)
Diagnostic Subjects, n (%)	6 (60%)	4 (33.33%)
Clinical Assessment Subjects, n (%)	1 (20%)	4 (80%)

PAPER 26

Ex Vivo Gene Therapy Using Human-induced Pluripotent Stem Cell-derived Neural Stem/Progenitor Cells to Deliver Synaptic Organizer CPTX for Spinal Cord Injury

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Keio University School of Medicine[1] Keio University School of Medicine[2]

Introduction: Although our laboratory has reported the efficacy of human-induced pluripotent stem cell-derived neural stem/progenitor cells (hiPS-NS/PCs) transplantation for spinal cord injury (SCI), functional recovery is not been fully achieved yet. Recent studies using chemogenetic stimulation on graft cells have shown that synaptic connections between the graft and host cells significantly influence lower limb movements. To enhance the result, we planned ex vivo gene therapy by inducing synapse organizer protein CPTX, which is an artificial synaptic organizer protein containing the domains of Cerebellin-1(Cbln1) and Pentraxin-1 (NP-1). It is known that CPTX binds to AMPAR receptors and promotes the formation of excitatory synapses.

The aim of this study is to examine whether ex vivo gene therapy using CPTX contributes to further improvement of lower limb function compared to conventional transplantation therapy.

Materials and Methods: We designed to express the CPTX protein under the CAG promoter and incorporated the gene into the Lentivirus. We verified the safe dose of virus and confirmed the expression of CPTX protein from hiPS-NS/PCs after virus administration in immunocytochemistry.

A contusive SCI was induced at the 10th thoracic vertebral level of the immunodeficient rat using IH impactor. Cell transplantation was performed 9 days after SCI. The lentivirus was transfected in hiPS-NS/PCs 5 days before transplantation. The follow-up period was set for 13 weeks after transplantation, during which we evaluated the motor function by the Basso, Beattie, and Bresnahan (BBB) score. Motor evoked potentials(MEP) and Allodynia assessment were performed at the endpoint.

Results: CPTX-expressing cells were identified in the transplantation cells, including various nerve cells such as neurons, oligodendrocytes, and astrocytes (**Fig.1**).

CPTX protein was secreted and localized around the graft cells, with no observed migration to the brain or blood. The neural cell differentiation of the transplanted cells and CPTX-expressing cells were similar. There was no increase in the immature makers Nestin and Ki-67-positive transplanted cells for the observed period.

Histological analysis presented an increase in synaptic-related proteins such as human synaptophysin and VGLUT2 in grafted cell-derived neurons in the CPTX group. Furthermore, synaptogenesis was found to be increased around the transplant site (**Fig.2**).

The CPTX group achieved higher BBB scores compared to the control group. Electrophysiological assessment using motor-evoked potential showed a significant increase in amplitude in the quadriceps muscle. They did not show significant differences compared to the control group in the evaluation of allodynia (Fig.3).

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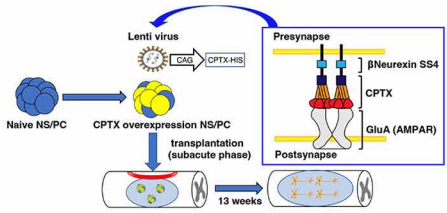
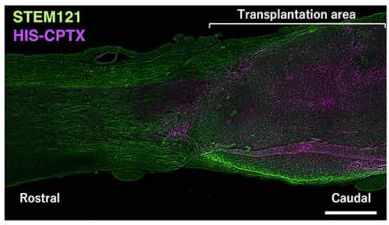
Conclusion: Expression of CPTX protein from hiPS-NS/PCs promoted synapse formation and maturation in the transplanted area, which reached the recovery of motor function and neuronal conduction. No adverse effects such as tumorigenesis or allodynia were observed. Thus, this gene therapy is expected to be a useful therapeutic strategy toward clinical applications, and combination therapy with interventions such as neurorehabilitation could potentially lead to further recovery of motor function.

Fig.1 The overexpression of CPTX in iPS-NS/PCs through ex vivo gene transduction



An overview of ex vivo gene therapy using lentivirus



Long-term secretion of CPTX from the transplantation center

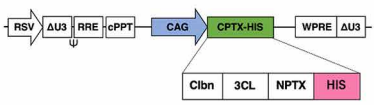
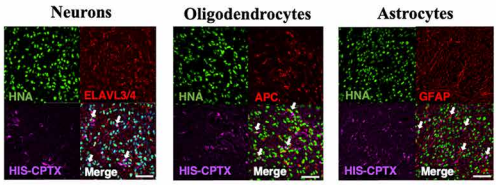
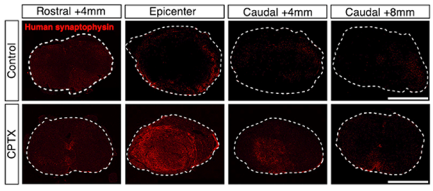


Illustration of the lentiviral vector CAG-CPTX-HIS

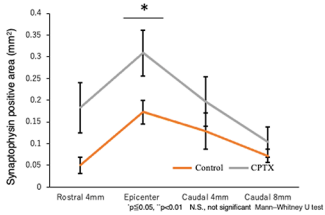


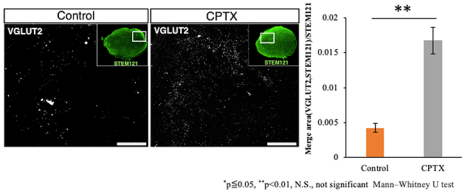
CPTX expression from various nerve cells

Fig.2 Enhancement of synaptic maturation and synaptogenesis at the transplantation site

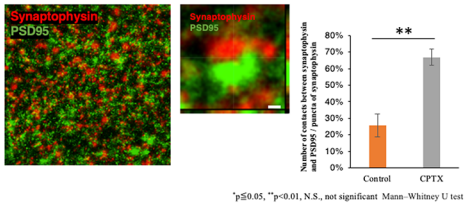


Synapse maturation of transplanted cell





Excitatory synaptic vesicle proteins at the transplanted cells



Synaptic formation surrounding the transplantation site

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.

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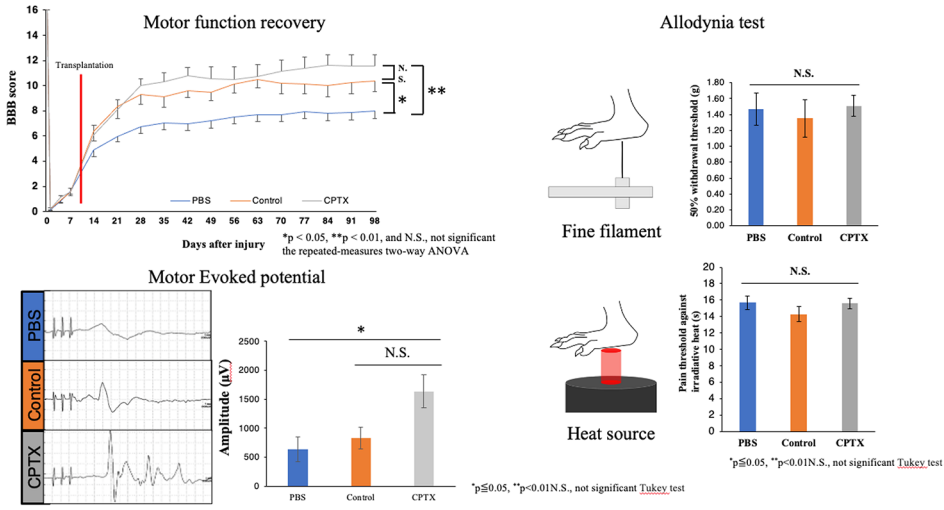
Fig.3 Assessment of motor and sensory function



PAPER 27

The Effects of Cervical Orthoses on Multiplanar Intervertebral Range of Motion

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University of Pittsburgh[1]

Introduction: Cervical orthoses are commonly used to restrict neck motion for treatment of injuries, for immobilization after surgical procedures, and for prevention of secondary injury in the trauma setting[1-3]. There is clinical equipoise between the poorly quantified immobility benefits of orthoses and the growing list of complications including the development of pressure ulcers, airway management difficulties, and increased venous congestion in brain injury. Previous studies evaluating the efficacy of cervical orthoses only measured global head motion and did not evaluate individual cervical motion segment mobility. Additionally, previous research focused only on the flexion/extension motion, while ignoring rotation and bending that occur during activities of daily living. The purpose of this study was to precisely quantify and compare the effectiveness of cervical orthoses on intervertebral kinematics of the cervical spine during active, dynamic, multi-planar motions in healthy adults.

Materials and Methods: Twenty healthy adults without neck pain were recruited. Head motion was measured using conventional optical motion capture, while intervertebral motion at all cervical motion segments from the skull-C1 junction through C7-T1 were obtained through biplane radiographic imaging and measured using an automated registration process with validated accuracy better than 1° in rotation[4] (Figure 1). Participants performed independent trials of maximal head flexion/extension, axial rotation, and lateral bending in a randomized order of unbraced, soft collar (foam), hard collar (Aspen), and CTO (Aspen) conditions. Repeated-measures ANOVA was used to identify differences in range of motion (ROM) among brace conditions for each of the three motions.

Results: Compared to no collar, the soft collar reduced flexion/extension ROM from skull/C1 through C4/C5 and reduced axial rotation ROM at C1/C2 and from C3/C4 through C5/C6, but the soft collar did not reduce motion at any motion segment during lateral bending. Compared to the soft collar, the hard collar reduced intervertebral motion at every motion segment during all motions, except for skull/C1 during axial rotation and C1/C2 during lateral bending. The CTO reduced motion compared to the hard collar only at C6/C7 during flexion/extension and at C7/T1 during lateral bending (Figure 2).

Conclusion: Soft collars are ineffective as a restraint to intervertebral motion during lateral bending but they do reduce intervertebral motion during flexion/extension and axial rotation. Hard collars reduce intervertebral motion compared to soft collars across all motion directions. CTOs provide minimal reduction in intervertebral motion compared to a hard collar.

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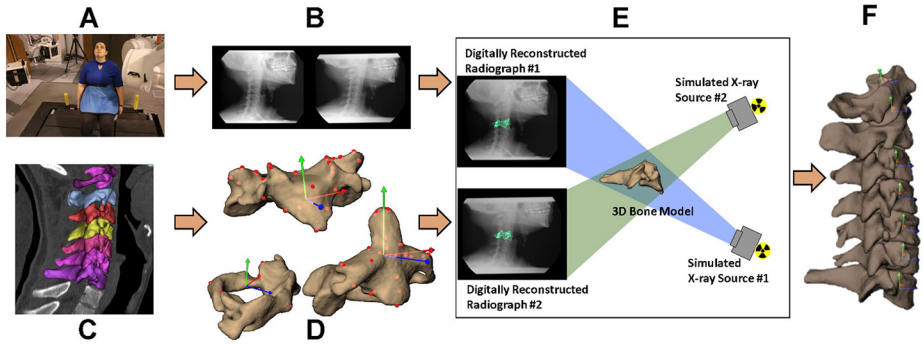

Figure 1. *The biplane radiography system and volumetric bone-model-based tracking technique. **A)** The participant performs dynamic movements within the biplane imaging system. **B)** Radiographs are collected using high-speed cameras. **C&D)** Three-dimensional subject-specific bone models of each vertebra are created from CT scans. **E)** Each subject-specific 3D bone model is placed in a computer-generated reproduction of the biplane system. Simulated X-rays are passed through the 3D bone model to generate digitally reconstructed radiographs (DRRs). Bone position and orientation are determined by an optimization process that matches the DRRs to the edge-enhanced radiographs. **F)** This process is repeated for each vertebra and the 3D kinematics of the cervical spine are determined over the entire movement.*

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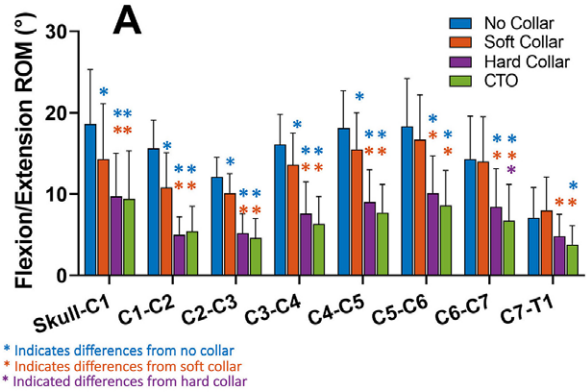
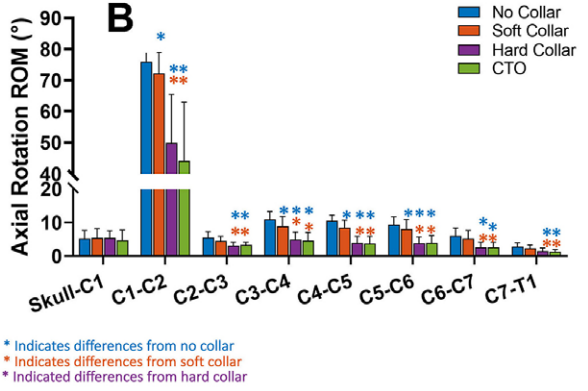


Soft Collar
- Reduced mid- to upper cervical spine (Skull/C1 through C4/C5) ROM compared to no collar.

Hard Collar
- Reduced ROM in (almost) all motion segments compared to both no collar and soft collar.

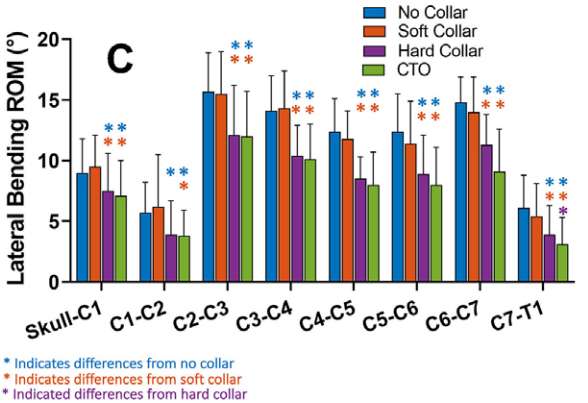
CTO
- Reduced ROM in all motion segments compared to both no collar and soft collar.
- Did not reduce motion compared to hard collar except at C6-C7.



Soft Collar
- Reduced mid-cervical spine (C3-4 through C5-6) ROM and C1-2 ROM compared to no collar.

Hard Collar
- Reduced ROM in all motion segments except Skull-C1 compared to both no collar and soft collar.

CTO
- Reduced ROM in all motion segments except Skull-C1 compared to both no collar and soft collar.
- Did not reduce motion compared to hard collar.



Soft Collar
- No reduction compared to no collar.

Hard Collar
- Reduced ROM in (almost) all motion segments compared to both no collar and soft collar.

CTO
- Reduced ROM in all motion segments compared to both no collar and soft collar.
- Did not reduce motion compared to hard collar except at C7-T1.

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.

PAPER 28

Does Approach Matter? Comparison of Early Postoperative Life-threatening Complications in Elderly Patients with Multilevel Cervical Stenosis

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Introduction: The optimal surgical approach for multilevel (3+ levels) cervical stenosis in elderly patients is controversial. There is limited research comparing complication rates between anterior fusion (ACDF) and laminoplasty or laminectomy (posterior surgery, PS) in the elderly. This study aims to compare 30-day complication rates between anterior and posterior approaches in elderly patients with multilevel cervical stenosis.

Materials and Methods: Data from the American College of Surgeons National Surgical Quality Improvement Program database (NSQIP) was queried to select patients aged 65 or older who underwent ACDF or PS between 2016 and 2021. Patients with sub-axial (C2-7) cervical degenerative disorders were identified using ICD10 codes. Surgical procedures were defined using Current Procedural Terminology (CPT) codes indicating ACDF (≥3 levels), laminoplasty or laminectomy (3-5 intervertebral levels), and posterior decompression and fusion (3-5 intervertebral levels). Anterior corpectomies or deformity corrections were excluded from analysis. Outcomes of interest included readmission, reoperation, airway complications, transfusions, surgical site infections (SSI), urinary tract infections (UTI), and venous thromboembolism (VTE). Airway complications were defined as unplanned reintubation or failed weaning ventilation over 48 hours. Propensity score matching was performed using a 1:1 ratio on the following variables: age, sex, weight, height, race, current smoking status, disseminated cancer, bleeding disorder, ASA class (<3/ ≥3), diabetes mellitus (DM), dialysis, hypertension (HT), history of chronic heart failure (CHF), and chronic obstructive pulmonary disease (COPD). Continuous and categorical variables in the matched cohort were compared with the student-t test and chi-square test, respectively.

Results: We identified 568 patients who underwent 3 or more levels of ACDF (ACDF3+ group) and 1590 patients who underwent posterior surgery. After propensity score matching, the cohorts were similar in terms of all demographic data including age (ACDF3+, 70.9±4.8 vs PS, 70.9±4.9), BMI (29.4±5.6 vs 29.1±5.8), current smoking status (12.3% vs 14.3%), ASA class ≥ 3(61.6% vs 62.1%), steroid use (6.2% vs 4.6%), CHF (0.5% vs 0.7%), and COPD (6.9% vs 6.2%). All patients with dialysis (n=17) and 24 of 28 patients with CHF were excluded in the matching process (all PS patients). Complications were comparable for readmission (ACDF3+, 5.3% vs PS, 6.2%; P=0.609), reoperation (2.1% vs 3.3%; P=0.275), airway complications (0.9% vs 0.9%; P=1.000), and VTE (1.1% vs 0.7%; P=0.751). However, PS had a higher rate of SSI (0.2% vs 1.4%; P=0.045), UTI (1.1% vs 3.0%; P=0.035) and LOS (2.5±6.1 days vs 4.3±3.9 days; P<0.001) (Table).

Conclusion: Among elderly patients who underwent 3 or more levels of surgery for cervical degenerative disorders, there were no statistically significant differences between anterior and posterior approaches in 30-day complications such as airway complications and VTE. ACDF showed significantly fewer patients with SSI and UTI. Further research will be needed to assess

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whether mechanical complications or patient reported outcomes differ between these two approaches.

Table. Outcomes after propensity score matching

		ACDF3+ (n=568)	PS (n=568)	P-value
Readmission	n (%)	30(5.3)	35(6.2)	0.609
Reoperation	n (%)	12(2.1)	19(3.3)	0.275
Airway Complications	n (%)	5(0.9)	5(0.9)	1
Unplanned reintubation	n (%)	4(0.7)	4(0.7)	1
Failed ventilator weaning (>48hrs)	n (%)	3(0.5)	2(0.4)	1
Venous thromboembolism	n (%)	6(1.1)	4(0.7)	0.751
Pulmonary embolism	n (%)	5(0.9)	2(0.4)	0.448
Cardiovascular event	n (%)	1(0.2)	0(0.0)	1
Cerebrovascular accident/stroke	n (%)	0(0)	0(0)	1
Surgical site infection	n (%)	1(0.2)	8(1.4)	0.045*
Superficial	n (%)	0(0.0)	6(1.1)	0.041*
Deep	n (%)	1(0.2)	2(0.4)	1
Wound dehisence	n (%)	0(0.0)	4(0.7)	0.133
Pneumonia	n (%)	9(1.6)	5(0.9)	0.42
Urinary tract infections	n (%)	6(1.1)	17(3.0)	0.035*
Sepsis	n (%)	7(1.2)	5(0.9)	0.772
Transfusion	n (%)	4(0.7)	13(2.3)	0.051
Length of Hospital Stay (days)	mean (SD)	2.5(6.1)	4.3(3.9)	<0.001*

PAPER 29

Similar Post-operative Complications but Increased Rates of Prolonged Hospitalization and Non-home Discharge in Octogenarians Undergoing Anterior Cervical Decompression and Fusion Compared to Matched Younger Patients

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UCLA[1]

Introduction: As the population continues to age, a larger proportion of the US population will be 80 years old or greater. Recent research has suggested that complications faced by octogenarians following surgical intervention for cervical degenerative conditions are similar to younger patients. An understanding of the risks following elective cervical spine surgery in this special population would be beneficial to surgeons, patients and health systems.

Materials and Methods: The ACS National Surgery Quality Improvement Program (NSQIP) database was queried from 2012-2020 to identify patients aged 65 to 89 undergoing elective 1 or 2 level ACDF procedures using CPT codes and associated diagnosis of cervical stenosis, myelopathy, radiculopathy and degenerative disc disease ICD9 and ICD10 diagnostics codes. Propensity score matching was performed with a ratio of 2:1 by procedure type to create balanced groups of octogenarians (age 80 to 89) and younger patients (age 65 to 79). Thirty-day post-operative complications were analyzed. Bonferroni correction was used to adjust for multiple comparisons.

Results: A total of 12,080 patients were identified, with octogenarians comprising 633 (5.2%) of patients. Over the study period the proportion of octogenarians did not change significantly. Octogenarians were more likely to have inpatient surgery (79.0 vs 73.0%, p<0.001), have one level surgery (51.2 vs 45.4%, p=0.006), have a lower BMI (mean 28.0 vs 30.1, p<0.001), and have higher levels of medical comorbidity (mean ASA 2.81 vs 2.67, p<0.001).

On PSM analysis, octogenarians had higher rates of prolonged hospitalization (LOS > 3 days, 19.0 vs 9.8% p <0.001) and non-home discharge (22.2 vs 8.5%, p < 0.001), but did not have higher rates of return to the OR (3.1% vs 3.0%, p > 0.99), unplanned readmission (7.2% vs 5.1%, p=0.73), mortality (1.0% vs 0.03%, p>0.99), reintubation (1.6 vs 0.8%, p>0.99), cardiac complications (1.6% vs 0.4%, p = 0.14), DVT or PE (0.5% vs 0.5%, p>0.99), post-op transfusion (1% vs 0.5%, p>0.99), wound complications (0.5 vs 0.7%), pneumonia (3.5 vs 1.9%, p=0.46), or UTI (1.6 vs 1.1%, p>0.99).

Conclusion: Octogenarians have similar rates of readmission, reoperation and medical complications following elective ACDF compared to younger matched patients. They did however have higher rates of prolonged hospitalization and non-home discharge. Prior studies using NSQIP data have found higher rates of post-op complications in elderly patients (age 60 or 65 and older) compared to younger patients, including blood transfusions, reoperations, urinary complications, pulmonary complication, cardiac complications and DVTs – none of which were found in our study [1,2]. In study using Medicare claims data, Octogenarians were found to have higher rates of medical complications and 90-day & 1-year mortality compared to younger patients [3]. This increased mortality rate in octogenarians may be unrelated to surgical intervention and rather a reflection of overall frailty.

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While elective anterior cervical fusion appears safe in patients 80 and older, surgeons should plan for increased likelihood of longer hospital stays and non-home discharges and council their patients accordingly. Overall cost of care will also likely be higher for these patients.

PAPER 30

Investigation of Risk Factors of C5 Palsy After Anterior Cervical Spine Surgery

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Tokyo Medical and Dental University[1]

Introduction: C5 palsy after cervical spine surgery is one of the most common complications, especially in posterior decompression and fusion surgery (1), but it can also occur in anterior surgery. In this study, we analyzed cases of C5 palsy in anterior cervical spine surgery and investigated risk factors.

Materials and Methods: From 784 cervical spine surgeries performed at our hospital between April 2011 and March 2022, we included anterior decompression fusion surgeries for degenerative diseases, including C4/5 fusion. A total of 154 cases (mean age 62.1 years, 116 males and 38 females) were included in the study, excluding cases of surgery for deformity correction, scheduled two-stage surgery, and revision cervical spine surgery. Patients were defined as having C5 palsy if their deltoid MMT decreased by at least one level compared to the preoperative MMT without lower limb dysfunction within 2 weeks after surgery. Age, gender, disease, number of fixed vertebrae, preoperative deltoid muscle weakness, preoperative JOA score, and C4/5 decompression procedure (C4/5 intervertebral decompression, C4 only corpectomy, C5 only corpectomy, C4,5 both corpectomy) were investigated and compared in the group with C5 palsy and the group without C5 palsy.

Results: Of the 154 patients included in the study, C5 palsy occurred in 14 patients (9.1%) and 2 patients had a revision surgery on during hospitalization. There were no significant differences in age at surgery, sex ratio, preoperative deltoid muscle weakness, or preoperative JOA score between the groups with and without C5 palsy. Regarding target diseases, the proportion of OPLL was significantly higher in the group with C5 palsy. The number of fixed vertebrae was tended to be higher in the group with C5 palsy (3.0 ± 0.6 with C5 palsy, 2.5 ± 0.9 without C5 palsy, p = 0.058). The incidence of C5 palsy was the highest in C4,5 both corpectomy, and was significantly higher than that in only C4/5 intervertebral decompression. Logistic regression analysis, in which the presence or absence of C5 palsy was the objective variable and the explanatory variable was the presence or absence of OPLL and the method of decompression was corpectomy for both C4 and C5, showed that only corpectomy for both C4 and C5 was a risk factor, with an odds ratio of 5.15(Table 1).

Conclusion: In anterior surgery for cervical degenerative disease, the risk factor of C5 palsy was the use of both C4,5 corpectomy for C4/5 decompression.

・**Risk Factors of C5 palsy by logistic regression analysis**

	OR	95% CI	*P*-value
OPLL	2.04	0.553-7.490	0.810
C4 and 5 corpectomy	5.15	1.350-19.70	0.017*

PAPER 31

Comparison of CTA and MRI for C1 Instrumentation Presurgical Planning

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Hospital For Special Surgery[1] Showa University School of Medicine[2]

Introduction: Atlantoaxial fusion poses a significant risk of direct vascular injury to the internal carotid artery (ICA) and presurgical imaging plays an essential role in mitigating this risk. Prior CTA based studies assessing the anatomical relationship of the ICA to key surgical landmarks at C1 have identified a wide variation in ICA anatomy relative to C1 and recommend preoperative CTAs for a bicortical fixation. One study discusses the role of CT imaging in deciding between unilateral vs bicortical fixation based on the distance between the anterior border of C1 and the ICA. Despite the surgical risks, CTA imaging is not widely obtained preoperatively, and surgical planning is often based on an MRI. However, prior studies have not compared CTA and MRI imaging for assessing C1 osseous and vascular anatomy. One study assessing the risk of ICA injury at C1 even included patients with either a CT, MRI or MRA, without demonstrating an equivalency between these modalities. This study aims to address this gap by comparing CTA and MRI based measurements to assess C1 anatomy prior to surgical instrumentation.

Materials and Methods: 209 patients who underwent both a CTA and MRI, for any reason, at a single academic institution between 2007 and 2018 were assessed. Exclusion criteria was any prior cervical surgery or MRIs that did extend cephalad to the atlas. 10 standardized measurements were made in each imaging modality assessing osseous and vascular anatomy. Intraclass correlation coefficients and correlations were calculated for each of the 10 measurements.

Results: A total of 119 patients fit the inclusion criteria; the mean age at CTA was 65.1 years. The agreement between CTA and MRI for the 10 standardized measurements was less than moderate, with intraclass correlation coefficients (ICC) ranging from 0.427 to 0.006. The bone to bone measurements of distance from the origin of the ideal screw trajectory to the posterior cortical surface of C1 and the AP dimension of C1 had the highest ICCs, 0.427 and 0.375 respectively. Measurements of the distance from the origin of the ideal screw trajectory to ICA and a straight line from the ICA to the anterior surface of C1 had ICCs of 0.193 and 0.213, respectively. Of the 10 measurements, only the distance from the end of the ideal screw trajectory to the anterior plane of C1 was not statistically significant ($p>0.05$) between CTA and MRI.

Conclusion: These findings demonstrate a lack of agreement between MRI and CTA based measurements at C1. Interestingly, the measurements with the highest ICCs and correlation coefficients were bone to bone measurements, demonstrating that although MRI can guide preoperative planning, the low ICCs for measurements of ICA position relative to C1 strongly support the use of CTA to assess the ICA safety margin when using bicortical C1 lateral mass screws.

PAPER 32

Do Tracheal Traction Exercises Help Prevent Dysphagia Following Anterior Cervical Spine Surgery: A Randomized Double Blind Placebo Controlled Trial

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Medstar Orthopaedic Institute/Georgetown University[1] University of Rochester Medical Center[2]

Introduction: Dysphagia is a common complication following anterior cervical spine surgery. Length of esophageal retraction, endotracheal tube pressure, multi-level fusions, revision surgeries and implant (plate) prominence have been associated with a higher risk of dysphagia. Studies have reported pre-operative Tracheal Traction Exercises (TTE) can decrease the rate of dysphagia associated with anterior cervical spine surgery. However, there has been no randomized clinical trial to examine the effects of TTE on dysphagia post-anterior cervical spine surgery. The goal is to determine the impact of TTE prior to anterior cervical spine surgery on decreasing the rate of post-operative dysphagia using the Swallowing Quality of Life questionnaire (SWAL-QOL).

Materials and Methods: Patients undergoing elective Anterior cervical spine surgery (C2-T1) for degenerative disc disease, or myelopathy, between 1/2015 to 5/2022 underwent computer randomization, to the intervention group (TTE) or control group. Subjects in the intervention group underwent training prior to their surgery on how to perform TTE exercise, and the control group underwent placebo training. The exercises were performed for 4 to 5 days prior to surgery (depending on the subject's surgical date) ten repetitions, three times a day. All subjects completed the SWAL-QOL, questionnaires pre-operatively, and the SWAL-QOL at 1 week, 6 week, 3 months, 6 months and 12 months post-operatively. Statistical analysis involved the use of bivariant analysis to examine changes perioperative and procedural characteristics between both groups. Multivariable regression analysis was performed. All multivariable models controlled for patient- and procedure-level confounders.

Results: 73 randomized TTE exercises prior to surgery whereas 72 randomized to perform placebo cervical exercises. The TTE cohort aged 54.5 ± 10.5 years, compared to the control cohort 54.2 ± 10.33 years (p=0.85). The TTE is composed of 47.67% females whereas the control cohort 51.95% (p=0.67). There is equal distribution of race groups between the intervention and cohort groups (White: 84.93%; Black: 10.96% versus White: 83.3%; Black: 16.6%, p=0.08). No difference between group in preoperative myelopathy (p=0.28) and radiculopathy (p=0.11). No difference between both study groups in the number of levels fused (p=0.75), type of anterior cervical plate used (p=0.59), and plate thickness (p=0.84). Intervention group had a shorter length of stay 1.90 ± 2.0, compared to the control group 2.40 ± 2.74 (p=0.041). There was no statistical difference between preoperative and 1 week, 6 week, 3 months, 6 months and 12 months post-op SWAL-QoL score, between both study groups. Surgical variables, cervical fusion levels, number of levels fused, type of cervical plate showed no impact on postoperative SWAL-QoL.

Conclusion: Dysphagia is common following anterior cervical spine surgery. This randomized double blind placebo controlled trial demonstrated pre-operative tracheal traction exercises did not decrease dysphagia rates and were equivalent to placebo exercises.

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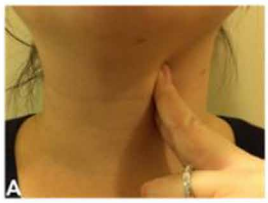

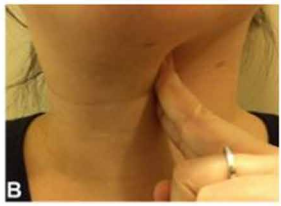

Figure 1A. ***TTE exercise.*** The index and middle finger are positioned medial to the sternocleidomastoid
Figure 1B. The trachea and esophagus are pushed medially. This is repeated 10 times, 3 times a day for 4 to 5 days pre-operatively.

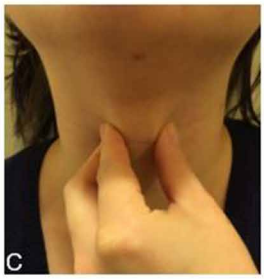

Figure 1C. ***Placebo exercise.*** The index, middle fingers and thumb are used to massage the midline structure (trachea and thyroid). This is repeated 10 times, 3 times a day for 4 to 5 days.

PAPER 33

The Surgical Learning Curve for Cervical Disc Replacement

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Introduction: A single surgeon learning curve has not been established for cervical disc replacement (CDR). We aim to characterize an experienced single surgeon learning curve for CDR.

Materials and Methods: Patients undergoing CDR were identified through retrospective review of a prospectively maintained database. The cumulative sum (CUSUM) of operative time was utilized to separate cases into three phases: learning, practicing, and mastery. A polynomial function was fitted to identify these three phases. Demographics, perioperative characteristics, complications, patient-reported outcomes (PROs), and radiographic outcomes were collected preoperatively and up to 1-year postoperatively. PROs included Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS-PF), Short Form-12 (SF-12) Physical Component Score (PCS), SF-12 Mental Component Score (MCS), visual analog scale (VAS) Arm, VAS Neck, and Neck Disability Index (NDI). Radiographic outcomes included segmental angle, segmental range-of-motion (ROM), and C2-C7 ROM. Minimum clinically important difference (MCID) achievement was determined through comparison of previously established values. Comparison between the three phases was determined through inferential statistics.

Results: A total 173 patients were identified, with 14 patients in the learning phase, 42 patients in the practicing phase, and 117 patients in the mastery phase. The mean postoperative follow-up time was 6.40±4.23 months. The mean postoperative follow-up time was 6.40±4.23 months. The mean operative time and mean postoperative day 0 narcotic consumption were significantly higher in the learning phase ($p \leq 0.006$, all). The preoperative segmental angle was significantly lower for the learning phase ($p=0.040$), though these differences were eliminated at the final postoperative time point. For PROs, patients in the learning phase reported worse improvement to 6-week postoperative, final postoperative, and worse overall final postoperative VAS Arm scores ($p \leq 0.040$, all) compared to practicing and mastery phases. MCID achievement rates did not differ between cohorts. No intraoperative complications occurred in any phase.

Conclusion: For an experienced spine surgeon, the learning phase for CDR was estimated to span 14 patients. During this phase, patients demonstrated longer operative times, higher postoperative narcotic consumption, and worse postoperative VAS Arm scores. No intraoperative complications occurred in any patients. Radiographically, no postoperative differences were noted between different phases of mastery. This single surgeon learning curve demonstrates that CDR may be performed safely and with comparable outcomes by experienced spine surgeons, despite decreased operative efficiency in the learning phase.

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Table 1. Patient Demographics

Characteristic	Total (n=173)	Learning (n=14)	Practicing (n=42)	Mastery (n=117)	*p-value
Age (mean ± SD, years)	46.66±10.27	41.37±8.03	44.14±10.61	48.20±10.06	**0.011**
Gender					0.930
Female	38.2% (66)	35.7% (5)	42.9% (18)	36.8% (43)	
Male	61.9% (107)	64.3% (9)	57.1% (24)	63.3% (74)	
Ethnicity					0.647
White	80.0% (135)	85.7% (12)	82.9% (34)	78.1% (89)	
Black	7.1% (12)	14.3% (2)	4.9% (2)	7.0% (8)	
Hispanic	9.5% (16)	0.0% (0)	7.3% (3)	11.4% (13)	
Asian	2.4% (4)	0.0% (0)	4.9% (2)	1.8% (2)	
Other	1.2% (2)	0.0% (0)	0.0% (0)	1.8% (2)	
BMI (mean ± SD, kg/m^2)	28.92±5.71	29.75±4.32	26.72±4.80	29.58±5.95	**0.022**
Comorbidities					
Smoker	8.7% (15)	0.0% (0)	9.5% (4)	9.5% (11)	0.483
Hypertension	17.5% (30)	14.3% (2)	7.1% (3)	21.7% (25)	0.098
Diabetes	5.8% (10)	0.0% (0)	2.4% (1)	7.7% (9)	0.281
ASA Classification					0.214
≤2	85.9% (146)	100.0% (14)	88.1% (37)	83.3% (95)	
>2	14.1% (24)	0.0% (0)	11.9% (5)	16.7% (19)	
CCI Score (Mean ± SD)	1.06±1.19	0.43±0.76	0.60±0.89	1.30±1.26	**<0.001**
Insurance Type					
Medicare/Medicaid	2.9% (5)	0.0% (0)	2.4% (1)	3.4% (4)	0.792
Workers' Comp	22.0% (38)	28.6% (4)	16.7% (7)	23.1% (27)	
Private	75.1% (130)	71.4% (10)	81.0% (34)	73.5% (5)	

BMI = body mass index; CCI = Charlson Comorbidity Index; ASA = American Society of Anesthesiologists; SD= standard deviation; Workers' Comp = workers' compensation
*p-value calculated using ANOVA for continuous variables and chi-square analysis for categorical variables
Bolding denotes statistical significance ($p < 0.05$)

Table 2. Perioperative Characteristics

Characteristic	Total (n=173)	Learning (n=14)	Practicing (n=42)	Mastery (n=117)	*p-value
Spinal Pathology					
Herniated Nucleus Pulposus	97.7% (169)	100.0% (14)	97.6% (41)	97.44% (114)	0.833
Central Stenosis	56.1% (97)	57.1% (8)	50.0% (21)	58.1% (68)	0.659
Foraminal Stenosis	24.9% (43)	7.1% (1)	2.4% (1)	35.0% (41)	**<0.001**
Number of levels					0.969
One	74.5% (120)	71.4% (10)	73.8% (31)	74.5% (79)	
Two	25.9% (42)	28.6% (4)	26.2% (11)	25.5% (27)	
Operative Time (Mean ± SD; min)	51.80±15.79	65.86±17.84	50.33±12.26	50.64±15.96	**0.002**
Estimated Blood Loss (Mean ± SD; mL)	26.70±6.78	28.57±9.08	27.92±9.59	26.00±4.92	0.193
Length of Stay (Mean ± SD; hours)	7.73±5.68	8.16±6.87	8.37±7.06	7.47±5.01	0.669
Postoperative VAS pain POD 0	4.72±2.22	4.40±1.45	4.64±2.02	4.78±2.37	0.809
Postoperative Narcotic Consumption (OME) POD 0	21.68±17.64	35.89±17.09	19.20±18.38	20.88±16.79	**0.006**

POD = postoperative day; mL = milliliters; SD = standard deviation; VAS = Visual Analog Scale; OME = oral morphine equivalents
*p-value calculated using ANOVA for continuous variables and chi-square analysis for categorical variables
Bolding denotes statistical significance ($p < 0.05$)

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Table 3. Inpatient Complications

Complication	Total (n=173)	Learning (n=14)	Practicing (n=42)	Mastery (n=117)	*p-value
Acute Renal Failure	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Altered Mental Status	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Anemia, postoperative	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Arrhythmia	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Aspiration/Re-intubation	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Atelectasis	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Dysphagia	0.6% (1)	0.0% (0)	2.4% (1)	0.0% (0)	0.208
Fever of Unknown Origin	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Ileus	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Incontinence, urinary	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Nausea/Vomiting	2.3% (4)	0.0% (0)	2.4% (1)	2.6% (3)	0.833
Pleural effusion	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Pneumonia	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Pulmonary Embolism	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Urinary Retention	0.6% (1)	7.1% (1)	0.0% (0)	0.0% (0)	**0.003**
Urinary Tract Infection	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-
Venous Thromboembolism	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	-

*p-value calculated using chi-square analysis
Bolding denotes statistical significance ($p < 0.05$)

Table 4. Radiographic outcomes between groups based on the Mobi-C segmental angulation on lateral radiographs.

	Total	Learning	Practicing	Mastery	*p-value
Pre-Op					
Segmental Angle	1.84±3.28	-0.03±2.83	2.28±4.10	1.92±2.96	**0.040**
Segmental ROM	2.51±4.27	-	-	2.51±4.27	-
C2-C7 ROM	19.30±24.61	-	-	19.30±24.61	-
Final Post-Op					
Segmental Angle	7.42±5.86	6.92±4.98	6.11±6.95	7.93±5.50	0.168
Segmental ROM	3.35±4.67	-	-	3.35±4.67	-
C2-C7 ROM	24.27±24.35	-	-	24.27±24.35	-
Δ Pre-Op to Final Post-Op					
Segmental Angle	6.13±6.18	8.32±4.39	8.32±4.39	5.07±7.17	0.240
Segmental ROM	0.67±5.35	-	-	0.67±5.35	-
C2-C7 ROM	1.40±28.28	-	-	1.40±28.28	-

*p-value calculated using ANOVA.
Bolding denotes statistical significance ($p < 0.05$)

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Table 5. Patient-reported outcomes between groups based on the Mobi-C segmental angulation on lateral radiographs.

	Total	Learning	Practicing	Mastery	p-value
Pre-Op					
PROMIS-PF	40.46±7.66	41.51±3.07	39.55±6.54	40.64±8.61	0.747
SF12 PCS	34.22±8.72	36.82±7.38	34.27±9.20	33.47±8.78	0.451
SF12 MCS	48.02±11.06	48.81±9.25	48.79±10.00	47.88±12.24	0.852
VAS Arm	5.71±2.73	5.33±2.81	6.09±2.95	5.60±2.63	0.601
VAS Neck	6.42±2.39	6.31±1.92	6.64±2.55	6.34±2.42	0.820
NDI	40.82±19.28	36.00±16.29	40.51±20.04	41.84±19.52	0.581
6-week Post-Op					
PROMIS-PF	45.00±9.93	43.55±5.28	47.38±9.08	44.24±10.99	0.473
SF12 PCS	40.76±9.87	35.82±8.94	44.16±10.01	40.29±9.60	0.087
SF12 MCS	53.04±10.27	50.53±10.31	54.31±7.64	53.08±11.64	0.648
VAS Arm	2.59±3.01	4.06±4.01	1.93±2.60	2.58±2.89	0.153
VAS Neck	3.17±2.70	3.13±1.89	2.91±3.06	3.28±2.71	0.856
NDI	27.29±21.26	32.91±17.38	21.92±19.21	28.50±22.60	0.292
Final Post-Op					
PROMIS-PF	48.62±10.12	46.24±5.81	48.56±10.93	49.08±10.39	0.675
SF12 PCS	43.40±10.59	41.12±8.65	43.78±11.09	43.76±10.88	0.729
SF12 MCS	51.28±10.73	51.65±11.93	50.18±10.16	51.91±10.95	0.795
VAS Arm	2.29±2.76	4.37±3.02	2.35±2.70	1.86±2.59	**0.010**
VAS Neck	2.66±2.67	3.16±1.66	3.12±2.79	2.37±2.75	0.316
NDI	20.62±19.52	25.38±11.12	20.61±17.54	19.75±21.56	0.637
Δ Pre-Op to 6-week Post-Op					
PROMIS-PF	3.93±11.60	1.69±6.19	5.81±8.23	3.59±13.68	0.695
SF12 PCS	6.04±10.09	-0.47±11.24	7.33±10.81	7.57±8.57	0.077
SF12 MCS	5.91±11.72	5.19±15.27	6.71±7.53	5.68±12.77	0.941
VAS Arm	2.93±3.48	0.62±4.64	4.05±3.60	2.95±2.86	**0.026**
VAS Neck	2.90±2.79	2.87±2.55	3.23±3.18	2.75±2.70	0.807
NDI	12.99±16.27	5.09±17.78	15.09±14.26	13.83±16.58	0.215
Δ Pre-Op to Final Post-Op					
PROMIS-PF	9.09±9.43	4.17±7.26	9.03±7.81	10.10±10.32	0.194
SF12 PCS	8.95±11.08	4.26±10.89	8.04±9.90	11.07±11.59	0.161
SF12 MCS	3.77±11.21	5.13±13.57	3.14±10.02	3.74±11.40	0.884
VAS Arm	3.12±3.46	0.90±3.98	3.24±3.42	3.58±3.22	**0.040**
VAS Neck	3.56±2.92	3.09±1.66	3.13±2.93	3.87±3.11	0.439
NDI	20.81±18.62	12.62±10.91	19.87±19.43	23.05±19.23	0.178
MCID Achievement					
PROMIS-PF	77.4% (65)	60.0% (6)	80.0% (20)	79.6% (39)	0.375
SF12 PCS	54.79% (40)	33.3% (4)	64.0% (16)	55.6% (20)	0.213
SF12 MCS	52.1% (38)	66.7% (8)	52.0% (13)	47.2% (17)	0.506
VAS Arm	43.4% (43)	23.1% (3)	45.2% (14)	47.3% (26)	0.278
VAS Neck	70.5% (74)	61.5% (8)	71.0% (22)	72.1% (44)	0.747
NDI	77.7% (80)	69.2% (9)	74.2% (23)	81.4% (48)	0.546

*p-value calculated using ANOVA for continuous variables and chi-square analysis for categorical variables
Bolding denotes statistical significance ($p < 0.05$)

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.

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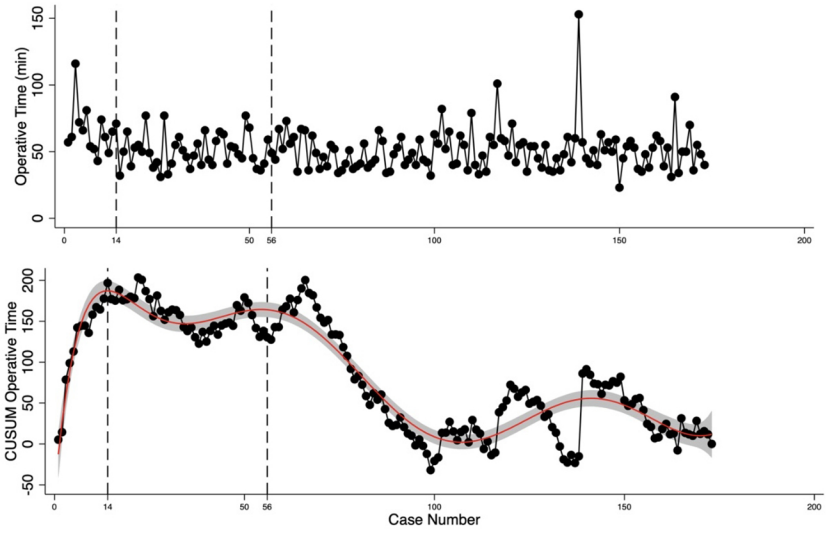

Fig. 1. Operative time (**Top**) and cumulative sum (CUSUM) of operative time (**Bottom**) plotted against the case number. The phases were separated from inflection points defined through the polynomial function that fit the data and are represented through the dashed lines for the Learning Phase (n<14), Practicing Phase (14≤n<56), and Mastery Phase (n≥56). The polynomial function for CUSUM was

$$OT = -56.67 + 48.64n - 3.56n^2 + 0.12n^3 - 2.23e - 3n^4 + 2.29e - 5n^5 - 1.31e - 7n^6 + 3.97e - 10n^7 - 4.90e - 13n^8$$

, where OT is the operative time and n is the case number. The r^2 value for the operative time and CUSUM was 0.075 and 0.88, respectively, after polynomial fitting.

PAPER 34

Determining Minimum Clinically Important Difference for PROMIS Domains in Patients Undergoing Cervical Disc Replacement

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Introduction: No studies have established the minimum clinically important difference (MCID) thresholds for Patient-Reported Outcomes Measurement Information System (PROMIS) values, outside of PROMIS physical function (PROMIS-PF), for patients undergoing cervical disc replacement (CDR). Our study aims to establish MCID thresholds in the patient-reported outcome measures (PROMs) PROMIS-PF, PROMIS anxiety (PROMIS-A), PROMIS pain interference (PROMIS-PI), and PROMIS sleep disturbance (PROMIS-SD) in patients undergoing CDR using anchor- and distribution-based methods.

Materials and Methods: Patients undergoing CDR with preoperative Neck Disability Index (NDI) scores were included. PROMs were collected up to 1-year postoperatively. MCID thresholds were established using anchor- and distribution-based methods, with the NDI as the anchor. For anchor-based methods, responders were classified as patients decreasing by at least 1 disability classification (e.g. moderate to mild) postoperatively. Anchor-based methods included average change, minimum detectable change (MDC), change difference, and receiver operating characteristic (ROC) curve. Distribution-based methods included standard error of measurement (SEM), reliable change index (RCI), effect size, and 0.5ΔSD.

Results: One hundred and twenty-four patients were identified. The mean postoperative follow-up time was 6.9 months. Anchor-based MCID thresholds ranged from 7.2-11.6 for PROMIS-PF, 3.4-8.5 for PROMIS-A, 8.9-13.7 for PROMIS-PI, and 6.2-20.5 for PROMIS-SD. The AUC ranged from 0.64-0.75, indicating fair to adequate discrimination between responders and non-responders. Distribution-based MCID thresholds ranged from 1.5-4.8 for PROMIS-PF, 2.4-7.5 for PROMIS-A, 2.1-7.1 for PROMIS-PI, and 1.9-6.8 for PROMIS-SD.

Conclusion: MCID thresholds for PROMIS values in patients undergoing CDR were dependent on the calculation method. The closest to (0,1) method from the ROC curve was selected as the most appropriate MCID calculation method due to its ability to account for clinical relevancy and measurement error through maximizing sensitivity and specificity. The corresponding PROMIS MCID thresholds that may be utilized in future studies for patients undergoing CDR are 8.3 for PROMIS-PF, 4.5 for PROMIS-A, 11.1 for PROMIS-PI, and 6.3 for PROMIS-SD.

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Table 1. Patient demographics and perioperative characteristics

Characteristic	Total (n=124)
Age (mean ± SD, years)	46.2±10.3
Gender	
Female	33.1% (41)
Male	66.9% (83)
Ethnicity	
Black	6.6% (8)
Asian	6.6% (8)
Hispanic	8.3% (10)
White	81.8% (99)
BMI (mean ± SD, kg/m^2)	29.2±5.4
Comorbidities	
Smoker	9.7% (12)
Hypertension	16.9% (21)
Diabetes	4.0% (5)
ASA Classification	
<2	26.7% (32)
≥2	73.3% (88)
CCI Score (Mean ± SD)	1.0±1.1
Insurance Type	
Medicare/Medicaid	2.4% (3)
Workers' Comp	21.0% (26)
Private	76.6% (95)
Spinal Pathology	
Herniated Nucleus Pulposus	99.2% (123)
Central Stenosis	57.3% (71)
Foraminal Stenosis	24.2% (30)
Levels Treated	
One level	71.1% (81)
Two levels	29.0% (33)
Operative Time (Mean ± SD; min)	51.8±14.3
Estimated Blood Loss (Mean ± SD; mL)	27.2±7.7
Length of Stay (Mean ± SD; hours)	7.6±5.5
Acute Postoperative Vas Pain	
POD 0	4.7±2.3
Postoperative Narcotic Consumption (OME)	
POD 0	21.3±18.0

BMI = body mass index; CCI = Charlson Comorbidity Index; ASA = American Society of Anesthesiologists; SD= standard deviation; Workers' Comp = workers' compensation; POD = postoperative day; mL = milliliters; SD = standard deviation; Vas = Visual analog scale; OME = oral morphine equivalents

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Table 2. Mean Patient Reported Outcomes

PROM	Mean ± SD	Range	Δ	*p-value
PROMIS-PF				
Preoperative	40.2±7.7	23.2-68.3	-	-
Postoperative	48.9±10.0	27.2-75.6	9.3±9.7	**<0.001**
PROMIS-A				
Preoperative	54.4±12.1	32.9-84.9	-	-
Postoperative	49.1±12.5	32.9-76.5	5.7±8.6	**<0.001**
PROMIS-PI				
Preoperative	60.7±10.6	34.2-80.1	-	-
Postoperative	48.0±9.9	27.2-83.8	10.8±14.3	**<0.001**
PROMIS-SD				
Preoperative	60.6±9.7	32.7-83.8	-	-
Postoperative	48.7±13.5	26.3-83.8	13.6±13.6	**<0.001**
NDI				
Preoperative	41.0±18.9	0.0-90.0	-	-
Postoperative	20.8±19.3	0.0-92.0	21.5±18.5	**<0.001**

*p-values calculated using paired sample t-test to determine preoperative to postoperative improvement
Boldface indicates statistical significance

Table 3. Minimal Clinically Important Difference Calculated Values

MCID Calculation	PROMIS-PF	PROMIS-A	PROMIS-PI	PROMIS-SD
Anchor-based				
Average Change	11.6	6.6	13.5	15.0
MDC	8.1	8.5	8.9	20.5
Change Difference	7.2	3.4	11.1	6.2
ROC, CZ	8.3	*	11.1	6.3
ROC, *J*	8.3	6.2	13.7	6.3
ROC, ER	**8.3**	**4.5**	**11.1**	**6.3**
ROC AUC	0.73	0.64	0.74	0.75
Distribution-based				
SEM	1.7	2.7	2.4	2.2
RCI	4.7	7.5	6.5	6.0
Effect Size	1.5	2.4	2.1	1.9
0.5ΔSD	4.8	4.3	7.1	6.8

MDC = minimal detectable change; ROC = receiver operating curve; CZ = concordance probability method; *J* = Youden index; ER = closest to (0,1) criteria; AUC = area under curve; SEM = standard error of measurement; RCI = reliable change index
*Multiple optimal cutoffs when using the concordance probability method.
Boldface indicates optimal MCID calculation method

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Table 4. Minimal Clinically Important Difference Achievement for different PROMs

MCID Calculation	PROMIS-PF	PROMIS-A	PROMIS-PI	PROMIS-SD
Total patients[a]	79	34	36	31
Anchor-based				
Average Change	36.7% (29)	38.2% (13)	36.1% (13)	35.5% (11)
MDC	53.2% (42)	29.4% (10)	52.8% (19)	25.8% (8)
Change Difference	62.0% (49)	55.9% (19)	44.4% (16)	67.7% (21)
ROC, CZ	49.4% (39)	*	44.4% (16)	67.7% (21)
ROC, *J*	49.4% (39)	38.2% (13)	36.1% (13)	67.7% (21)
ROC, ER	**49.4% (39)**	**47.1% (16)**	**44.4% (16)**	**67.7% (21)**
Distribution-based				
SEM	79.8% (63)	64.7% (22)	75.0% (27)	80.7% (25)
RCI	70.9% (56)	47.1% (16)	63.9% (23)	67.7% (21)
Effect Size	79.8% (63)	67.7% (23)	75.0% (27)	80.7% (25)
0.5ΔSD	70.9% (56)	47.1% (16)	61.1% (22)	67.7% (21)

MDC = minimal detectable change; ROC = receiver operating curve; CZ = concordance probability method; *J* = Youden index; ER = closest to (0,1) criteria; AUC = area under curve; SEM = standard error of measurement; RCI = reliable change index
*Multiple optimal cutoffs when using the concordance probability method.
[a]Total patients with preoperative and final postoperative PROM scores
Boldface indicates optimal MCID calculation method

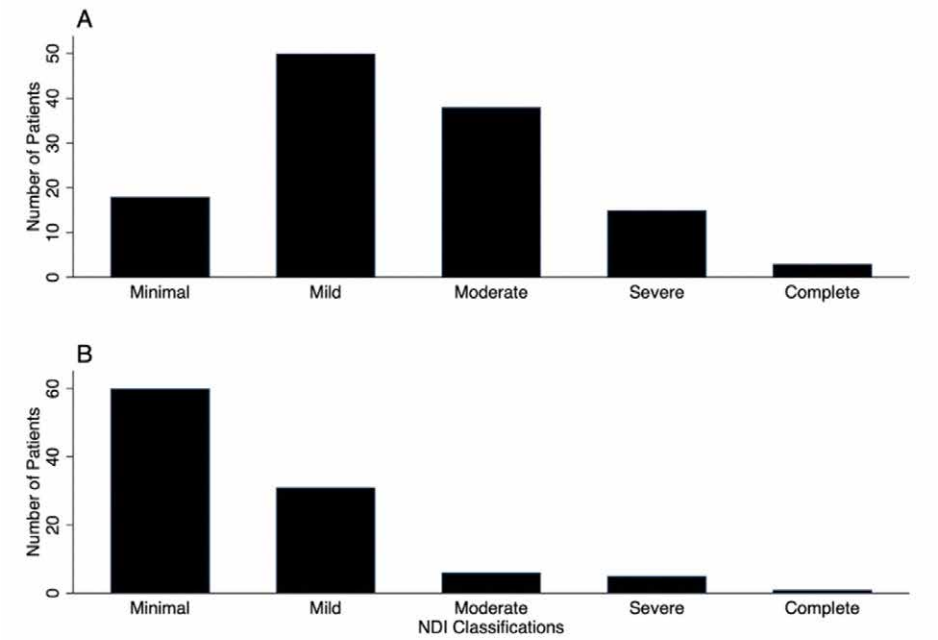

Fig. 1. Neck Disability Classifications at (A) preoperative and (B) postoperative time points. The distribution of patients at the preoperative time point was 14.5% (18) with minimal disability, 40.3% (50) with mild disability, 30.7% (38) with moderate disability, 12.1% (15) with severe disability, and 2.4% (3) with complete disability. The distribution of patients at the final postoperative time point was 58.3% (60) with minimal disability, 30.1% (31) with mild disability, 5.8% (6) with moderate disability, 4.9% (5) with severe disability, and 1.0% (1) with complete disability. There were (C) 73.4% (91) responders and 26.6% (33) non-responders.

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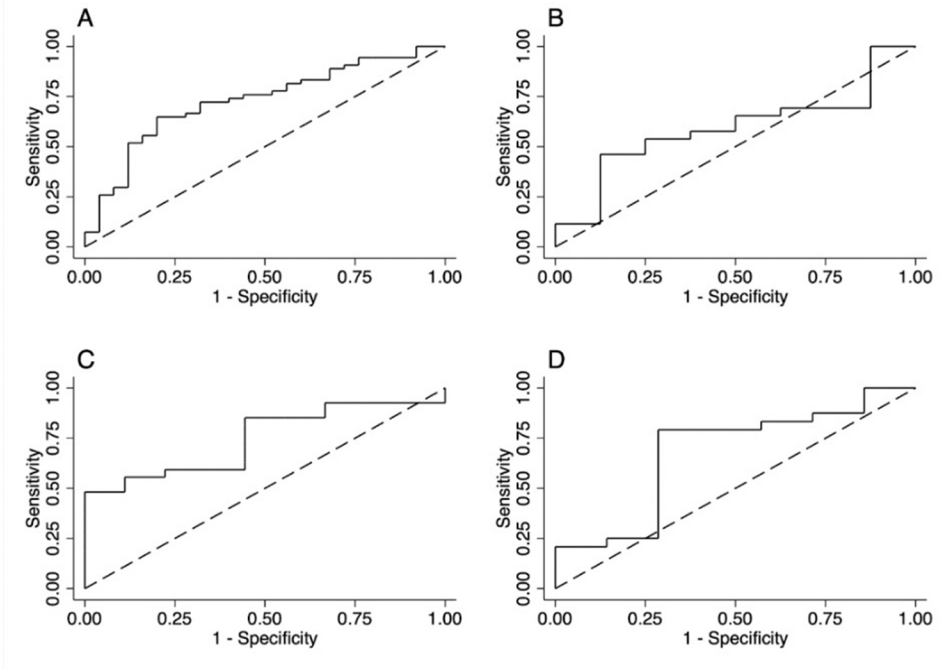

Fig. 2. Receiver operating characteristic curves for (A) PROMIS-PF, (B) PROMIS-A, (C) PROMIS-PI, and (D) PROMIS-SD. The area under curve (AUC) was (A) 0.73, (B) 0.64, (C) 0.74, and (D) 0.75.

PAPER 35

Anterior Cervical Disc Replacement (ACDR) versus Minimally Invasive Posterior Cervical Foraminotomy (MI-PCF) in the Treatment of Cervical Radiculopathy: A 5-Year Retrospective Analysis

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Introduction: Cervical radiculopathy is a common pathology that may be managed with various surgical options. Historically, anterior cervical discectomy and fusion (ACDF) has been utilized to address radiculopathy in patients. However, anterior cervical disc replacement (ACDR) and minimally invasive posterior cervical foraminotomy (MI-PCF) are two effective alternatives that have become increasingly popular. Both techniques provide advantages of segmental motion preservation and lower rates of adjacent segment degeneration (ASD) compared to ACDF. However, there is a paucity of literature directly comparing these two techniques using an adequate period of follow-up. Therefore, the purpose of this study was to compare the clinical and functional outcomes of patients undergoing single level ACDR or MI-PCF for the treatment of unilateral cervical radiculopathy.

Materials and Methods: A retrospective cohort review at a single institution was performed to identify all patients between 2012-2017 who underwent ACDR or MI-PCF. Patients were included in this study if they met the following criteria: adult (> 18 years of age), single level procedure from C3 to C7, minimum follow-up of 5 years, availability of complete medical records and functional outcome scores. Patient demographics including age, gender, BMI, diabetes, and smoking status were assessed between the two groups. Perioperative outcomes and postoperative complications including dysphagia, dysphonia, infections, revisions, and ASD were analyzed. Patient reported outcome measures based on Visual Analogue Scale (VAS) and Neck Disability Index (NDI) scores were recorded at follow-up visits.

Results: 57 patients were included in our study (23 ACDR and 34 MI-PCF). There were no significant differences between the groups regarding months of follow-up, BMI, or percentage of patients with diabetes (Table 1). However, the MIPCF group was significantly older (51.6 years vs 43.1 years, p=0.007), and had a lower percentage of smokers (14.7% vs 39.1%, p=0.036) when compared to the ACDR group. The ACDR group had a significantly greater mean operative time (91.2 minutes vs 66.0 minutes, p<0.001) and estimated blood loss (22.9 mL vs 12.2 mL, p<0.001) (Table 2). Revision rates and postoperative complications are illustrated in Table 3. The overall complication rate was significantly greater in the ACDR group than the MI-PCF group (39.1% vs 0.0%; p=0.003), but was largely driven by the rate of approach-related dysphagia present in 30.4% of ACDR patients which resolved within 12 weeks. However, the MI-PCF group did have significantly greater revision rates (14.7% vs 0%; p=0.048) due to persistent symptoms postoperatively with an average time to revision of 23.2 months. Both groups demonstrated significant improvement in VAS and NDI scores compared to preoperative values (p<0.001). However, the ACDR cohort had significantly greater improvement in both VAS (3.5 vs 2.1, p<0.001) and NDI (23.7 vs 13.6, p<0.001) scores at final follow-up.

Conclusion: At final follow-up ACDR demonstrated a significantly greater complication rate due to transient approach-related postoperative dysphagia, whereas MIPCF had a greater rate

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of revision to ACDF. Therefore, ACDR may offer more clinically relevant advantages over MI-PCF in terms of long-term revision rates and patient reported outcome measures in the treatment of unilateral cervical radiculopathy.

Table 1. Patient Demographics and Levels Operated On

Demographic	ACDR	MI-PCF	p-value
# of patients	23	34	
Age (years)	43.1	51.6	**0.007***
Males (%)	21.7%	55.9%	**0.010***
BMI (kg/m^2)	30.4	27.4	0.055
Smoking	39.1%	14.7%	**0.036***
Diabetes (%)	17.4%	12.1%	0.579
Months of Follow-Up	67.9	68.3	0.838

ACDR= Anterior Cervical Disc Replacement; MI-PCF= Minimally Invasive Posterior Cervical Foraminotomy; BMI= Body Mass Index; * Indicates significance at 95% confidence level ($p<0.05$)

Table 2. Perioperative Data

Perioperative Data	ACDR	MI-PCF	p-value
EBL (ml)	42.9	19.2	**<0.001***
Operative Time (min)	91.2	66.0	**<0.001***

ACDR= Anterior Cervical Disc Replacement; MI-PCF= Minimally Invasive Posterior Cervical Foraminotomy; EBL= Estimated Blood Loss; * Indicates significance at 95% confidence level ($p<0.05$)

Table 3. Reoperation Rates, Meant Time to Revision, and Postoperative Complications

Demographic	ACDR	MI-PCF	p-value
Revisions	0 (0.0%)	5 (14.7%)	**0.048***
Mean Time to Revision	-	23.2 months	**<0.001***
Complications	9 (39.1%)	0 (0.0%)	**<0.001***
ASD	1 (4.3%)	0 (0.0%)	0.220
Dysphagia	7 (30.4%)	0 (0.0%)	**<0.001***
Dysphonia	0 (0.0%)	0 (0.0%)	0.379
Infection	1 (4.3%)	0 (0.0%)	0.220

ACDR= Anterior Cervical Disc Replacement; MI-PCF= Minimally Invasive Posterior Cervical Foraminotomy; ASD= Adjacent Segment Disease; * indicates significance at 95% confidence level ($p<0.05$)

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WITHDRAWN

PAPER 37

Opioid-free Analgesia is Safe and Effective in Anterior Cervical Spine Surgery: A Randomized Controlled Trial

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Introduction: A number of standardized pain management protocols have been reported following cervical spine surgery, aimed at hastening recovery while lowering opioid consumption. However, to date, no randomized controlled trial has been reported comparing an opioid-free (OF) perioperative pain control pathway to a traditional opioid-containing (OC) pathway for anterior cervical spine surgery. The purpose of this clinical trial was to compare the efficacy of a multimodal OF pain management pathway to an OC pathway in patients undergoing anterior cervical discectomy and fusion or anterior cervical disc arthroplasty procedures.

Materials and Methods: This was a single-center, non-inferior, randomized controlled trial of 50 opioid-naive adult patients (OF = 22, OC = 28) undergoing primary, one- or two-level anterior cervical surgery for degenerative pathology by one of seven fellowship-trained orthopaedic spine surgeons (Table 1). Patients were randomly allocated to one of two perioperative pain management protocols: A multimodality (OF) pathway or a traditional (OC) pathway. Patient characteristics, total morphine milligrams equivalents (MME), and numeric pain rating were measured preoperatively, and at 24-hour, 2-week, and 6-week postoperative time points. Satisfaction with postoperative pain control was collected at 2- and 6-week follow-up. Where applicable, reported values represent median and interquartile range (IQR), unless noted otherwise.

Results: During the surgical encounter, 28 of 28 OC patients consumed a median of 61.25 MME, while 4 of 22 OF patients consumed 7.50 MME (Table 2). At 2 weeks postoperative, 21 OC patients reported taking a median of 250.00 MME and 2 OF patients consumed a median of 45.00 MME. By 6 weeks postoperative, 5 OC patients reported taking a median of 150.00 MME and no OF patients reported opioid consumption. The OF group was statistically non-inferior to the OC group and patients reported significantly lower median postoperative pain levels at 6 hours (4 for OF vs. 7 for OC; p=0.041) and 24 hours (3 for OF vs. 5 for OC; p=.032). At 2- and 6-week follow-up, pain levels were similar between groups. Patients in the OF group reported significantly greater comfort at 12 (9 for OF vs. 5 for OC; p=0.003) and 24 hours (9 for OF vs. 5 for OC; p=0.011) postoperative. Pain satisfaction was similar between groups at 2- (85.7% for OC vs. 86.4% for OF; p>0.99) and 6-week (77.8% for OC vs. 95.2% for OF; p=0.118) follow-up.

Conclusion: The results of this randomized trial support that an OF pathway following anterior cervical spine surgery results in statistically non-inferior pain control and equivalent patient-reported outcomes compared with a traditional OC pathway. Specifically, average

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postoperative pain levels at 6 and 24 hours reported by patients in the OF group were statistically non-inferior to pain levels reported by patients in the OC group. In addition, postoperative comfort levels at 12 and 24 hours reported by patients in the OF group were significantly higher than comfort levels reported by patients in the OC group. To our knowledge, this is the first study to show that OF pain management is possible in this population.

	OC	OF	Overall	p-value
Number of patients	28	22	50	
Number of females	14 (50.0%)	13 (59.1%)	27 (54.0%)	0.577
Age (years)	**53.3 [48.2, 60.2]**	**45.5 [40.3, 51.6]**	**50.4 [44.2, 57.9]**	**0.017***
Body mass index (kg/m^2)	29.3 [25.5, 33.0]	31 [26.6, 37.3]	29.8 [26.4, 34.4]	0.348

Table 1: Comparison of preoperative patient characteristics between patients in the OC and OF pathways. Where applicable, values represent median and [interquartile range, IQR], unless noted otherwise. *Denotes significance, p<0.05.

	OC	OF	Overall	p-value
Total MME				
In-hospital	28 patients: 61.25 [38.25, 108.25]	4 patients: 7.50 [4.75, 7.75]	32 patients: 57.75 [26.00, 102.75]	-
2 weeks	21 patients: 250.00 (45.00, 1,410.00)	2 patients: 45.00 (30.00, 60.00)	23 patients: 135.00 (30.00, 1,410.00)	-
6 weeks	5 patients: 150.00 (125.00, 200.00)	0 patients	5 patients: 150.00 (125.00, 200.00)	-
Average Pain Rating				
Preoperative	6 [5, 8]	7 [6, 8]	7 [6, 8]	0.326
6 hours	**7 [4, 8]**	**4 [0, 6]**	**6 [3, 7]**	**0.041***
12 hours	5.5 [4, 6.5]	5.5 [1, 7]	5.5 [3.5, 7]	0.76
24 hours	**5 [3, 7]**	**3 [2, 5]**	**4 [2, 6]**	**0.032***
2 weeks	6 [5, 9]	6.5 [4, 8]	6 [4, 8]	0.30
6 weeks	4 [1, 5]	3 [2, 5]	3 [1.5, 5]	0.557
Comfort				
6 hours	6 [4, 8]	8 [6, 9]	6 [5, 9]	0.194
12 hours	**5 [4, 6]**	**9 [8, 9]**	**6 [5, 9]**	**0.003***
24 hours	**5 [3, 8]**	**9 [7, 9.5]**	**7 [5, 9]**	**0.011***
Binary Pain Satisfaction				
Satisfied at 2 weeks	24 (85.7%)	19 (86.4%)	43 (86.0%)	>0.99
Satisfied at 6 weeks	21 (77.8%)	20 (95.2%)	41 (85.4%)	0.118
Satisfaction With Surgical Experience	10 [9, 10]	10 [9, 10]	10 [9, 10]	0.309

Table 2: Comparison of postoperative outcomes between patients in the OC and OF pathways. Where applicable, values represent median and [interquartile range, IQR], unless noted otherwise. MME, morphine milligrams equivalents. *Denotes significance, p<0.05.

PAPER 38

20 Year Radiographic Outcomes of BRYAN Cervical Disc Arthroplasty: A Prospective, Randomized, Controlled Trial

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Introduction: Anterior cervical discectomy and fusion (ACDF) has long been considered the standard of treatment for single level cervical disc degeneration causing radiculopathy. However, there is concern that alterations in the biomechanical relationships of the cervical spine may lead to accelerated adjacent level degeneration. Relative to fusion procedures, cervical disc arthroplasty is claimed to reduce the shear strain and adjacent level range of motion (ROM) changes hypothesized to hasten ASD. This prospective randomized controlled clinical trial study evaluates 20 year radiographic outcomes of cervical disc arthroplasty (CDA) versus ACDF.

Materials and Methods: As part of a US FDA IDE trial, a single center collected prospective clinical outcomes data and routine radiographs on 47 patients randomized in a 1:1 ratio to ACDF or arthroplasty. Lateral dynamic and neutral cervical spine radiographs were evaluated in 32 participating patients at preoperative, immediate postoperative, and 20 year follow-up periods for alignment, ROM, adjacent level degeneration, prevertebral ossification, and anterior bone loss.

Results: Seventy-one percent (15 / 21) of patients undergoing CDA returned for 20 year radiographic follow-up compared to 65% (17 / 26) of ACDF patients. At 20 year follow-up, total cervical (C2-C7) ROM was statistically different between the CDA and fusion groups (44.92 degrees vs 33.84 degrees, $p = 0.042$). Total cervical ROM was not significantly different between preoperative and 20 year periods following CDA (49.90 degrees vs 46.63 degrees, $p = 0.634$) and fusion (44.58 vs 34.52, $p = 0.151$). Differences in preoperative and 20 year index-level ROM following CDA were not significant (7.84 degrees vs 8.34 degrees, $p = 0.791$). Cranial adjacent level degeneration was statistically different following ACDF compared to CDA ($p = 0.028$). No difference in ASD formation at the caudal level was found ($p = 0.435$). Of the adjacent levels that did not require operation, adjacent level ossification development was not different at 20 years between CDA and ACDF ($p > 0.10$). Polyethylene mean thickness decreased from 11.53 mm immediately postoperatively to 10.97 mm at 20 year follow up ($p = 0.009$). Changes in adjacent level ROM from preoperative to 20 year follow up in both the ACDF and CDA groups did not meet statistical significance ($p > 0.05$). No patients in the arthroplasty group were noted to have heterotopic ossification at the index disc space. No differences in index-level functional spinal unit height were noted at any period in either treatment group ($p > 0.05$). One patient in the CDA group (6.7%) required reoperation of the cervical spine compared to 6 fusion patients (35.3%; $p = 0.051$).

Conclusion: CDA is an effective alternative to ACDF with superior total cervical ROM and decreased cranial level ASD at long term follow-up. While caudal levels trended toward lower ASD rates in CDA than fusion, these results did not meet statistical significance. This is possibly a consequence of small sample sizes and poor visibility at caudal cervical levels. Our results are consistent with prior evidence that the maintenance of cervical ROM with CDA leads to less compensatory changes and subsequent ASD.

PAPER 39

Five-year Follow-up of a Prospective FDA IDE Trial Evaluating Single-level PEEK-on-Ceramic Cervical Disc Replacement

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Center for Disc Replacement at Texas Back Institute[1] Carolina Neurosurgery & Spine Associates[2] Spine Institute of Louisiana[3] Indiana Spine Group[4] NorthShore University Health System[5] The Spine Institute[6] Texas Back Institute Research Foundation[7]

Introduction: Cervical total disc replacement (TDR) has gained acceptance as a treatment for symptomatic disc degeneration related to symptoms of radiculopathy with/without myelopathy. Clinical outcomes of cervical TDR have consistently been reported to be similar or superior to those of cervical discectomy and fusion. The design and materials used for these devices continue to evolve. The purpose of this study was to evaluate the results during 5-year follow-up of single-level PEEK-on-ceramic cervical TDR

Materials and Methods: Data were from the prospective Food and Drug Administration (FDA) Investigational Device Exemption (IDE) trial for the Simplify cervical disc. The study was based on 150 patients, of which 127 have completed 4-year follow-up, and to date 67 have completed 5-year follow-up which is ongoing. All patients were treated for single-level cervical disc degeneration with symptoms of radiculopathy and/or myelopathy. Evaluations were performed pre-operatively and post-operatively within 2 and 6 weeks, and 3, 6, 12 months and annually thereafter. Radiographs were evaluated by an independent lab specializing in image assessment. Clinical outcome was based on the Neck Disability Index (NDI), visual analog scale (VAS) assessing neck and arm pain, and patient satisfaction. Radiographic measures included flexion/extension range of motion (ROM), disc space height, and heterotopic ossification. Re-operations were also recorded.

Results: The percentage of patients reaching NDI success (defined as at least 15-point improvement from baseline) was more than 90% at the 3 month follow-up and remained greater than 90% throughout 5-year follow-up. The mean NDI scores was 63.3 pre-operatively, reduced significantly to 23.1 at 6-week follow-up, and remained below 20 for the 5-year follow-up duration. VAS pain scores followed a similar pattern improving significantly from a baseline value of 81.6 to 22.9 at 6 weeks post-operative and remaining below 20 through 5-year follow-up. More than 90% of patients reported to be very satisfied or satisfied throughout follow-up. On radiographic parameters, the mean ROM was 7.3o prior to surgery and was 10.3o at the most recent follow-up. Mean disc height increased from 3.3 mm pre-operatively to 4 mm or more during follow-up. Bridging heterotopic ossification was noted in 10% of patients at most recent follow-up. There were 6 re-operations in the series. These included 2 revisions, 2 removals, and 2 patients received supplemental fixation.

Conclusion: This study found that the PEEK-on-ceramic TDR produced significantly improved clinical and radiographic outcomes maintained throughout 5-year follow-up, with bridging heterotopic ossification in 10% of patients. The re-operation rate was similar to other studies. These results add further support to the use of cervical TDR in appropriately selected patients.

PAPER 40

Obesity Does Not Negatively Affect Patient-Perceived Outcomes Following Cervical Disc Replacement for Disc Herniation

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Introduction: Body mass index (BMI) may affect patient-reported outcome measures (PROMs) after spine surgery. Our study aims to assess the impact of BMI on PROMs following cervical disc replacement (CDR).

Materials and Methods: Data from patients who had undergone elective, primary CDR as indicated for herniated disc(s) were retrospectively reviewed from a single-surgeon prospective registry. Patients missing BMI data or with a BMI≥40 were excluded. Cohorts were divided into Non-Obese (BMI<30) and Obese (BMI≥30). In-hospital complication rates were compared between cohorts via independent samples t-tests. Preoperative, 6-week follow-up, and final follow-up PROMs were compared between cohorts via multivariable regression accounting for demographic differences. Final follow-up dates varied between patients, averaging 11.8±9.3 months. PROMs assessed included Patient-Reported Outcomes Measurement Information System-Physical Function (PROMIS-PF), Neck Disability Index (NDI), Visual Analog Scale-Neck (VAS-N), VAS-Arm (VAS-A), and the 9-item Patient Health Questionnaire (PHQ-9). Improvement in PROMs were evaluated at each follow-up period and compared within cohorts via paired t-tests. Magnitude of improvement in PROMs from preoperative baseline at 6-week follow-up (ΔPROM-6W) and final follow-up (ΔPROM-FF) along achievement rates of minimum clinically important differences (MCID) were compared between cohorts via multivariable regression accounting for demographic differences.

Results: 152 patients were included, with 53 noted as Obese. Demographic differences included age, prevalence of hypertension and diabetes, and comorbidity burden scores (p≤0.011, all). No significant variations in in-hospital complications were found. The Non-Obese cohort demonstrated improvements in all PROMs at 6-week and final follow-up periods (p≤0.005, all). The Obese cohort demonstrated improvements in all PROMs at 6-week and final follow-up periods (p≤0.015, all) with the exception of PHQ-9 at 6-weeks. After accounting for variations in age and comorbidity burdens, there were no significant differences in raw PROM scores, ΔPROM-6W, ΔPROM-FF, or MCID achievement rates between cohorts.

Conclusion: Regardless of BMI, patients experience significant improvements in physical function, disability, pain, and mental health following CDR for disc herniation. Obese patients do not suffer inferior patient-perceived outcomes following CDR. These findings may help surgeons counsel patients in the preoperative period.

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Table 1. Patient Demographics and Perioperative Characteristics

Characteristic	Total (n=152)	Non-Obese (n=99)	Obese (n=53)	*p-value
Age (mean±SD, years)	46.9±10.5	45.2±10.3	50.3±10.0	**0.004**
Female Gender	36.8% (56)	38.4% (38)	34.0% (18)	0.590
BMI (mean ± SD, kg/m^2)	28.2±4.8	25.4±3.0	33.5±2.6	-
Ethnicity				0.243
Asian	2.7% (4)	4.2% (4)	0.0% (0)	
Black	6.1% (9)	4.2% (4)	9.6% (5)	
Hispanic	10.8% (16)	9.4% (9)	13.5% (7)	
White	79.1% (117)	80.2% (77)	76.9% (40)	
Other	1.4% (2)	2.1% (2)	0.0% (0)	
Comorbidities				
Smoker	7.2% (11)	6.1% (6)	9.4% (5)	0.444
Hypertension	14.6% (22)	9.2% (9)	24.5% (13)	**0.011**
Diabetes	3.3% (5)	0.0% (0)	9.4% (5)	**0.002**
ASA Score (mean ± SD)	1.9±0.6	1.7±0.6	2.1±0.5	**<0.001**
CCI Score (mean ± SD)	1.0±1.1	0.7±1.0	1.4±1.1	**<0.001**
Insurance Type				0.428
Medicare/Medicaid	3.3% (5)	2.0% (2)	5.7% (3)	
Workers' Comp	21.7% (33)	23.2% (23)	18.9% (10)	
Private	75.0% (114)	74.8% (74)	75.5% (40)	
No. Consecutively Operated Levels				0.238
One	73.7% (112)	76.8% (76)	67.9% (36)	
Two	26.3% (40)	23.2% (23)	32.1% (17)	
Operative Time (min, mean ± SD)	51.0±15.6	50.7±16.8	51.4±13.6	0.801
Estimated Blood Loss (mL, mean ± SD)	26.4±6.3	25.9±5.7	27.2±7.2	0.253
Postoperative LOS (hours, mean ± SD)	7.7±5.7	7.9±6.2	7.4±4.5	0.667
POD 0 VAS Pain	4.7±2.3	4.8±2.3	4.6±2.1	0.547
POD 0 Narcotic Consumption (OME)	19.9±17.7	21.7±20.4	16.7±10.5	0.097

BMI = Body Mass Index; ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD = Standard Deviations; Workers' Comp = workers' compensation; POD = postoperative day of discharge; No.= Number of; SD = standard deviation; LOS = Length of Stay; VAS = Visual analog scale; OME = oral morphine equivalents

*p-value calculated using Chi-square analysis for categorical variables or Student's t-test for continuous variables

Boldface indicates significance

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Table 2. In-Hospital Complications by Body Mass Index

Complication	Non-Obese	Obese	Total	*p-value
Acute Renal Failure	0.0% (0)	0.0% (0)	0.0% (0)	-
Altered Mental Status	0.0% (0)	0.0% (0)	0.0% (0)	-
Anemia, postoperative	0.0% (0)	0.0% (0)	0.0% (0)	-
Arrhythmia	0.0% (0)	0.0% (0)	0.0% (0)	-
Aspiration/Re-intubation	0.0% (0)	0.0% (0)	0.0% (0)	-
Atelectasis	0.0% (0)	0.0% (0)	0.0% (0)	-
Dysphagia	0.7% (1)	0.0% (0)	2.0% (1)	0.175
Epidural Hematoma	0.0% (0)	0.0% (0)	0.0% (0)	-
Fever of Unknown Origin	0.0% (0)	0.0% (0)	0.0% (0)	-
Ileus	0.0% (0)	0.0% (0)	0.0% (0)	-
Incontinence, urinary	0.0% (0)	0.0% (0)	0.0% (0)	-
Nausea/Vomiting	2.8% (4)	3.2% (3)	2.0% (1)	0.659
Pleural effusion	0.0% (0)	0.0% (0)	0.0% (0)	-
Pneumonia	0.0% (0)	0.0% (0)	0.0% (0)	-
Pulmonary Embolism	0.0% (0)	0.0% (0)	0.0% (0)	-
Urinary Retention	0.7% (1)	1.1% (1)	0.0% (0)	0.457
Urinary Tract Infection	0.0% (0)	0.0% (0)	0.0% (0)	-
Venous Thromboembolism	0.0% (0)	0.0% (0)	0.0% (0)	-

*p-value calculated using Chi-square analysis
Boldface indicates significance

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Table 3. Patient-reported outcome measures and minimum clinically important difference

	Non-Obese	†p-value	Obese	†p-value	*p-value
Pre-Op					
PROMIS-PF	41.2±7.8		39.2±6.0		0.502
NDI	41.5±20.1		41.5±12.4		0.882
VAS-N	6.6±2.4		6.0±1.8		0.303
VAS-A	6.0±2.6		5.3±2.7		0.150
PHQ-9	6.5±5.8		6.4±5.0		0.818
6-week Post-Op					
PROMIS-PF	46.5±8.2	**0.002**	44.9±8.1	**0.015**	0.298
NDI	25.9±21.2	**<0.001**	25.9±13.9	**<0.001**	0.886
VAS-N	3.0±2.7	**<0.001**	2.7±1.8	**<0.001**	0.310
VAS-A	2.4±3.1	**<0.001**	2.1±2.1	**<0.001**	0.495
PHQ-9	4.1±5.0	**0.005**	4.9±4.6	0.091	0.551
Final Post-Op					
PROMIS-PF	50.0±9.6	**<0.001**	48.1±10.3	**<0.001**	0.369
NDI	18.7±18.4	**<0.001**	19.9±17.1	**<0.001**	0.928
VAS-N	2.6±2.5	**<0.001**	2.2±2.3	**<0.001**	0.706
VAS-A	2.1±2.7	**<0.001**	2.0±2.5	**<0.001**	0.473
PHQ-9	3.9±5.3	**<0.001**	4.3±4.6	**0.013**	0.656
Δ Pre-Op to 6-week Post-Op					
PROMIS-PF	4.6±8.1		5.0±8.3		0.191
NDI	12.7±19.2		18.7±14.4		0.435
VAS-N	2.9±3.2		3.2±2.6		0.933
VAS-A	3.0±3.9		3.2±2.8		0.442
PHQ-9	2.4±5.7		1.7±4.6		0.399
Δ Pre-Op to Final Post-Op					
PROMIS-PF	9.2±8.9		9.3±10.5		0.731
NDI	23.1±18.8		21.1±19.0		0.642
VAS-N	3.8±3.1		3.6±2.8		0.320
VAS-A	3.5±3.5		3.0±3.4		0.496
PHQ-9	2.8±5.7		1.9±4.2		0.931
MCID Achievement					
PROMIS-PF	79.3%		73.1%		0.586
NDI	77.6%		78.1%		0.922
VAS-N	77.6%		65.6%		0.141
VAS-A	43.9%		45.2%		0.736
PHQ-9	18.3%		18.2%		0.545

*p-value calculated using linear and logistic multivariable regression accounting for demographic variations for patient-reported outcome measures and MCID achievement rates, respectively
†p-value calculated using paired samples t-tests assessing 6-week PROMs and Final PROMs to Preoperative PROMs
Bolding denotes statistical significance ($p<0.05$)

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.

PAPER 41

The Impact of Smoking on Outcomes Following Cervical Disk Arthroplasty: A Quality Outcomes Database Study

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Introduction: Cervical disk arthroplasty (CDA) is a surgical procedure commonly used to treat degenerative cervical spine conditions.[1] While smoking is known to have detrimental effects on other spine surgeries, particularly those involving arthrodesis,[2] its specific impact on outcomes following non-fusion procedures like CDA remains unclear. The purpose of this study is to assess the impact of smoking on clinical outcomes and patient-reported outcomes (PROs) following elective CDA.

Materials and Methods: A retrospective cohort study was conducted querying data from the Quality Outcomes Database for all adult patients who underwent primary elective CDA for degenerative cervical spine conditions. Patients were grouped into smokers and nonsmokers. Propensity score (PS) was constructed for being a current smoker based on covariates, and only patients contained in the PS overlapped region were included in the analysis set. Covariates included age, body mass index (BMI), sex, race, medical comorbidities, indication for surgery, underlying pathology, and baseline PROs, including Visual Analog Scale (VAS) neck and arm pain, neck disability index (NDI) %, and EuroQol-5 Dimension (EQ-5D). Outcomes of interest included complications, 3-month readmissions and reoperations, and 12-month NDI%, VAS neck/arm pain, EQ-5D, and patient satisfaction. Multivariable ordinal logistic regression models were fitted on current smoking status for each of the endpoints, controlling for covariates. Separate models were fitted for myelopathy patients, and baseline modified Japanese Orthopedic Association (mJOA) score was also included as a covariate.

Results: The study included 761 patients, with 650 (81.2%) nonsmokers and 111 (18.8%) smokers. Mean age was 48.3 ± 10.4, mean BMI was 29.29 ± 5.43, 49.9% of patients were male, and 87.4% of patients were white. No differences were found between groups in any demographic variable. A higher proportion of smokers had COPD at baseline (6.2% vs. 1.5%, p=0.003), but no differences were found in any other comorbidity, surgical indication, or underlying pathology. Smokers had significantly worse baseline EQ-5D scores (0.579±0.226 vs. 0.627±0.210, p=0.037) but all other baseline PROs were similar. On comparison of outcomes, smokers demonstrated significantly worse 12-month NDI% (20.5±19.1 vs. 16.0±18.2, p=0.006), neck pain (2.96±2.82 vs. 2.24±2.55, p=0.007), arm pain (2.48±3.00 vs. 1.78±2.54, p=0.01), and EQ-5D (0.780±0.203 vs. 0.840±0.192, p<0.001). There were no differences in 12-month patient satisfaction, or in rates of complications, revisions, or readmissions. On multivariable regression analysis, smoking was associated with worse 12-month NDI% (OR=1.526, p=0.023), neck pain (OR=1.518, p=0.029, arm pain (OR=1.578, p=0.020) and EQ-5D (OR=0.543, p=0.001). In a sub-analysis of myelopathy patients only, smokers had significantly worse 12-month mJOA scores (14.22±2.32 vs. 15.10±2.84, p=0.013), but this was not significant on multivariable regression.

Conclusion: This study provides evidence that smoking has a negative impact on clinical outcomes and patient-reported outcomes following elective cervical disk arthroplasty. The

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results indicate that smokers are at higher risk for worse 12-month NDI%, VAS neck and arm pain, and EQ-5D scores compared to nonsmokers, although there were no differences in patient satisfaction or rates of complications, revisions, or readmissions. The findings suggest that smoking cessation should be encouraged in patients undergoing CDA to optimize postoperative outcomes.

PAPER 42

Is Upper Extremity or Lower Extremity Function More Important for Patient Satisfaction? An Analysis of 24-Month Outcomes from the QOD Cervical Myelopathy Cohort

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Introduction: Patient-reported outcomes (PROs) are key measures of surgical efficacy, with the modified Japanese Orthopaedic Association (mJOA) commonly used to assess patient functional status with cervical spondylotic myelopathy (CSM). CSM notably presents with dysfunction in the upper and/or lower extremities, as captured by the mJOA scale. It is currently unclear whether upper limb or lower limb mJOA improvement is more strongly correlated with patient satisfaction.

Materials and Methods: This study utilizes the prospective Quality Outcomes Database (QOD) from the fourteen highest-enrolling sites to analyze patients undergoing surgical management of CSM. PROs of interest included mJOA and patient satisfaction via the North American Spine Society (NASS) satisfaction index. The upper limb mJOA score was defined as upper limb motor plus sensory mJOA, and the lower limb mJOA score as lower limb motor plus sensory mJOA (range 0-6 for each, respectively). Ordered logistic regression was used to determine whether upper or lower limb mJOA was more closely associated with 24-month NASS satisfaction, while adjusting for other covariates.

Results: Overall, 1,141 patients with CSM were included with 948 (83.1%) reaching 24-month follow-up. This cohort was on average 61±11.5 years old, 457 (48.3%) were female, and mean BMI was 30.1±6.3. Baseline VAS neck pain (VAS-NP) was 5.1±3.3, VAS arm pain (VAS-AP) was 4.8±3.5, and mJOA score was 14.0±2.7. Postoperatively, 789 (83.4%) would undergo surgery again (NASS 1/2; i.e., satisfied). Patients exhibited mean improvement in upper limb (baseline: 4.0±1.4 vs 24m: 5.0±1.1, $p<0.001$) and lower limb mJOA scores (baseline: 3.9±1.4 vs 24m: 4.5±1.5, $p<0.001$), however the magnitude of 24-month upper limb mJOA improvement was larger (upper change: +1.1±1.6 vs lower change: +0.5±1.6, $p<0.001$). Clinically, patients with longer preoperative symptoms had less upper limb mJOA improvement ($p=0.004$). There was no association between symptom duration and lower limb mJOA improvement ($p=0.65$).

With four cohorts based on 24-month NASS satisfaction scores, baseline upper limb mJOA scores were not significantly different across satisfaction levels ($p = 0.096$), but as 24-month NASS satisfaction decreased, 24-month upper limb mJOA improvement decreased as well ($p<0.001$). Similarly, baseline lower limb mJOA scores were not significantly different for

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the four cohorts (p=0.201), but the amount of lower limb improvement decreased as NASS satisfaction decreased (p<0.001). Patients with NASS scores of 4 (lowest satisfaction) did not demonstrate significant improvement in upper (baseline: 3.9±1.4 vs 24m: 4.0±1.2, p=0.58) or lower limb (baseline: 3.8±1.5 vs 24m: 4.0±1.2, p=0.58) mJOA scores. In ordered logistic regression, NASS satisfaction level was independently associated with upper limb mJOA improvement (OR=0.81; 95% CI 0.68-0.97; p=0.019), but not lower limb mJOA improvement (OR=0.84; 95% CI 0.70-1.0; p=0.054).

Conclusion: As patient satisfaction with surgical interventions decreased, so too did the magnitude of upper and lower limb mJOA improvement. Upper limb mJOA improvement is ultimately more associated with patient satisfaction as compared to lower limb mJOA improvement. These findings may aid preoperative counseling, which may be stratified based on a patient's upper and lower extremity treatment expectations.

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Table 1. Demographic comparison of 24-Month mJOA outcomes in patients with cervical spondylotic myelopathy

Table 1. Demographic Groups	24-Month Upper Limb mJOA	24-Month Lower Limb mJOA	Change in Upper Limb mJOA	Change in Lower Limb mJOA
Age				
>= 65	5.0 ± 1.2	4.4 ± 1.5	1.1 ± 1.7	0.7 ± 1.7
< 65	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.5	0.5 ± 1.6
p value	0.92	0.47	0.98	0.12
Gender				
Male	5.0 ± 1.2	4.4 ± 1.5	1.0 ± 1.6	0.5 ± 1.6
Female	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.6 ± 1.7
p value	0.73	0.16	0.62	0.40
BMI				
>= 30	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.5 ± 1.6
< 30	5.0 ± 1.2	4.6 ± 1.5	1.1 ± 1.7	0.6 ± 1.6
p value	0.75	0.16	0.57	0.82
Ethnicity				
Hispanic or Latino	4.8 ± 1.3	3.9 ± 1.8	1.1 ± 1.6	0.2 ± 1.7
Not Hispanic or Latino	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.6 ± 1.6
p value	0.36	0.06	0.96	0.33
Education				
High School or Less	4.9 ± 1.1	4.4 ± 1.5	1.1 ± 1.5	0.6 ± 1.6
College or More	5.1 ± 1.1	4.6 ± 1.5	1.1 ± 1.6	0.6 ± 1.6
p value	0.13	0.14	0.98	0.89
Insurance				
Medicare or Medicaid	4.9 ± 1.2	4.3 ± 1.6	1.1 ± 1.7	0.6 ± 1.7
Private	5.1 ± 1.1	4.6 ± 1.4	1.0 ± 1.5	0.4 ± 1.5
p value	0.16	**0.003****	0.48	0.09
Symptom Duration				
< 3 mos	5.4 ± 0.9	4.7 ± 1.6	1.5 ± 1.6	0.6 ± 1.9
3-12 mos	5.0 ± 1.1	4.6 ± 1.4	1.1 ± 1.6	0.6 ± 1.6
> 12 mos	4.9 ± 1.2	4.3 ± 1.5	0.9 ± 1.5	0.5 ± 1.5
p value	**<0.001****	**<0.001***	**0.004**†	0.65
Primary Indication				
Radiculopathy	5.0 ± 1.1	4.6 ± 1.4	1.1 ± 1.6	0.5 ± 1.5
Myelopathy	5.0 ± 1.1	4.5 ± 1.5	1.1 ± 1.6	0.5 ± 1.6
Neck Pain	4.8 ± 1.3	3.9 ± 1.5	1.7 ± 2.0	-0.2 ± 1.6
p value	**<0.001****	**<0.001***	0.15	0.07

**Difference in upper or limb mJOA score was statistically significant ($p < 0.05$).
†Difference in change in upper or lower limb mJOA was statistically significant between subgroups ($p < 0.05$).

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

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Table 2. Post-operative mJOA Outcomes Stratified by NASS Satisfaction Level

Table 2. 24-Month mJOA Outcomes	NASS 1 (n=610)	NASS 2 (n=182)	NASS 3 (n=89)	NASS 4 (n=62)	*p* value
mJOA					
Baseline mJOA Score	12.4 (2.7)	11.9 (2.8)	11.3 (2.9)	11.8 (2.9)	0.003**
24-Month mJOA Score	14.7 (2.4)	13.6 (2.4)	12.2 (2.9)	11.5 (2.7)	<0.001**
24-Month mJOA Change	2.3 (3.1)	1.7 (3.0)	0.8 (3.2)	-0.1 (3.1)	<0.001**
24-Month Recovery Rate	33.0 (56.8)	14.6 (57.0)	-0.6 (62.8)	-16.9 (71.5)	<0.001**
mJOA Upper Limb					
Baseline Upper Limb Function Score	4.0 (1.3)	3.9 (1.4)	3.6 (1.6)	3.9 (1.4)	0.096
24-Month Upper Limb Function Score	5.2 (1.0)	4.8 (1.2)	4.5 (1.3)	4.0 (1.2)	<0.001**
24-Month Upper Limb Function Change	1.2 (1.5)	0.9 (1.7)	0.9 (1.9)	0.1 (1.5)	<0.001**
No. Full Recovery	253 (41.7)	40 (22.0)	9 (15.5)	5 (5.7)	<0.001**
mJOA Lower Limb					
Baseline Lower Limb Function Score	4.0 (1.5)	3.9 (1.3)	3.7 (1.3)	3.8 (1.5)	0.201
24-Month Lower Limb Function Score	4.7 (1.4)	4.3 (1.4)	3.7 (1.4)	3.4 (1.5)	<0.001**
24-Month Lower Limb Function Change	0.7 (1.7)	0.4 (1.5)	0.1 (1.5)	-0.2 (1.5)	<0.001**
No. Full Recovery	216 (35.6)	36 (19.8)	5 (8.6)	7 (8.0)	<0.001**

mJOA recovery rate was calculated according to the Hirabayashi method.
**Difference was statistically significant ($p < 0.05$).

PAPER 43

Quantitative Romberg on a Force Plate: Objective Assessment After Surgery for Patients with Cervical Spondylotic Myelopathy

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Introduction: Cervical Spondylotic Myelopathy (CSM) is characterized by balance deficiencies produced by impaired proprioception. Evaluation is subjective and binary physical exam findings lack the precision to assess postoperative outcome improvement. The purpose of this study was to evaluate the utility of quantitative Romberg measurements as a pre- and post-op balance outcome measure.

Materials and Methods: CSM patients were prospectively enrolled to undergo pre- and postoperative Romberg tests on a force plate to record center of pressure (COP) motion for 30 seconds with eyes open followed by eyes closed. Revision cases were excluded. Kinematics of COP movement parameters were compared between pre- and postop state for each patient.

Results: LINK Word.Document.12"/Users/kylekesler/Dropbox/Spine/Leatherman/Research/Romberg/DIERS_Pre_Post_Analysis_15Feb2023.docx""OLE_LINK6" a Twenty-seven CSM patients were enrolled and completed pre/post testing. Mean age was LINK Word.Document.12"/Users/kylekesler/Dropbox/Spine/Leatherman/Research/Romberg/DIERS_Pre_Post_Analysis_15Feb2023.docx""OLE_LINK7" a 60.0 years with 13 (48%) males, 9 (33%) smokers. Mean number of surgical levels was 2.48. The minimum mean follow up was six months. There was a statistically significant improvement in eyes closed postop compared to pre-op for total COP motion (523.44cm vs 387.00cm, $p<0.001$), average sway speed (17.41cm/s vs 13.00cm/s, $p<0.001$) and total lateral COP motion (253.44cm vs 186.70cm, $p<0.001$). There was no statistically significant improvement in mJOA (13.29 vs 14.29, $p=0.28$).

Conclusion: CSM balance findings on Romberg quantitative testing significantly improves postoperatively in patients with CSM. These findings support this testing as representative of proprioceptive balance deficiencies seen in CSM. Quantitative Romberg may be used as an objective measure of clinical outcome and assist in stratification of surgical interventions, surgery timing and technique.

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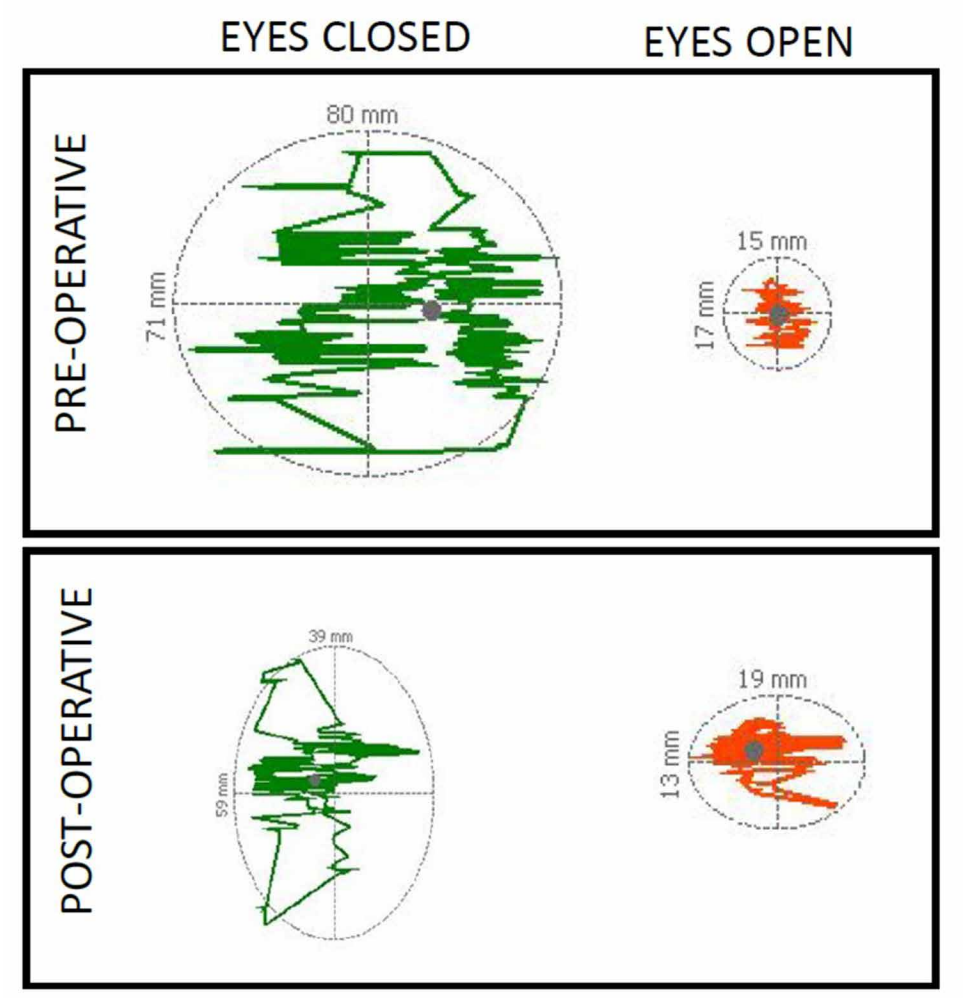

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PAPER 44

Anterior Cervical Discectomy and Fusion Versus Laminectomy and Posterior Cervical Fusion Across 3 Interspaces Using the QOD CSM Module: Are There Differences in Outcomes?

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Introduction: Prior studies comparing anterior versus posterior approaches for multilevel cervical spondylotic myelopathy (CSM) are limited by the heterogeneity of surgical technique. This study specifically focuses on fusions across three interspaces in the cervical spine.

Materials and Methods: The prospective QOD CSM cohort was queried for fusions across three interspaces. Surgeries crossing the cervicothoracic junction were excluded. The cohort was divided into anterior cervical discectomy and fusion (ACDF) and posterior laminectomy and fusion (PCF). Rates of reaching minimum clinically important difference (MCID) for patient-reported outcomes (PROs) were compared at 24 months after anterior versus posterior approaches. Multivariable analyses adjusted for potential confounders elucidated in the univariable analysis.

Results: Overall, 199 patients met inclusion criteria—123 ACDF (60.9%) and 76 PCF (38.2%). Twenty-four-month follow-up rates were similar (ACDF: 90.2% vs. 92.1%, p=0.67). Preoperatively, ACDF were younger (60.8±10.2 vs. 65.0±10.3 years, p<0.01), privately insured (56.1% vs. 36.8%, p=0.02), actively employed at the time of surgery (39.8% vs. 22.8%, p=0.04), and independently ambulatory (14.6% vs. 31.6%, p<0.01). Otherwise, the cohorts had equivalent baseline mJOA, NDI, NRS Arm Pain, NRS Neck Pain, and EQ-5D (p>0.05). Length of stay (1.6 vs. 3.9 days, p<0.01) and non-routine discharge (7.3% vs. 22.8%, p<0.01) were lower for ACDF. Both groups demonstrated improvements in all outcomes at 24 months, compared to baseline (p<0.05). In multivariable analyses, ACDF was associated with the greatest 24-month NASS Satisfaction (NASS 1 score) (69.4% vs. 53.7%, OR=2.44 95%CI [1.17-5.09], $adjusted\text{-}p$=0.02). Otherwise, the cohorts shared similar 24-month outcomes for reaching an MCID in mJOA, NDI, NRS Arm Pain, NRS Neck Pain, and EQ-5D ($adjusted\text{-}p$>0.05). There were no differences in 3-month readmission (ACDF: 4.1% vs. PCF: 3.9%, p=0.97) and 24-month reoperation rate (ACDF: 13.5% vs. PCF: 18.6%, p=0.36).

Conclusion: In a cohort limited to 3-level surgeries, ACDF was associated with shorter lengths of hospitalization and higher routine discharge rates. However, the two procedures yielded comparably significant improvements in functional status (mJOA score), neck pain, arm pain,

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neck pain-related disability, and quality of life at 3, 12, and 24 months. While there were no differences in overall satisfaction (NASS 1 or 2),Importantly, the ACDF cohort had a significantly higher odds of maximum satisfaction (NASS 1).Given comparable outcomes except for maximum satisfaction, patients should be counseled on each approach's complication profile to aid in surgical decision-making.

Table 1. Baseline characteristics of patients undergoing ACDF and PCF at 3 segments.

	ACDF (N=123)	PCF (N=76)	p value
Age, mean (SD)	60.8 (10.2)	65.0 (10.3)	**< 0.01**
Female sex, n (%)	46 (37.4%)	34 (44.7%)	0.30
Body Mass Index, mean (SD)	29.9 (5.7)	28.9 (5.3)	0.21
Insurance payor, n (%)			
Medicaid	9 (7.3%)	8 (10.5%)	**0.03**
Medicare	40 (32.5%)	38 (50.0%)	
Private	69 (56.1%)	28 (36.8%)	
Uninsured	0 (0.0%)	1 (1.3%)	
VA/Government	5 (4.1%)	1 (1.3%)	
Workers' compensation, n (%)	3 (2.4%)	3 (3.9%)	0.55
SES index, (mean (SD)	52.6 (4.7)	53.5 (5.3)	0.22
Preoperative employment status, n (%)			
Employed and active	49 (39.8%)	17 (22.4%)	**0.04**
Employed on short-term leave	7 (5.7%)	6 (7.9%)	
Unemployed	67 (54.5%)	53 (69.7%)	
Smoking, n (%)	23 (18.7%)	12 (15.8%)	0.60
Diabetes mellitus, n (%)	36 (29.3%)	17 (22.4%)	0.28
COPD, n (%)	9 (7.3%)	6 (7.9%)	0.88
Depression, n (%)	31 (25.2%)	19 (25.0%)	0.97
Anxiety, n (%)	22 (17.9%)	18 (23.7%)	0.32
ASA grade, n (%)			
I-II	48 (39.0%)	30 (39.5%)	0.95
III-IV	75 (61.0%)	46 (60.5%)	
Motor deficit, n (%)	80 (65.0%)	56 (73.7%)	0.20
Dependent ambulation, n (%)	18 (14.6%)	24 (31.6%)	**< 0.01**
Symptom duration, n (%)			
<3 months	10 (8.1%)	13 (17.1%)	0.13
3-12 months	48 (39.0%)	30 (39.5%)	
>12 months	65 (52.8%)	33 (43.4%)	
mJOA score at baseline, mean (SD)	12.0 (2.5)	11.4 (3.3)	0.15
Arm pain (NRS) score at baseline, mean (SD)	5.1 (3.4)	4.6 (3.6)	0.25
Neck pain (NRS) score at baseline, mean (SD)	5.6 (3.1)	5.1 (3.2)	0.25
NDI score at baseline, mean (SD)	39.3 (19.7)	35.7 (20.2)	0.22
EQ-5D score (QALY) at baseline, mean (SD)	0.542 (0.218)	0.548 (0.215	0.85

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.

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Figure 1: Unadjusted timeline plots of patient-reported outcomes – ACDF vs PCF

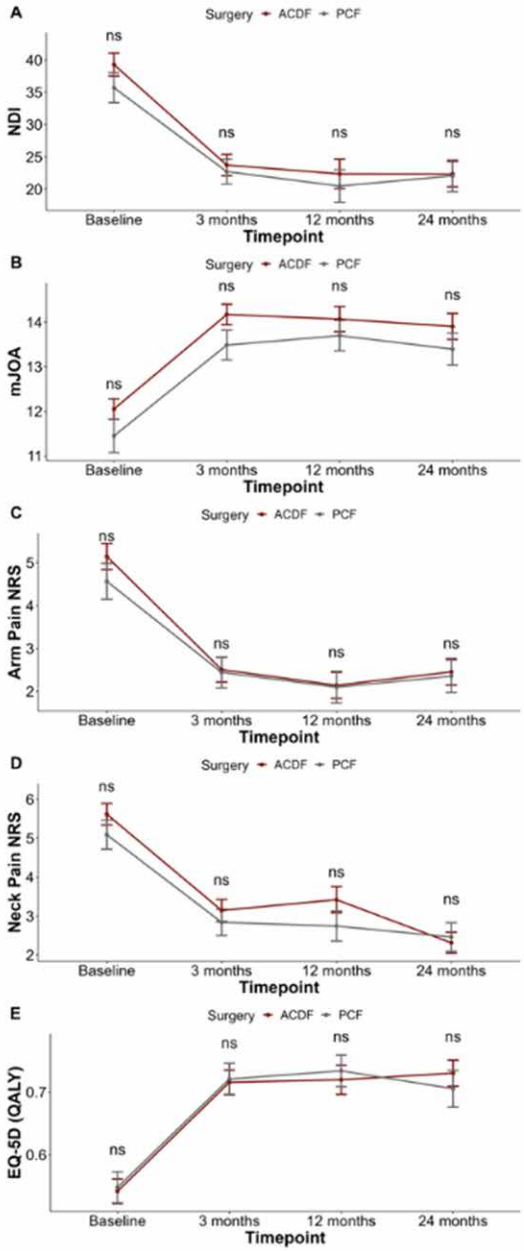

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Table 2. Univariate and multivariable comparison of ACDF and PCF on clinical outcomes and PROs. Odds ratios < 1 suggest that the outcome is associated with PCF more that with ACDF.

	ACDF (N=123)	PCF (N=76)	p value	aOR (95%CI)	Adjusted p-value
24-month follow-up rate (%)	111 (90.2%)	70 (92.1%)	0.67	*Not applicable*	
Estimated blood loss – ml, mean (SD)	77.5 (53.1)	125.6 (127.5)	**<0.01**	-51.8 (-79.5 – -24.2)*	**<0.01**
Not available	6	8			
Length of stay – days, mean (SD)	1.8 (1.6)	3.9 (3.9)	**< 0.01**	-1.7 (-2.49 – -0.92)*	**<0.01**
Not available	7	4			
Non-routine discharge, n (%)	9 (7.3%)	17 (22.4%)	**< 0.01**	0.43 (0.14 – 1.33)	0.14
Dysphagia, n (%)	10 (13.5%)	2 (3.5%)	**0.049**	4.14 (0.68 – 25.33)	0.12
Not available	49	19			
Readmission within 3 months, n (%)	5 (4.1%)	3 (3.9%)	0.97	1.52 (0.24 – 9.35)	0.65
Reoperation within 24 months, n (%)	15 (13.5%)	13 (18.6%)	0.36	0.65 (0.26 – 1.61)	0.36
Not available	12	6			
Return to activities within 3 months, n (%)	47 (45.6%)	27 (40.3%)	0.49	1.48 (0.72 – 3.03)	0.28
Not available	20	9			
Return to activities within 24 months, n (%)	78 (67.8%)	46 (63.0%)	0.50	1.77 (0.85 – 3.65)	0.12
Not available	8	3			
Return to work within 3 months, n (%)	25 (78.1%)	14 (70.0%)	0.51	2.42 (0.39 – 15.00)	0.34
No plans to return to work / NA	91	59			
Return to work within 24 months, n (%)	27 (96.4%)	17 (94.4%)	0.56	*Not applicable*	
No plans to return to work / NA	95	61			
MCID in mJOA at 24 months, n (%)	55 (58.5%)	31 (50.8%)	0.35	1.63 (0.75 – 3.52)	0.22
Not available	29	15			
MCID in arm pain at 24 months, n (%)	61 (57.5%)	31 (47.7%)	0.21	1.92 (0.85 – 4.35)	0.12
Not available	17	11			
MCID in neck pain at 24 months, n (%)	67 (63.2%)	42 (64.6%)	0.85	0.97 (0.41 – 2.27)	0.94
Not available	17	11			
MCID in NDI at 24 months, n (%)	67 (62.0%)	36 (53.7%)	0.28	1.72 (0.81 – 3.65)	0.16
Not available	15	9			
MCID in EQ-5D score (QALY) at 24 months, n (%)	34 (32.1%)	28 (43.1%)	0.15	0.57 (0.21 – 1.46)	0.24
Not available	17	11			
Satisfaction (NASS 1-2) at 24 months, n (%)	95 (88.0%)	53 (79.1%)	0.11	2.41 (0.93 – 6.22)	0.07
Not available	15	9			
Maximal satisfaction (NASS score 1) at 24 months, n (%)	75 (69.4%)	36 (53.7%)	**0.04**	2.44 (1.17 – 5.09)	**0.02**
Not available	15	9			

PAPER 45

Clinical Predicting Models for Diagnosis the Patients with Degenerative Cervical Myelopathy: An Analysis of 180 Cases of Degenerative Cervical Myelopathy Comparison with 1211 Asymptomatic Subjects

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Introduction: Due to its complexity, diagnosing degenerative cervical myelopathy (DCM) is often delayed, leading to poor outcomes.[1] The extent to which neurological examinations may increase the clinical likelihood of DCM is not clear, as no comparison was made with many asymptomatic subjects. The aim of the current study is to establish a prediction model for DCM based on physical examinations.

Materials and Methods: The study included one hundred and eighty DCM cases and 1,211 asymptomatic subjects. Selection criteria were as follows: 1) patient group: DCM patients with MRI evidence of spinal cord compression and archived improvement after surgery. 2) Control group; asymptomatic subjects recruited were between 20 and 79 years, with about 100 individuals per decade, per gender, and performed MRI.

The patient group was compared to the control group in terms of age, gender, and pyramidical signs (BTR, TTR, Hoffmann reflex, PTR, ATR, Babinski sign): positive for hyperreflexia and negative for non-hyperreflexia, upper extremity motor deficits, upper extremity sensory disturbance by touch and pinprick, and the number of 10-second grip and release tests. Multiple logistic regression analysis was used to calculate a DCM prediction model based on the above-described findings. 1) Model A was calculated from all parameters 2) Model B was calculated excluding sensory impairment and motor deficits 3) Model C was calculated from age, gender, Hoffmann reflex, PTR, and 10-second test only.

Results: The sensitivity and specificity of each neurological finding are shown in Table 1. Multiple logistic regression analysis showed that the area under the curve for Model A was 0.998. (Figure 1A) Model B had an AUC of 0.985 (Figure 1B) and Model C had an AUC of 0.97. (Figure 1C) In all models, older age, positive Hoffmann reflex, and exaggerated PTR had higher odds ratios. Men and fewer 10-second grip and release tests were significant parameters in the model B and C. (Table 2)

Conclusion: The prevalence of spinal cord compression increases with age, and spinal cord compression is a future risk for developing DCM. [2] However, there was an underestimation of DCM diagnosis in the elderly population. [3] Hence the importance of the neurological examination will be more emphasized.

Even if motor deficits and sensory disturbance, which can occur with peripheral neuropathy like carpal tunnel syndrome or cervical radiculopathy were excluded,[4] the model B showed high AUC with the additional information of the 10-second grip and release test and gender. Symptoms may be difficult to serve as markers in DCM diagnosis due to their heterogeneity. [5] The examinations in the model C may be practically useful for primary care doctors

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because simple and quick to examine. The limitation is that the study included asymptomatic subjects and relatively severe DCM, and further comparisons with patients with peripheral neuropathy and cervical spondylotic radiculopathy, which are more in line with the real world, are needed. By comparing the physical examinations of a large number of asymptomatic subjects, the current study was able to determine for the first time the weighting of physical examinations useful for the diagnosis of DCM.

Table 1 Univariate analysis and accuracy of neurological examinations

	DCM	Normal	P
Age	68.2±11.5	49.5±16.8	<0.001
Female(%)	55 (30.6)	605 (50.0)	<0.001
10 second grip and release test	14.4±5.2	22.0±5.7	<0.001
	Sensitivity	Specificity	
BTR	23.9%	89.2%	
TTR	64.4%	81.4%	
PTR	87.8%	78.2%	
ATR	61.1%	80.7%	
Hoffmann reflex	68.3%	97.2%	
Babinski sign	54.4%	97.5%	
Sensory disturbance	88.9%	98.5%	
Motor deficits	63.3%	93.5%	

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Table 2. Clinical prediction models for diagnosis of DCM

Item	z	P	Odds ratio	Δβ	95%CILL	95%CIUL
Model A						
Age	3.71	0.00021	1.63	5	1.26	2.12
female	-1.29	0.19	0.43	1	0.12	1.53
exaggerated BTR	-2.75	0.0059	0.057	1	0.007	0.43
exaggerated TTR	-1.19	0.23	0.34	1	0.059	1.97
positive Hoffman reflex	4.05	0.00005	72.54	1	9.15	575.12
exaggerated PTR	4.69	<0.001	247.05	1	24.82	2459.20
exaggerated ATR	-2.91	0.0036	0.20	1	0.069	0.59
positive Babinski sign	4.64	0	89.09	1	13.38	593.20
S-D	6.16	0	589.44	1	77.66	4473.45
Motor deficits	3.20	0.0013	12.53	1	2.67	58.75
10 second grip and release test	0.159	0.87	1.045	5	0.606	1.80
Model B						
Age	5.58	<0.001	1.50	5	1.30	1.73
female	-2.72	0.0065	0.31	1	0.13	0.72
exaggerated BTR	-2.76	0.0057	0.17	1	0.05	0.60
exaggerated TTR	-1.27	0.20	0.51	1	0.18	1.42
positiveHoffmann reflex	6.61	<0.001	71.78	1	20.24	254.47
exaggerated PTR	8.25	<0.001	71.62	1	25.97	197.53
exaggerated ATR	-5.52	<0.001	0.14	1	0.071	0.28
positive Babinski sign	6.22	<0.001	30.33	1	10.35	88.84
10 second grip and release test	-4.54	0.00001	0.38	5	0.25	0.57
Model C						
Age	6.73	<0.001	1.46	5	1.31	1.64
female	-4.4	0.00001	0.22	1	0.11	0.43
positive Hoffman reflex	9.04	<0.001	23.86	1	11.99	47.46
exaggerated PTR	6.41	<0.001	9.6	1	4.81	19.15
10second grip and release test	-6.48	<0.001	0.34	5	0.24	0.47

Figure 1

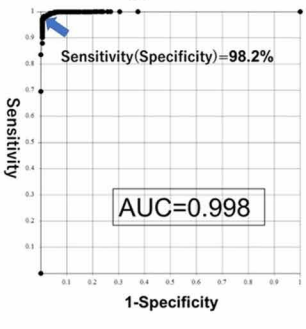


Figure 2

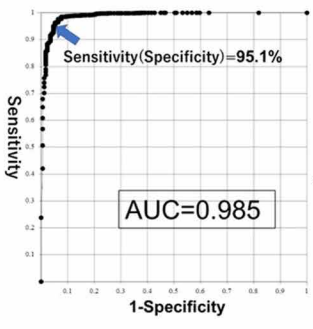
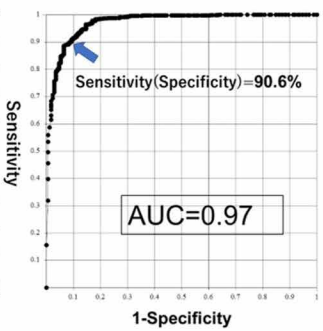


Figure 3



PAPER 46

Development of the Cervical Myelopathy Severity Index: A New Myelopathy Specific Patient Reported Outcome Measure to Facilitate Clinical Care and Research

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Introduction: Patients with DCM exhibit a heterogenous constellation of signs and symptoms including impaired sensation, loss of hand dexterity, gait imbalance, neck and upper extremity pain and sphincter disturbance, with the severity of symptoms and associated impairments, ranging from minimal to severe (1-3). Existing degenerative cervical myelopathy (DCM) severity scales have significant shortcomings, including poor sensitivity to clinical change in patients with mild symptoms, modest reliability and lack of items pertaining to neck and upper-extremity pain (4-6). There is a need to develop an improved DCM specific outcome measurement tool to facilitate clinical care and research. We report the item generation and reduction of the Cervical Myelopathy Severity Index (CMSI), a new DCM patient-reported outcome measure of symptoms and functional limitations.

Materials and Methods: This prospective observational study included adult DCM patients belonging to one of three treatment groups: 1) observation, 2) preoperative surgical, 3) 6-12 months postoperative treatment groups. Item generation was performed using semi-structured patient focus groups emphasizing symptoms experienced and functional limitations. Readability was assessed through think-aloud patient interviews. Item reduction involved surveys of DCM patients with a spectrum of disease severity and board-certified spine surgeons experienced in the treatment of DCM. A priori criteria for item removal included: patient median importance/severity <2 (of 4), 30% or more no severity (response of zero), item severity correlations $\leq$ 0.80 (Spearman), item severity reliability (weighted kappa <.60) based on a 2-week interval and clinician median importance <2 with retention of items with very high clinical importance.

Results: There were 42 items generated from a combination of specialist input and patient focus groups. Items captured sensorimotor symptoms and limitations related to upper and lower extremities as well as sphincter dysfunction. Ninety-eight patients (43, 30, 25 observation, pre- and post-surgery, respectively) and 51 surgeons completed the assessment. Twenty-three items remained after application of median importance and severity thresholds and weighted kappa cutoffs. After elimination of highly correlated (> 0.80) items and combining two similar items, the final CMSI questionnaire list included 14 items. This final list captured the following domains of functional limitation and symptoms: upper extremity sensory (2 items), upper extremity motor (5 items), upper extremity sensorimotor (1 item), lower extremity sensory (1 item), lower extremity motor (1 item), lower extremity sensorimotor/ balance (3 items) and sphincter function (1 item). A summative score can be determined (out of 42), with higher values reflecting greater DCM severity.

Conclusion: We have developed a new patient-completed 14-item measure for patients with

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DCM to evaluate symptom severity and functional limitations (Table 1). Importantly, individual subgroups of DCM patients in observation, pre-operative, and post-operative cohorts were included to ensure the spectrum of myelopathy was represented by the CMSI. Future work will employ multi-center design to study the validity, reliability and responsiveness of this measure. If these properties are confirmed, the incorporation of CMSI could help to improve clinical care, communication and research in this field.

Table 1. Cervical myelopathy severity index after item reduction.

Item	Domain
1. discomfort or pain in the upper extremity (arm/hand)?	Upper extremity sensory
2. numbness or tingling in the hand(s)?	Upper extremity sensory
3. using your hands to perform everyday tasks?	Upper extremity motor
4. picking up small objects (e.g., pins, beads, small screws, or nails, etc.)?	Upper extremity motor
5. opening food packaging, snack wrappers?	Upper extremity motor
6. opening a jar?	Upper extremity motor
7. doing up small buttons like those on a shirt or blouse?	Upper extremity motor
8. dropping light objects such as cup or cutlery?	Upper extremity sensorimotor
9. numbness or tingling in the leg(s)?	Lower extremity sensory
10. quickly changing direction when walking (e.g., quickly turn around if someone were to call your name while walking)?	Lower extremity motor
11. going up or downstairs due to your balance? (use the hand-rail)	Lower extremity sensorimotor / balance
12. feeling unsteady on the feet or walking?	Lower extremity sensorimotor / balance
13. concerns about falling?	Lower extremity sensorimotor / balance
14. difficulty controlling or emptying the bladder?	Sphincter function

PAPER 47

The Degenerative Cervical Myelopathy Subjective and Objective Score (DCM-SOS): A Novel Outcome Measure

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Introduction: Degenerative cervical myelopathy (DCM) is a common, debilitating, and treatable condition in which the discs, ligaments and vertebrae compress the cervical spinal cord causing neurological dysfunction[1-3].Clinical management of DCM is informed by clinical practice guidelines (CPGs) that recommend surgical treatment for patients categorized with moderate to severe neurological impairment, and patients with mild impairment that deteriorate. However, categorization of DCM severity is based solely on the modified Japanese Orthopedic Association (mJOA) score, which is a simplistic and subjective tool that assesses 4 domains on ordinal scales (using terms such as "mild" or "severe") [1-3]. In this study, we sought to develop and validate a novel outcome measure, the DCM Subjective and Objective Score (DCM-SOS) that combines subjective questions with a brief objective scored neurological examination.

Materials and Methods: A prospective cohort study was conducted with extensive data collection that included demographics, medical history, symptom history (duration, severity, etc.), mJOA, NDI, QuickDASH, EQ-5D-5L, EQ-VAS, power testing in 22 myotomes, JAMAR grip dynamometer, 1-2, 1-5, and 2-3 digit pinch dynamometer, sensory testing (light touch - LT, pin prick - PP, monofilaments, proprioception, vibration) in upper extremities (UE) and lower extremities (LE), GRASSP-Myelopathy (UE strength, sensation, dexterity), Berg Balance, manual gait and balance testing, and quantitative gait and balance testing using an electronic Protokinetics Zeno Walkway (self-paced, fast-paced, tandem gait, tandem stance, Romberg, standing on one foot). Subjective questions were developed based on differences between DCM and healthy subjects including those used in mJOA but with more explicit scoring of levels. Objective physical measurements were selected for inclusion based on the following criteria: significant differences between DCM and healthy controls, correlation with mJOA score, no correlation with age (in healthy subjects), and no requirement for specialized equipment.

Results: 95 patients with DCM and 80 healthy subjects were enrolled. Subjective ordinal questions were developed for UE coordination, UE strength, LE ambulation, UE and LE sensation, urinary/bowel/sexual function, and overall pain ($p = 6 \times 10^{-11}$). Among 278 objective measurements that were considered for inclusion, the following showed strong differences between DCM and healthy subjects and were selected based on the criteria above: manual power testing of 1st dorsal interosseous ($p = 1 \times 10^{-14}$), thumb opposition ($p = 6 \times 10^{-12}$), finger extension ($p = 4 \times 10^{-7}$), elbow flexion ($p = 1 \times 10^{-6}$), and elbow extension (3×10^{-6}); sensory testing of UE PP ($p = 1 \times 10^{-7}$), and UE LT (1×10^{-7}); tandem gait score (4×10^{-8}); and reflex testing for Hoffman, Tromner, or Babinski ($p = 6 \times 10^{-7}$). A draft version of the DCM-SOS was developed with 6 subjective domains (/30 points) and 4 objective domains (/30 points).

Conclusion: The DCM-SOS is a data-driven outcome measure that can be performed in 5-10 minutes without specialized equipment and incorporates focused subjective and objective data regarding neurological function. Validation of this tool in a large prospective cohort is

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ongoing, with the hope that this may help improve clinical management, inform future CPGs, and enhance clinical trials for patients with DCM.

Table 1:

		DCM	Control	P-value
Demographics				
	Age	37.9 ± 11.46	66.6 ± 3.55	
	Gender	39 F, 21 M	38 F, 22 M	
Motor Strength (scored out of 5)				
	UE Motor Deficit	4.4 ± 0.2	5 ± 0.0	1.44E-67
	LE Motor Deficit	4.7 ± 0.1	5 ± 0.0	5.47E-35
	Intrinsic Hand	4.5 ± 0.2	4.9 ± 0.1	6.12E-41
	Jamar Hand Grip			8.4E-8
Sensation (scored out of 2)				
	UE Pinprick Deficit	1.8 ± 0.2	2 ± 0.0	5.9E-11
	LE Pinprick Deficit	1.9 ± 0.0	2 ± 0.0	2.5E-13
	Vibration	0.7 ± 0.2	1.9 ± 0.1	3.1E-7
	Proprioception	1.7 ± 0.2	1.9 ± 0.2	2.29E-4
Reflexes				
	Special reflexes	0.5 ± 0.1	0.1 ± 0.1	1.98E-7
Symptom History (severity out of 10)				
	Gait Imbalance	2.5 ± 2.9	0.1 ± 0.82	1.28E-10
	Hand Coordination	2.3 ± 3.16	0 ± 0	7.9E-9
	UE Weakness	2.0 ± 2.48	0.1 ± 0.57	2.69E-8
	UE Numbness	3.0 ± 3.22	0.2 ± 0.89	4.9E-10
	LE Weakness	1.5 ± 2.56	0 ± 0.27	7.14E-7
	LE Numbness	1.3 ± 2.31	0 ± 0	7.1E-7
	Neck Pain	3.9 ± 2.8	1.5 ± 2.4	5.38E-8
Manual Gait Testing Assessing Trunk Correction and Touch Downs				
	Standing 1 Foot			6.8E-8
	Tandem Stance			3.37E-7
	Tandem Gait			8.8E-8

Figure 1: Brief Description of DCM SOS Score

		Max Score	mJOA
Subjective (30)	Upper Extremity Coordination	5	Included
	Upper Extremity Strength	5	
	Ambulation	5	Included
	Upper Extremity Sensation	5	Included
	Lower Extremity Sensation	5	
	Bladder/Bowel/Sexual Fxn	5	Bladder Only
Objective (30)	Strength Testing	10	
	Sensation Testing	10	
	Tandem Gait	5	
	Reflexes	5	
	Balance	10	

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PAPER 48

Impact of Cervical Spondylotic Myelopathy on Preoperative and Postoperative Care Dependency: A Quality Outcomes Database (QOD) Study

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Introduction: Chronic degenerative diseases have been associated with reduced quality of life and dependency on others for personal needs and care. The aspect of preoperative and postoperative care dependency has yet to be explored in patients with cervical spondylotic myelopathy (CSM).

Materials and Methods: The CSM dataset of the Quality Outcomes Database (QOD) was queried. Care dependency was assessed using the personal care component of the Neck Disability Index (NDI) questionnaire – an ordinal scale from 0 to 5; 5 being the inability to get dressed with activity restriction. Numeric rating scale (NRS) arm pain, neck pain, and EuroQol-5D (EQ-5D) in quality-adjusted life years (QALY) scores were recorded up to 24 months postoperatively. Multivariable logistic regression analyses were performed to identify baseline risk factors for the inability to care for oneself and the symptoms leading to care dependency at 24 months postoperatively.

Results: Of the 1,137 patients with CSM who underwent surgical management, 167 patients (14.7%) were care-dependent at baseline (NDI personal care score > 2). Patients with care dependency were predominantly Medicare beneficiaries, had a high school or lower level of education, with severe myelopathy at baseline. At 24-month follow-up, 112 (81.8%) patients who were dependent before surgery became independent in the ability to take care of themselves. Patients who experienced a resolution in their care dependency at 24 months had higher EQ-5D scores ($p < 0.01$). Neck pain, upper extremity dysfunction, lower extremity dysfunction, and bladder dysfunction were symptoms that were significantly associated with care dependency at 24 months postoperatively ($p < 0.01$).

Conclusion: Personal care impairment is a rare, yet burdensome, consequence of CSM. Surgical management of CSM helped to achieve independence in personal care. Patients who regained the ability to care for themselves postoperatively reported a better quality of life.

PAPER 49

Selective Modified K-line Interval on T2-weighted MRI can Predict JOA Recovery Rate After Posterior Decompression Surgery in Patients with Cervical Spondylotic Myelopathy

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Introduction: Modified K-line interval (mK-line INT) was reported by Taniyama et al., as the distance between the anterior compression factor of the spinal cord and a line connecting the midpoints of the spinal cord at C2 and C7 level on sagittal MRI, named "mK-line." mK-line INT less than 4mm reportedly predicts insufficient decompression after posterior decompression in patients with cervical spondylotic myelopathy (CSM). However, when the spinal cord is decompressed not throughout C2-7 but only at selected intervertebral levels, the level where mK-line INT is measured is not always included in the decompression levels or corresponds to the most stenotic level where mK-line INT ideally should be measured. This study aimed to propose "selective mK-line (SmK-line)" that is drawn within the selected decompression levels, and to investigate the efficacy of SmK-line interval (SmK-line INT) to predict surgical outcomes after posterior decompression in patients with CSM.

Materials and Methods: SmK-line was defined as the line connecting the midpoints of the spinal cord at the rostral endplate level of the uppermost vertebra and at the caudal endplate level of the lowermost vertebra of the intended decompression levels on sagittal T2-weighted MRI. SmK-line INT was defined as the minimum distance between the anterior compression factor and SmK-line. Consecutive 62 patients (44 males, 18 females, mean age 68.8 years) with CSM who underwent posterior decompression at our institute from 2015 to 2021 with minimum 1 year follow-up were reviewed (laminoplasty in 40 patients, muscle-preserving selective laminectomy in 22 patients, mean number of decompressed levels 3.4). Patients' demographics (age and sex), clinical parameters (preop and postop JOA scores, and JOA recovery rate [RR] at 1 year postop), radiographic parameters (C2-7 cobb and local cobb of decompressed levels on lateral radiographs, and mK-line INT and SmK-line INT on MRI), the most stenotic level, and the levels where mK-line INT and SmK-line INT were measured were recorded. Multiple regression analysis was performed to identify the parameters associated with JOA RR. Receiver operating characteristic (ROC) curve was used to determine the cut-off value of mK-line INT and SmK-line INT predicting poor outcomes, i.e; JOA RR less than 40%.

Results: Mean values of mK-line INT and SmK-line INT were 4.4 ± 2.0mm and 3.7 ± 1.8mm, respectively. mK-line INT was measured outside the decompression levels in 14 patients (22.6%). The percentage of the patients whose mK-line INT or SmK-line INT were measured at the most stenotic level were 64.5% (mK-line INT) and 85.5% (SmK-line INT, p=0.006). Multiple regression analysis revealed that mK-line INT (p=0.03), age (p=0.01), and SmK-line INT (p=0.007) were associated with JOA RR. Area under the ROC curve and the cut-off value of mK-line INT and SmK-line INT to predict poor JOA RR was 0.568 (p=0.03) and 4.7mm (mK-line INT, sensitivity 68.2%, Specificity 52.5%), and 0.714 (p=0.01) and 3.4mm (SmK-line INT, sensitivity 77.3%, Specificity 70.0%), respectively.

Conclusion: SmK-line INT, which is measured within the intended decompressed levels, can

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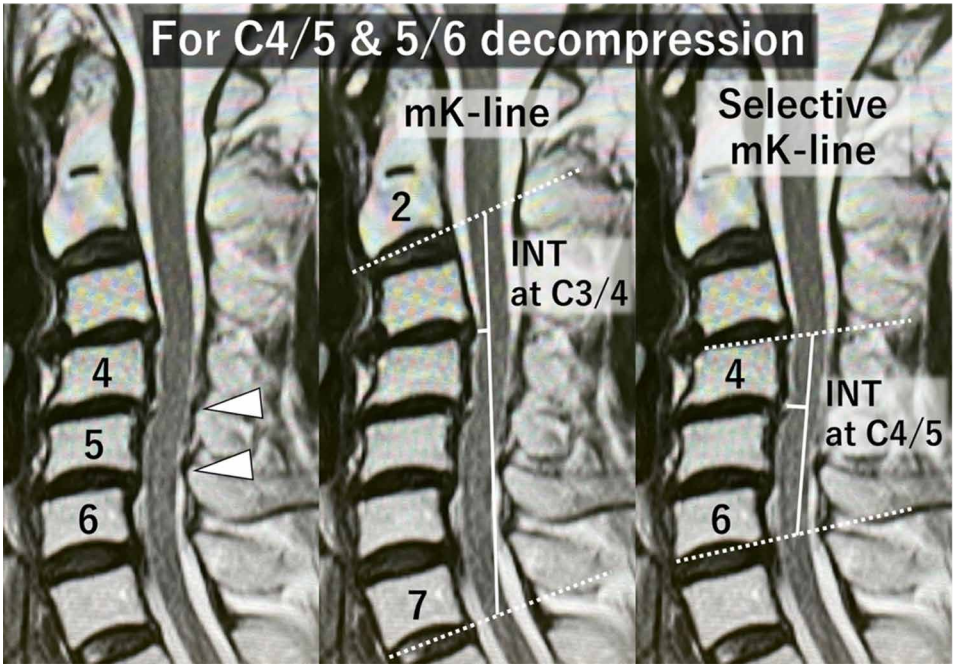
evaluate the magnitude of anterior compression factor at the most stenotic level and predict JOA RR more accurately than mK-line INT.



PAPER 50

Which Social Determinants of Health Affect the Odds of Readmission Following Surgical Treatment of CSM?

Mohamed Macki, MD, MPH[1], Vardhaan Ambati, BS[1], Timothy Chryssikos, MD, PhD[1], Andrew Chan, MD[2], Dean Chou, MD[2], Erica Bisson, MD, MPH[3], Mohamad Bydon, MD[4], Anthony Asher, MD[5], Domagoj Coric, MD[5], Eric Potts, MD[6], Kevin Foley, MD[7], Michael Wang, MD[8], Kai-Ming Fu, MD, PhD[9], Michael Virk, MD, PhD[9], John Knightly, MD[10], Scott Meyer, MD[10], Paul Park, MD[11], Cheerag Upadhyaya, MD[12], Mark Shaffrey, MD[13], Luis Tumialan, MD[14], Jay Turner, MD[14], Oren Gottfried, MD[15], Christopher Shaffrey, MD[15], Regis Haid, MD[16], Praveen Mummaneni, MD, MBA[1]

UCSF[1] Columbia University[2] University of Utah[3] Mayo Clinic[4] Carolina Neurosurgery and Spine Associates[5] Goodman Campbell Brain and Spine[6] Semmes Murphy Clinic[7] University of Miami[8] Weill Cornell Medicine[9] Atlantic Health System[10] University of Michigan[11] UNC Chapel Hill[12] University of Virginia[13] Barrow Neurological Institute[14] Duke University[15] Atlanta Brain and Spine[16]

Introduction: There has been increased focus on studying how social determinants of health affect patient outcomes. As cervical spondylotic myelopathy (CSM) is the leading indication for spine surgery, we aim to determine which SDOH affect rates of readmission following surgical treatment for CSM.

Materials and Methods: Prospectively collected data from the 14 highest enrolling sites of the Quality Outcomes Database was queried for cervical spine surgeries. Data on social determinants of health included age, gender, sex, socioeconomic status (SES) index (a standardized measure created by the US Department of Health and Human Services), insurance payor, education level, and employment. Univariable and multivariable logistic regression analyses were performed to identify social predictors of early readmission following surgery for CSM.

Results: Among 1,128 CSM patients who underwent surgery, the rate of readmission within 90 days was 5.5%. Univariate logistic regression found a significant association between completion of high school/GED level education (compared to those who did not complete high school) and decreased rates of readmission (OR: 0.28, 95% CI: 0.10-0.78, p=0.015). Importantly, univariate analysis found no association between readmission rates and the following: SES index, gender, race (white, black, Asian, Native American/Alaskan Native, Native Hawaiian/Pacific islander), insurance payor (private, Medicare, Medicaid, VA/Government), and employment status. Further, after controlling for the potential confounders of SES index, gender, race, insurance payor, and employment status in a multivariate logistic regression model, only education was statistically significantly associated with 90-day readmissions. Patients who completed high school/General Educational Development (GED) equivalent compared to those with a below high school-level education demonstrated a 74% decreased odds of readmission (ORadj=0.26, 95% CI: 0.09-0.77, adjusted-p=0.015).

Conclusion: CSM patients with a high school-level (or above) education have reduced odds of readmission compared to those who did not complete high school. Education is repeatedly cited as a major social determinant of health that affects health outcomes in a number of medical conditions. Our findings suggest that this trend holds true for CSM and its treatment. Previous studies indicate that patient-centered strategies, including adequate education on postoperative care, avoidance of jargon, and increased follow-up, have been shown to improve outcomes and may be applicable to CSM patients with limited education.

PAPER 51

The Comparison Between Ossification of Posterior Longitudinal Ligament and Cervical Spondylotic Myelopathy Patients in Health-related Quality of Life: A Multicenter Cross-sectional Study

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Introduction: Ossification of the posterior longitudinal ligament (OPLL) can occur throughout the entire spine. There have been many reports on epidemiological studies, the risk of developing myelopathy, and treatment outcomes. Although patients with cervical spondylotic myelopathy (CSM) also present with myelopathy, there have been very few reports focusing on the difference in the health-related quality of life (HR-QOL) between these two diseases. Therefore, we have prospectively collected patient-based data on neurological symptoms and pain-related questionnaires of patients with cervical OPLL(C-OPLL) from multiple centers nationwide. This study aims to compare each item of HR-QOL of C-OPLL patients with that of CSM patients and investigate associated symptoms for each HR-QOL domain in each disease.

Materials and Methods: C-OPLL patients who visited 16 institutions with symptoms from September 2015 to December 2017 and symptomatic CSM patients during the same period were also enrolled. Demographic data and the score of the SF-36, JOA-BPEQ, and JOA-CMEQ were evaluated in each patient. Propensity score matching analysis was used to determine the differences in SF-36 between these diseases. Multi-regression analysis was used to investigate associated symptoms with each HR-QOL domain in each disease.

Results: A total of 246 C-OPLL patients (167 males, 79 females) and fifty-one CSM patients (33 and 18) were included. There were significant differences between these groups in Body Mass Index (BMI), age, and JOA scores. Propensity score matching analysis was performed for sex, age, BMI, and JOA score. After the one-to-one matching analysis including fifty-one pairs of each group, there were no significant differences in the demographic data. CSM patients had significantly lower scores in Role Physical (RP), Bodily Pain (BP), and Role Emotional (RE) of the SF-36 (Fig. 1-3). We additionally investigated which domain of pain score had a stronger impact on BP in the SF-36 in each disease. Neck pain had significant effects on CSM patients (Table 1), whereas Neck pain, low back pain, and numbness of upper limbs significantly affected in C-OPLL patients (Table 2).

Conclusion: This study is the first high-volume multicenter study that analyzed the characteristics of C-OPLL patients and CSM patients in terms of HR-QOL. Even with similar degrees of neuropathy between the two groups, bodily pain, and daily physical and mental function were worse in the CSM patients than in the C-OPLL patients. A previous study reported that continuous-type C-OPLL patients complained less of neck pain than segmental or mixed-type patients. Taking this evidence, mobility of the cervical spine might cause severe pain in CSM patients.

In terms of BP, not only neck pain but the low back pain had significant effects in C-OPLL patients. It had been reported that C-OPLL patients had diffuse idiopathic skeletal hyperostosis (DISH) with high probabilities. More bony bridging and mechanical stress to the thoracolumbar lesion might cause back pain.

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In conclusion, C-OPLL patients would less impaired HR-QOL than CSM patients, but would complain of not only the symptoms of myelopathy but low back pain.

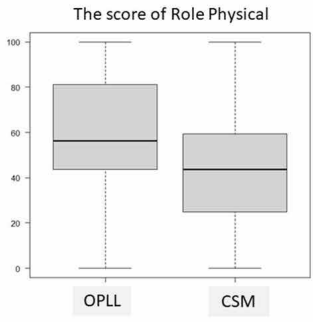

Figure 1

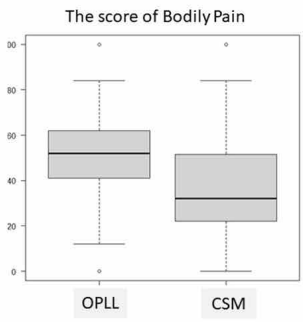

Figure 2

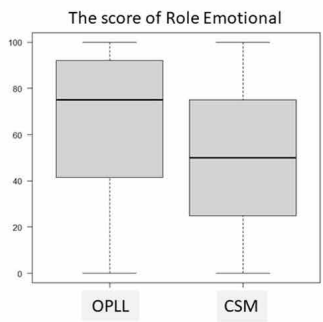

Figure 3

CSM	B	lower95% CI	upper 95% CI	p -value
Low back pain	-0.023	-0.283	0.236	0.857
Pains in buttock and lower limbs	-0.141	-0.367	0.084	0.214
Numbness of buttock and lower limbs	0.035	-0.189	0.258	0.757
Neck Pain	-0.274	-0.527	-0.022	0.034
Chest tightness	-0.059	-0.398	0.279	0.726
Numbness of upper limbs	-0.181	-0.416	0.054	0.128
Numbness of lower limbs	0.008	-0.227	0.244	0.943
Adjusted R-squared: 0.269				

Table 1

OPLL	B	lower95% CI	upper 95% CI	p -value
Low back pain	-0.158	-0.278	-0.037	0.011
Pains in buttock and lower limbs	-0.06	-0.206	0.085	0.414
Numbness of buttock and lower limbs	-0.102	-0.243	0.038	0.153
Neck Pain	-0.262	-0.363	-0.16	0.000000743
Chest tightness	0.032	-0.105	0.169	0.643
Numbness of upper limbs	-0.11	-0.202	-0.018	0.0191
Numbness of lower limbs	-0.018	-0.142	0.106	0.776
Adjusted R-squared: 0.380				

Table 2

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

PAPER 52

Factors Associated with Repeat Surgery in Cervical Ossification of the Posterior Longitudinal Ligament: An 8-year Follow-up Study

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Introduction: Cervical ossification of the posterior longitudinal ligament (C-OPLL) is a common spinal disorder that can lead to neurological deficits and requires surgical intervention. While surgery can alleviate the symptoms and prevent further damage, some patients experience recurrence of OPLL and require repeat surgery. Identifying the factors that contribute to repeat surgery is crucial for improving the long-term outcomes of OPLL surgery. Our findings provide important insights into the long-term outcomes of OPLL surgery and can help guide clinical decision-making for the management of this complex spinal disorder.

Materials and Methods: This study is a retrospective single-center study that included 117 patients who underwent surgery for C-OPLL and had a follow-up of at least 8 years. OPLL type, surgical extent, surgical method, and sagittal radiological parameters were measured, and OPLL characteristics were analyzed.

Results: The mean age of patients at surgery was 53.4 years, with a male-to-female ratio of 71:45. The median follow-up period was 114 months (range: 97-163 months), and 21 cases (17.9%) required repeat surgery for Cervical OPLL. No cases of repeat surgery were observed in patients who underwent posterior decompression and fusion surgery, while 10 cases (8.5%) required repeat surgery in the surgical site, including 3 cases after anterior surgery (AP group) and 7 cases after laminectomy or laminoplasty (PA or PP group). Regrowth of OPLL in the remaining surgical site was observed in the AP group, while the beak portion was present in 6 out of 7 cases in the PA or PP group. The cervical range of motion was significantly larger in patients who underwent repeat surgery than in those who did not ($p<0.05$).

Conclusion: Surgeons should take into account the potential for reoperation in cases of C-OPLL with a beak portion following laminoplasty or laminectomy, or a significant remaining area after anterior surgery, when planning the initial surgery.

PAPER 53

The Incidence and Alert Timing of Spontaneous Electromyogram in Surgery for Ossification of the Posterior Longitudinal Ligament

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Introduction: Multi-modal intraoperative neurophysiological monitoring (IONM) including trans-cranial muscle evoked potential (Tc-MEP), spontaneous electromyogram (sEMG), and somatosensory evoked potentials is essential for high-risk spinal surgeries such as ossification of the posterior longitudinal ligament (OPLL) to reduce postoperative neurological deficit. sEMG reflects nerve invasion and can continuously monitor descending pathways in real time, unlike Tc-MEP which is measured intermittently between invasive surgical maneuvers. However, when sEMG occurs and how sEMG differs with surgical approach and procedures are not yet understood. The aim of this study is to investigate the incidence of sEMG and the timing of its appearance in cervical OPLL surgery, one of the most nerve-invasive surgery, because it will allow surgeons to understand how maneuvers are more invasive to the nerves and to perform safer surgery.

Materials and Methods: A prospective observational study was conducted at a single university hospital from 2017 to 2022. Consecutive patients undergoing anterior decompression and fusion (ADF), laminoplasty (LAMP), or posterior decompression and fusion (PDF) with IONM for cervical OPLL were included. Tc-MEP and sEMG were recorded from skin incision to closure. The incidence of Tc-MEP and sEMG were investigated and statistically compared between ADF, LAMP, and PDF with ***chi square*** test. In addition, surgical maneuvers causing Tc-MEP and sEMG were investigated for each surgical procedure. Tc-MEP alert was defined as a decrease in amplitude from baseline to 30% or less. sEMG was alerted when it lasted more than 5 seconds in relation to the surgical maneuver.

Results: The study included ninety-eight OPLL patients with a mean age of 63.8 years, mean body mass index of 27.0, a mean cervical Japanese orthopedic association score of 9.4, and mean occupancy ratio of 50.6%. Alerts of Tc-MEP and sEMG were issued in 27% and 70% of all cases, respectively. When comparing ADF (39 cases), PDF (38 cases), and LAMP (21 cases), there was no significant difference in the incidence of Tc-MEP (ADF 28%, LAMP 14%, PDF 32%, $p=0.34$), however, sEMG occurred significantly more frequently in ADF (ADF 90%, PDF 68%, LAMP 38%, $p<0.001$). The surgical maneuvers in which sEMG occurred most frequently were decompression including thinning OPLL (87%) in ADF, lamina excavation and decompression (both 40%) in PDF, and lamina excavation (33%) in LAMP. Four patients (4.1%) had postoperative neurological deficits.

Conclusion: Cervical OPLL surgery was found to be a highly neuroinvasive procedure with sEMG occurring in 70% of cases. sEMG occurred most frequently with ADF decompression including thinning OPLL, suggesting irritation and invasion of anterior horn cells and nerve roots. sEMG may reflects temporary nerve invasion as there was little postoperative neurological deficits despite the high sEMG incidence, and real-time feedback to the surgeon would lead to safer surgery.

PAPER 54

Evaluating Changes to The Modified K-line Using Kinematic MRIs

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USC Spine Center, Keck School of Medicine USC, Los Angeles[1] USC CTSI BERD Core, Keck School of Medicine USC, Los Angeles[2] Gerling Institute[3]

Introduction: The modified K-line is a radiological tool used in surgical planning of the cervical spine –typically utilized with neutral radiographs. As cervical decompression and fusion often results in patients being fused in a more lordotic position than the preoperative neutral radiograph, a K-line measured in the extension position may offer better utility for these patients. Little is known regarding extension K-lines for treatment of cervical myelopathy. Therefore, this study seeks to examine differences between K-lines drawn in neutral and extension.

Materials and Methods: 97 patients were selected with T2-weighted, upright cervical MRIs taken in neutral and extension. For each patient, the K-line was drawn at the mid-sagittal position for both neutral and extension. The distance from the most posterior portion of each disc (between C2-C7) to the K-line was measured in neutral and extension and the difference was calculated. Distance from disc to K-line <4mm is considered K-line (-) while >4mm is K-line (+). Neutral measurements (T1 Slope, Cervical Lordosis, T1S-CL, cSVA) were investigated for prediction of K-line status conversion. Paired t-test was used to assess significant differences.

Results: Across all levels between C2-C7 there was an increase in the distance between the dorsal aspect of the disc and K-line when comparing neutral and extension radiographs. The average change in difference (extension minus neutral) at each cervical spinal level was 0.9mm (C2-C3), 2.5mm (C3-C4), 2.6mm (C4-C5), 2.0mm (C5-C6), and 0.9mm (C6-C7). A paired t-test showed that the K-line increase from neutral to extension was statistically significant across all disc levels ($p < 0.001$). Higher cervical lordosis and T1 slope values were less likely to exhibit conversion of K-line status between C4-C6.

Conclusion: When positioned in extension, patients experience a significant increase in distance from the dorsal aspect of a disc to the K-line compared to when positioned in neutral, especially between C3-C6. With some patients, the change was enough to exhibit K-line status conversion. This is clinically relevant for surgeons considering a posterior cervical decompression and fusion in patients with a negative modified K line on preoperative MRI imaging, as these patients may have enough cervical cord drift back when fused in an extended position, maximizing likelihood of improving postoperative CSM functional outcomes.

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Table 1: Distance from cervical disc to K-line in neutral and in extension

Disc Level	Measurements		p-value[1]
	Neutral, N = 100	**Extended**, N = 100	
C2-C3			<0.001
Median (IQR)	7.80 (7.10, 9.20)	8.70 (7.50, 10.00)	
Mean (SD)	8.03 (1.62)	8.79 (1.86)	
Range	3.90, 11.70	4.00, 13.20	
C3-C4			<0.001
Median (IQR)	8.5 (6.3, 10.4)	11.0 (8.6, 13.0)	
Mean (SD)	8.3 (2.7)	10.6 (3.0)	
Range	-0.1, 13.8	2.0, 16.5	
C4-C5			<0.001
Median (IQR)	8.5 (6.0, 10.8)	11.1 (8.9, 13.3)	
Mean (SD)	8.3 (3.4)	11.1 (3.5)	
Range	-2.3, 15.5	1.5, 18.2	
C5-C6			<0.001
Median (IQR)	7.6 (5.3, 9.8)	9.6 (7.5, 11.8)	
Mean (SD)	7.6 (3.1)	9.9 (3.2)	
Range	-1.4, 15.9	2.3, 19.2	
C6-C7			<0.001
Median (IQR)	6.50 (5.40, 8.10)	7.40 (6.30, 9.10)	
Mean (SD)	6.69 (1.84)	7.67 (2.10)	
Range	2.20, 11.20	3.00, 14.30	

[1] Paired t-test
Abbreviations: IQR – interquartile range, SD – standard deviation
P Values <.05 deemed statistically significant

Table 2: Relationship between predictors and change in K-line classification

	C2/C3			**C3/C4**			**C4/C5**			**C5/C6**			**C6/C7**		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
Cervical lordosis	0.98	0.84, 1.15	.801	0.93	0.82, 1.04	.215	0.89	0.80, 0.96	**.006**	0.86	0.77, 0.93	**.002**	0.97	0.89, 1.06	.515
T1 Slope	1.07	0.86, 1.44	.564	0.92	0.79, 1.08	.289	0.9	0.81, 0.98	**.02**	0.84	0.74, 0.92	**.001**	1.02	0.90, 1.17	.782
T1 Slope minus CL	1.08	0.90, 1.35	.445	1.04	0.92, 1.20	.539	1.06	0.99, 1.16	.105	1.05	0.99, 1.13	.148	1.06	0.95, 1.19	.323
C2-C7 SVA	0.91	0.70, 1.12	.446	0.93	0.78, 1.07	.377	0.98	0.89, 1.05	.567	1.03	0.96, 1.09	.455	1.07	0.97, 1.18	.133
Observations	97			93			93			95			96		

Logistic regression of (outcome) having a (-) to (+) conversion in K-line status on several predictors. Only individuals that were (+) at both time points or had a (-) to (+) conversion are included. Each parameter estimate is from a separate univariable model.
Abbreviations: CL –cervical lordosis (cobb angle), SVA- sagittal vertical axis, CI – confidence interval
P values <.05 are deemed statistically significant

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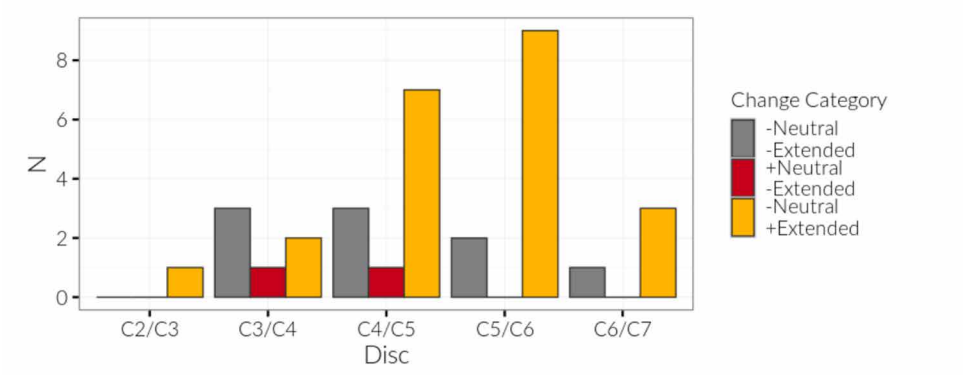

Figure 1: K-line classification change (restricted to patients that did not have positive in both neutral and extended; n = 15). Most K-line classifications changes occurred at the level of C4-C5 and the C5-C6 disc.

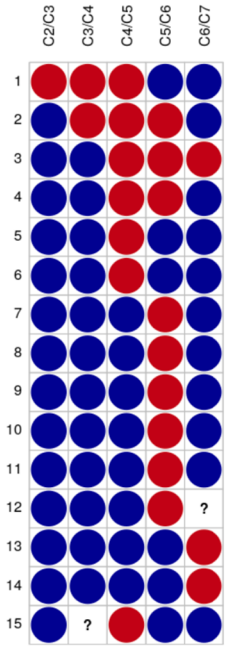

Figure 2: Number of co-occurring values for 15 individuals that had -Neutral to +Extended in at least one location (red dots). Blue dots reflect +Neutral to +Extended. ? indicates another category. Each row represents one individual.

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.

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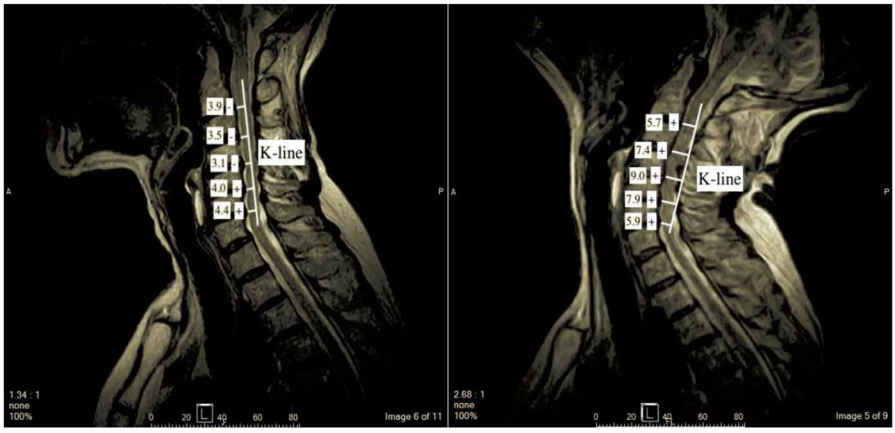

Figures 3A and 3B: K-line measurements were taken on a neutral and extension cervical MRI, respectively. K-line values taken between C2-C7 on each MRI were classified as either K-line (-) or K-line (+) with K-line (+) being defined as greater than 4mm in distance from disc to mK-line and K-line (-) being defined as less 4mm in distance to mK-line. These images show that when the cervical radiograph changes from neutral to extension there is a change K-line (-) to K-line (+) at the C2-C3, C3-C4, and C4-C5 levels for this patient.

PAPER 55

Investigation of Orthopaedic Surgery Resident Education Regarding the Management of Unintentional Durotomies

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Introduction: Unintentional dural tears are estimated to occur in 2-5% of all spine surgeries and in 20% or more of patients with spinal trauma. While neurosurgeons have typically managed dural and intradural pathology, as the number of spine surgeries performed each year continues to increase, unintentional durotomies will continue to occur at an increasing rate with significant morbidity. It is critical that all orthopaedic spine surgeons receive adequate training in the intra-operative and post-operative management of unintentional durotomies. To our knowledge, no study has previously studied orthopaedic surgery resident education and experience regarding the management of unintentional durotomies.

Materials and Methods: This was an anonymous eight question survey sent to all 207 accredited orthopaedic residency programs. Questions included the resident's post-graduate year (PGY), whether or not the resident was planning to pursue a spine fellowship, questions about experience with the intra-operative (primary suture repair, fibrin glue/muscle patch repair) and post-operative (head of bed restrictions/lumbar drain) management of unintentional durotomies, and whether they felt their training would benefit from additional experience.

Results: 219 residents responded to the survey with 43.4% being senior residents (PGY4-5). Of the 219 respondents, 28.3% (62/219) reported feeling comfortable with intra-operative management of unintentional durotomies. Regarding primary suture repair, 2.7% (6/219) stated they have completed the procedure as lead surgeon with 62.6% (137/219) having assisted an attending with the process (Fig. 1). 34.7% (76/219) reported having never seen a primary dura suture repair. Regarding fibrin glue or muscle patch repair, 7.3% (16/219) reported performing the procedure as lead surgeon, with 47.9% (105/219) having partially completed or assisted an attending with the procedure (Fig 2). 44.7% (98/219) reported having never seen a patch repair. Of the 219, 52.5% (115/219) reported feeling comfortable with post-operative management of unintentional dural tears. 50.2% (110/219) stated they do not feel comfortable managing lumbar drains. 58.9% (130/219) felt they would benefit from additional experience during their training.

48 of the 219 participants stated they plan to pursue a spine fellowship with the majority of these (25/48) being senior residents. Of these 48 residents, 31.3% (15/48) feel comfortable with intra-operative management of unintentional durotomies. Regarding primary suture repair 4.2% (2/48) reported having completed the procedure as lead surgeon, while 72.9% (35/48) stated they have assisted an attending with the procedure (Fig. 3). 25% (12/48) reported having never seen a primary dural suture repair. Regarding fibrin glue or muscle patch repair, 10.4% (5/48) reported performing the procedure as lead surgeon, with 52.1% (25/48) having assisted an attending, and 37.5% (18/48) having never seen a patch repair (Fig. 4). 79.2% (38/48) felt they would benefit from additional experience while 12.5% (6/48) stated they believe they will develop these skills during fellowship.

Conclusion: Unintentional dural tears frequently occur iatrogenically or during spinal trauma

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with significant morbidity. Although the majority of orthopaedic spine surgeons do not treat intradural pathology, all spine surgeons should be competent managing unintentional durotomies. In this survey study, a minority of residents reported confidence managing unintentional dural tears with the majority reporting they would benefit from additional experience.

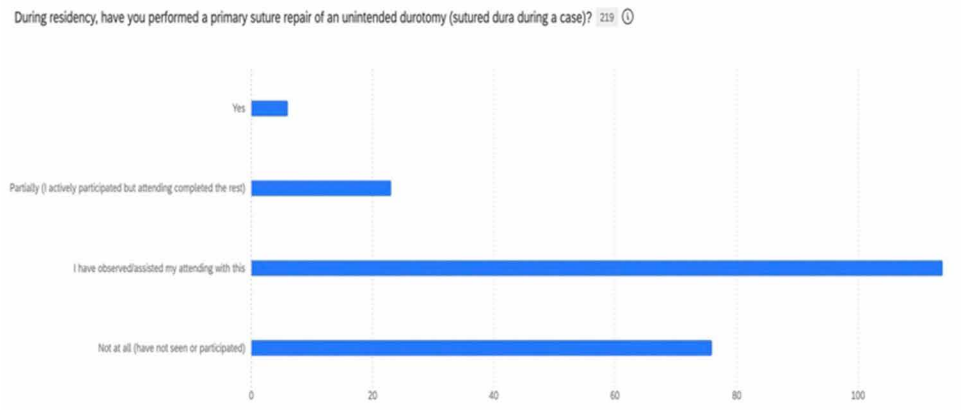

Figure 1.

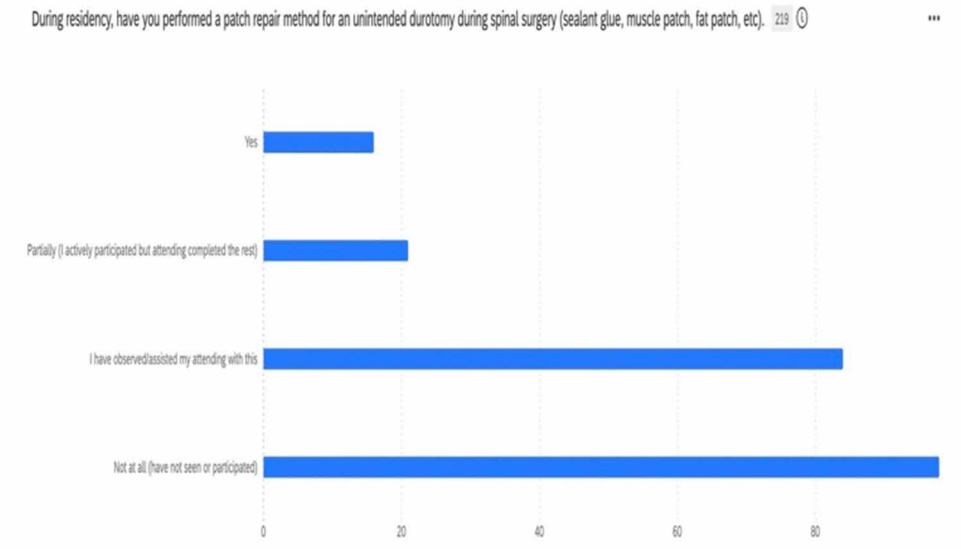

Figure 2.

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

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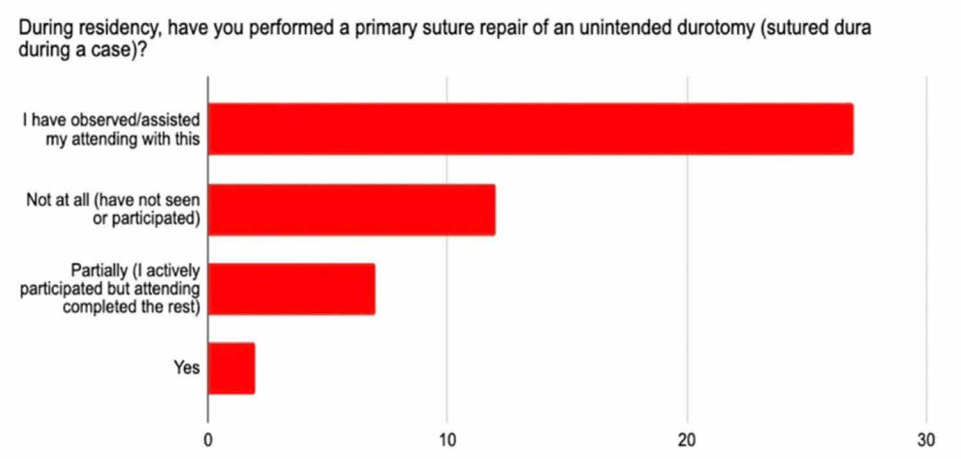

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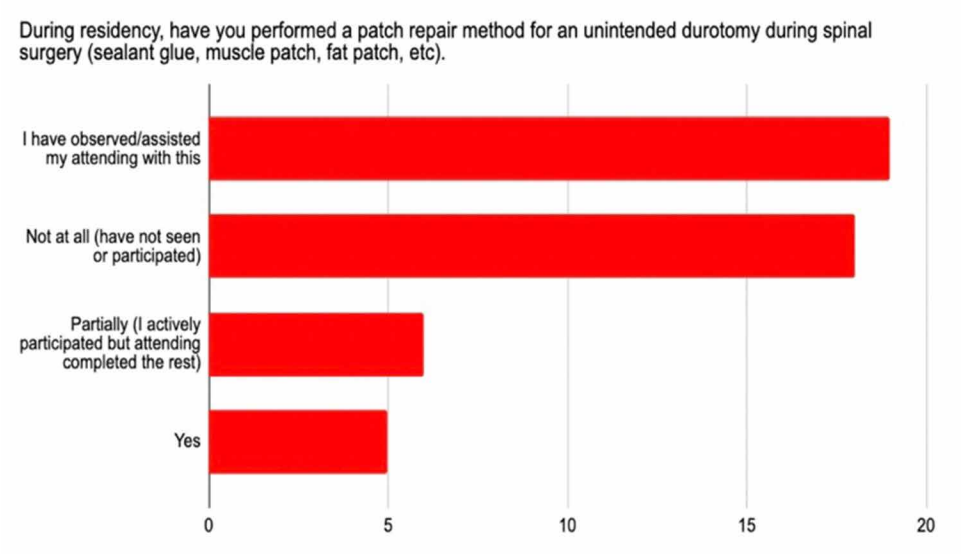

Figure 4.

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.

PAPER 56

Indications and Limitations of Laminoplasty for Cervical Spondylotic Myelopathy Using Modified K-line –Importance of Dynamic Factor-

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Introduction: The usefulness of the modified K-line (mK-line) on cervical spine MRI has been reported in selecting a surgical approach for cervical spondylotic myelopathy (CSM). MK-line connects the midpoints of the spinal cord at the C2 and C7 levels on midsagittal MRI. Laminoplasty is recommended in cases where the distance from the mK-line to anterior compression of the spinal cord (ACS) is 4 mm or more. On the other hand, the mK-line reflects only the static alignment in the supine position and does not consider the influence of dynamic alignment in the upright position. The purpose of this study was to investigate the dynamic factors of cervical spine upright lateral X-ray images in addition to the mK-line and to clarify indications and limitations of laminoplasty for CSM using modified K-line.

Materials and Methods: 162 patients (101 males and 61 females, mean age 69.6 years, mean follow-up 42.0 months) who underwent laminoplasty for the treatment of CSM since 2014 at our hospital and could be followed up for at least 2 years after surgery. The patients were classified into two groups: (+) group, in which the distance between the mK-line and ACS on MRI was more than 4 mm, and (-) group, in which the distance between the mK-line and ACS was less than 4 mm. On the basis of the Japanese Orthopedic Association (JOA) scoring system for cervical myelopathy, the rate of recovery of the JOA scores was investigated as a clinical outcome to compare these 2 groups. In the (+) group, local kyphosis, local intervertebral angle of motion and vertebral slippage on lateral X-ray images were investigated as dynamic factors in the anterior maximally compressed intervertebral space on MRI.

Results: The (+) group consisted of 120 patients and the (-) group consisted of 42 patients. the recovery rate of the JOA scores was 53.5% and 41.1%, respectively, which was significantly higher in the (+) group ($p<0.01$). In the (+) group, 44.0% of the patients with local kyphosis in flexion had a significantly lower improvement rate ($p<0.01$). When the (+) group was divided into those with an improvement rate of more than 50% and those with an improvement rate of less than 50%, the local intervertebral angle of motion was 11.3° in cases with an improvement rate of less than 50%, which was significantly greater than in cases with an improvement rate of more than 50% (8.5°) ($p<0.05$) . From ROC analysis, the cut-off value was determined to be 9.5°, and the improvement rate was significantly lower in cases with a local intervertebral motion angle of 9.5° or greater ($p<0.01$). There was no significant difference in clinical results for vertebral slippage.

Conclusion: The results of laminoplasty for the mK (+) group were generally good, but those with local kyphosis in the flexed position and those with local intervertebral angles of motion greater than 9.5°had poor results.

mK-line does not take dynamic factors into account. In these cases, even with mK-line (+), the combination of fixation should be considered.

PAPER 57

"Adjacent-Level Ossification Development" and Clinical Implications for Adjacent Segment Pathology Following ACDF

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Johns Hopkins School of Medicine[1]

Introduction: Adjacent-level ossification development (ALOD) is a heterotrophic ossification process that can occur at spinal segments following ACDF. ALOD has been shown to occur in up to 64% of ACDF patients, causing significant morbidity and may require revision surgery, which can be associated with higher complication rates. Several risk factors for ALOD have been identified, including instrumentation use and short plate-to-disc distance (PDD) within the construct. However, the clinical implications of ALOD, such as patient-reported outcomes and the incidence of re-operation, remain unclear. Our objective is to identify risk factors for the development of ALOD after ACDF and its association with surgical and radiographic outcomes.

Materials and Methods: Retrospective review of academic hospital database of patients with ALOD after undergoing primary ACDF for cervical degenerative disc disease. Radiographic measurements and potential risk factors were assessed and compared at pre-operative visit and last follow-up. Outcomes assessed included the incidence of Clinical Adjacent Segment Pathology (CASP), CASP requiring additional surgery, visual analog scale (VAS) scores for neck pain or back pain, and Physical Component Score (PCS) on the 12-Item Short-Form Health Survey (SF-12). Significance was considered at $p<0.05$.

Results: In this study, 64 out of 140 patients (46%) developed adjacent-level ossification disease (ALOD) in the cranial segment, while 44 out of 120 patients (37%) developed ALOD in the caudal segment. The ALOD group in the cranial segment had a higher incidence of hyperlordotic ACDF and a shorter preoperative PDD ($p<0.01$) compared to the non-ALOD group. Additionally, the ALOD group in the cranial segment had significantly higher preoperative adjacent segment kyphosis angles ($p=0.01$), significantly lower adjacent segmental range of motion (ROM) at final follow-up ($p<0.01$) and significantly higher underlying OALL ($p=0.02$). There was no significant difference in clinical outcomes, including VAS scores for neck and back pain, and SF-12PCS between the ALOD and non-ALOD groups in the cranial segment (Table 1). Similarly, in the caudal segment, the ALOD group had a higher incidence of preoperative adjacent segment kyphosis ($p<0.01$), shorter PDD than the non-ALOD group ($p<0.01$) and underlying OALL ($p=0.04$), as well as a higher incidence of CASP requiring surgery ($p=0.02$). Additionally, patients with ALOD had significantly lower preoperative adjacent segment angles and ROM at the last follow-up visit compared to the non-ALOD group (5.46 vs. 8.19, $p<0.01$).

Conclusion: Development of ALOD in ACDF patients was found to be associated with short PDD, hyperlordotic ACDF, underlying OALL and stopping ACDF below a kyphotic segment. Preservation of maximum PDD and avoidance of identified risk factors when performing ACDF could decrease the incidence of ALOD. Additionally, development of ALOD in ACDF patients was observed to decrease segmental ROM of adjacent segments but did not appear to impact clinical outcomes or the incidence of CASP.

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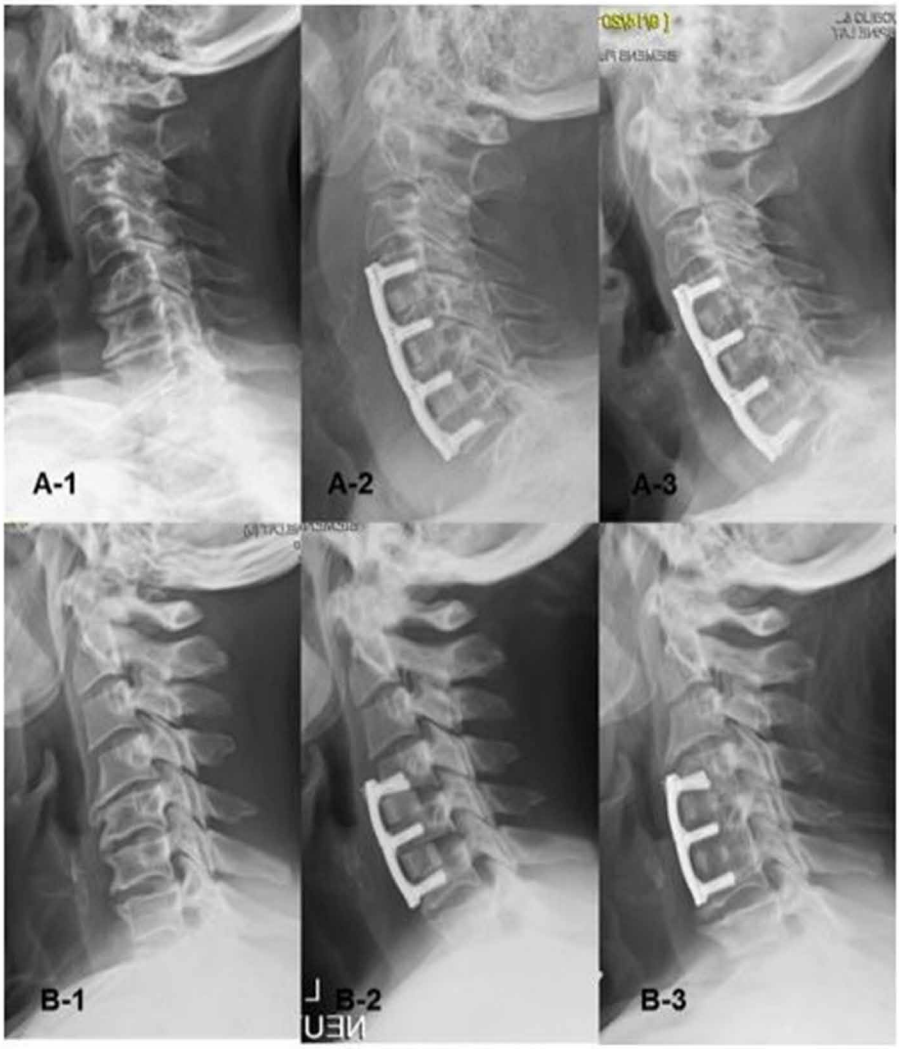

Figure 1: A: Serial lateral radiographs at preoperative (A), immediate (B) and 38-month postoperative (C) time points from a 65-year-old woman showing lordosis of the upper adjacent segment and no evidence of ALOD or CASP even with 0 mm of plate-disc distance (PDD). B: Serial lateral radiographs of preoperative (A), immediate (B) and 26 months after surgery (C) on 66-year-old man show kyphosis of upper adjacent segment and advanced ALOD even with 5 mm of PDD. The patient did not show any CASP.

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	The cranial adjacent segments			The caudal adjacent segments		
	ALOD (-), N=76	ALOD(+), N=64	P-value	ALOD (-), N=76	ALOD(+), N=44	P-value
Radiographic parameters						
PDD group (short : long)	47:27	56:8	0.001*	9:66	20:23	0.001*
Adjacent segment kyphosis (- : +)	51:25	29:34	0.012*	70:6	33:11	0.001*
Underlying OALL (- : +)	43:33	24:40	0.032*	44:32	17:27	0.042*
No. of fusion level	2.14±0.74	2.13± 0.75	0.876	2.06 ±0.73	2.09 ±0.80	0.862
Clinical parameters						
Sex (M:F)	39/37	23/41	0.68	35/41	19/25	0.761
Age	56.11± 11.24	53.43 ±11.54	0.167	55.18 ±12	53.18 ±11.48	0.373
Follow-up period (Mo)	45.85± 28.3	51.43 ±25.42	0.226	44.34 ±26.1	52.43 ±29.3	0.121
CASP requiring imaging (%)	50/26	41/23	0.831	53/23	28/16	0.492
CASP requiring surgery (%)	66/10	57/7	0.689	74/2	38/6	0.02*
VAS-neck pain	1.58 ±2.37	1.94 ±2.52	0.426	1.66 ±2.44	1.91 ±2.5	0.635
VAS-arm pain	0.86± 2.08	1.14 ±2.25	0.497	1.06 ±2.34	0.62 ±1.62	0.334
SF12-PCS	43.92 ±7.77	42.37 ±6.58	0.38	43.6 ±6.85	42.76 ±8.68	0.697

Table 1: Radiographic and Clinical parameters of patients with cranial or caudal development of ALOD. ALOD: Adjacent Level Ossification Development; PDD: Plate-to-disc distance; OALL: Ossification of Anterior Longitudinal Ligament; ROM: Range of motion; SVA: Sagittal vertical axis; CASP: Clinical adjacent segment pathologies; VAS: Visual analog scale; SF-12 PCS: Short-form 12 physical component summary.

PAPER 58

Predictors of Ligamentum Flavum Buckling in Patients with Congenital Cervical Stenosis

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Keck School of Medicine of USC[1]

Introduction: Congenital cervical stenosis (CCS) is an abnormal narrowing of the cervical spinal canal present at birth that can predispose to cervical cord compression. Ligamentum flavum buckling can further contribute to preexisting cervical stenosis, placing CCS patients at additional risk for cervical myelopathy. Prior research has demonstrated that positional changes may exacerbate LF buckling. This study uses kinetic magnetic resonance imaging (kMRI) to evaluate structural and kinetic parameters of the cervical spine as independent predictors of ligamentum flavum buckling in patients with CCS.

Materials and Methods: A retrospective review of 113 cervical spine kMRI images was performed. Patients who underwent cervical kMRI with reported neck or arm pain were included in this study. Patients with a history of cervical spine surgery or imaging indications for infection, malignancy, or trauma were excluded.

Results: Overall, 113 patients (49% male) with a mean age of 44.83 + 11.73 were included in our study. Ligamentum flavum buckling most commonly occurred at the C4/C5 disc level (43/113). The highest incidence of congenital cervical spinal stenosis was at the C5/C6 disc level (29/113). At C3/C4, translational motion at the index level was predictive of LF buckling (p=0.037; OR:8.16, 95%CI:1.13 to 58.86). LF thickness was predictive of LF buckling at C4/C5 (p=.047; OR:6.68, 95%CI:1.02 to 43.68). Translational motion at C6/C7 was protective against LF buckling at C5/C6 (p=.042; OR:0.06, 95%CI: .004 to .902). Angular motion at C5/C6 level when analyzing the C6/C7 level approached significance (p=.08; OR:0.513, 95%CI: 0.243 to 1.083).

Conclusion: LF buckling is a dynamic phenomenon associated with cervical spine instability. Standard radiography cannot detect buckling due to the radiolucent nature of the structure, whereas kMRI allows the characterization of dynamic-based pathologies such as LF buckling. Kinetic and structural parameters at the index level are predictors of LF buckling. Kinetic parameters at adjacent levels are protective factors, decreasing the incidence of LF buckling. Used in conjunction with static radiography, these parameters may assist surgeons in predicting a dynamic pathology from static imagery.

PAPER 59

Predictive Risk Factors for the Incidence of Cervical Spine Instabilities in Rheumatoid Arthritis: A Multicenter Prospective Study During Over 10 years

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Kobe University Graduate School of Medicine[1] Hyogo Prefectural Harima-Himeji General Medical Center[2] Mahoshi Hospital[3]

Introduction: Predictive risk factors for the incidence of cervical spine instabilities in patients with rheumatoid arthritis (RA) are still open to debate.[1] A prospective study was designed to clarify the >10-year incidence and predictors of cervical spine instabilities in RA.

Materials and Methods: At baseline, 634 outpatients who fulfilled the criteria for "classical" or "definite" RA were enrolled. In total, 292 (46.1%) patients without any cervical spine instabilities were identified, and 114 (39.0%) patients were prospectively followed for >10 years (11.3±0.8 years), although 178 (61.0%) patients were lost to follow-up or died (**Figure 1**). Cervical spine radiographs were taken to assess the three types of instability: atlantoaxial subluxation (AAS: anterior atlantodental interval (ADI) >3 mm), vertical subluxation of the axis (VS: Ranawat value <13 mm), and subaxial subluxation (SAS: irreducible anteroposterior vertebral translation ≥2 mm). Based on literature evidence, "severe" extents of cervical spine instabilities were defined as AAS with ADI ≥10 mm, VS with Ranawat value ≤10 mm, and SAS with translation ≥4 mm or at multiple levels. Baseline clinical characteristics and radiological parameters were compared between patients with and without instabilities at >10-year follow-up. Finally, multivariable logistic regression model was developed from variables with $p<0.05$ in the univariable analysis to identify independent predictive risk factors for the >10-year incidence of cervical spine instabilities ($p<0.05$).

Results: The number of patients without any types of cervical spine instability decreased from 114 to 47 (41.2%) patients during over 10 years ($p<0.01$), while 67 (58.8%) patients experienced the occurrence of instabilities: AAS in 38.6%, VS in 19.3%, SAS in 26.3% with combinations (**Figure 2**). From the comparison, CRP value ≥1 mg/dl ($p=0.012$), previous joint surgery ($p=0.007$), administration of corticosteroids ($p=0.029$), and Steinbrocker stages III–IV in the hands ($p=0.007$) were identified as significant categorical risk factors. Additionally, baseline Ranawat value was significantly lower ($p=0.002$) in patients with instabilities at endpoint. From the receiver operating characteristic curve with the Youden index, the cut-off Ranawat value was calculated as 15.3 mm. In fact, cervical spine instabilities were developed in 41 (74.5%) of 55 patients with Ranawat value <15.3 mm but in 26 (44.1%) of 59 those with Ranawat value ≥15.3 mm ($p=0.001$). Multivariable analysis identified Ranawat value <15.3 mm ($p=0.001$, odds ratio [OR] 4.37), Steinbrocker stages III–IV ($p=0.048$, OR 2.62), previous joint surgery ($p=0.047$, OR 2.54), and corticosteroid administration ($p=0.047$, OR 2.41) as independent predictive risk factors for the >10-year incidence of instabilities (**Table 1**). Sixteen (14.0%) of 114 patients further developed the "severe" category of instabilities during >10 years: AAS, 5.3%; VS, 7.9%; SAS, 6.1%. Similar comparison clarified the association of Steinbrocker stages III–IV and corticosteroid administration with "severe" instabilities. Multivariable analysis identified corticosteroid administration as the predictor for the >10-year incidence of "severe" instabilities ($p=0.024$, OR 4.67).

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Conclusion: Ranawat value <15.3 mm, Steinbrocker stages III–IV, previous joint surgery, and corticosteroid administration at baseline are predictive risk factors for the incidence of cervical spine instabilities in patients with RA during >10 years. Notably, patients who take concomitant corticosteroids are at high risk for "severe" cervical spine instabilities, possibly inducing myelopathy.

Figure 1. Number of patients at baseline and followed as outpatients during >10 years

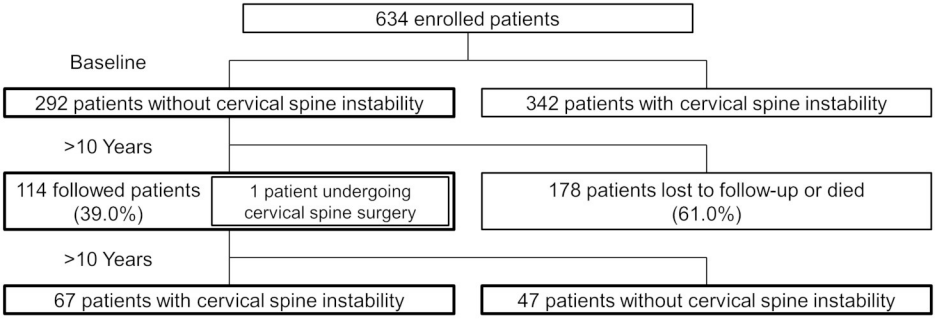

Figure 2. Changes in the incidence of cervical instabilities during >10 years

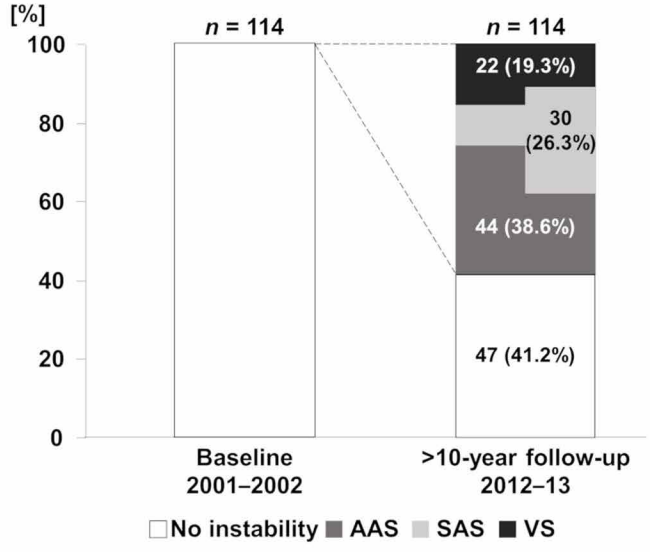

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Table 1. Multivariate analysis for the incidence of cervical spine instabilities during >10 years

	Odds ratio	95% confidence interval	*P* value
Ranawat <15.3 mm	**4.37**	**1.78–10.70**	**0.001**
Steinbrocker stages Ⅲ–Ⅳ	**2.62**	**1.01–6.81**	**0.048**
Previous joint surgery	**2.54**	**1.01–6.37**	**0.047**
Corticosteroid administration	**2.41**	**1.01–5.75**	**0.047**
CRP ≥1.0mg/dl	1.81	0.75–4.38	0.188

PAPER 60

Fifty Percent of Patients with Chronic Renal Failure Experience Major Medical Complication with a Third Requiring ICU admission for Anterior Cervical Discectomy and Fusion Surgery.

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Oregon Health & Science University[1]

Introduction: The prevalence of chronic renal failure (CRF) as a solid organ failure is high. However, the extent to which this condition affects cervical surgery and whether undergoing a kidney transplant reduces postoperative complications is uncertain. This study aimed to analyze a national database and compare medical complication, ICU admission, hospital readmission and one-year revision surgery rates for primary anterior cervical discectomy and fusion (ACDF) among normal, CRF, and renal transplant (RT) patients.

Materials and Methods: Pearldiver data base was queried for ACDF patients between 2016 and 2019. We identified end-stage renal failure patients on dialysis (CRF patients) and those who had renal transplant within this cohort. We compared 30-day medical complication, 90-day readmission, 30-day intensive care unit (ICU) admission, and one-year revision rates among the three groups. To compare the rates of dependent outcomes, we performed univariate analysis. To account for other independent variables, logistic regression analyses was done using age, Charlson Comorbidity Index (CCI), gender, obesity, osteoporosis, and tobacco use as additional independent covariates. The results were presented as odds ratios (OR) and p-values reported, with a significance level set at <0.01.

Results: Within the PearlDiver database, we found 152,199 patients who underwent ACDF. Among them, 288 had undergone renal transplant (RT) and 1400 had chronic renal failure (CRF) without RT. The univariate analysis revealed that the medical complication rate was 2.8% for normal patients compared with 54.3% for CRF patients and 12.2% for RT patients (P<0.0001 for both). The calculated OR was 41.2 for CRF patients and 4.8 for RT patients compared with normal patients. ICU admission rates was 1.0% for normal patients compared with 14.6% for CRF patients and 3.8% for RT patients (P<0.0001 for both). The 90-day readmission rates were 3.1%, 37.1%, and 10.8% for normal, CRF, and RT patients, respectively (P<0.0001). The revision rate was 4.5% for normal patients, 5.7% for CRF patients, and 2.8% for RT patients (p=0.04). Logistic regression analysis showed that CRF and RT patients had significantly higher rates of 30-day medical complications (OR = 21.8 and 1.9, respectively), ICU admission (OR = 8.0 and 1.7, respectively), and 90-day readmission (OR = 9.8 and 1.8, respectively). However, there were no statistically significant differences in revision rates among the three patient groups.

Conclusion: ACDF is generally considered a safe surgery with low complication rates. However, the complication rates were surprisingly high for CRF patients, with more than half experiencing major medical complications and a third requiring ICU admission. In contrast, RT patients had much lower rates of complications, implying that delaying ACDF until after renal transplantation, if neurologically feasible, may be a prudent approach.

PAPER 61

Neck Pain Does NOT Contraindicate Cervical Laminoplasty

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Twin Cities Spine Center[1]

Introduction: Cervical laminoplasty is a commonly used surgical technique for the management of cervical myelopathy, with a relative contraindication of axial neck pain as a predominant symptom. In this study, we investigate the effect of laminoplasty on neck pain in patients with differing levels of pre-operative neck pain.

Materials and Methods: Patients who underwent cervical laminoplasty for cervical myelopathy at a single institution from 2010-2019 were included in the study. Patient demographics, pre- and postoperative radiographs, patient report outcome measures (PROMs) including Neck Disability Index (NDI), Visual Analog Scales for neck and arm pain (VASn, VASa) were assessed. Data were tested for normality using the Shapiro-Wilk Test; t-tests and paired t-tests were used to establish statistical significance.

Results: 69 patients met the inclusion criteria. The average age was 58.7±10.1 years and 62% were male. 25 patients (36%) had a preoperative VASn >5. 88% of cases included C3 or C7 (n=61). Patients showed statistically significant improvement from preoperative values in NDI (34±19) at 3 months, 6 months and 1 year (14±10,25±20, 22±20; ($p < 0.01$), with continued, but not significant improvement at 2 years (32±20); ($p= 0.42$). Patients showed statistically significant improvement from preoperative values in VASn (4.0±3.1) and VASa (3.9±3.1) at 3 and 6 months ($p < 0.01$), with continued, but not significant improvement at 1 and 2 years (VASn: 2.5±2.9, 2.5 ±2.9, 2.3±2.8, 3.3±3.0; ($p = 0.08$, $p = 0.15$); VASa: 2.5±2.9, 2.5±2.9, 2.3±2.8, 3.3±3.3); ($p = 0.08$, $p = 0.65$). Patient's with a preoperative VASn >5 (n=25) had an overall but not statistically significant improvement in NDI and VASn at 2 years postoperatively (NDI: 48±18 to 35±19); ($p = 0.35$); (VASn: 7.7±1.2 to 3.5±3.4); ($p= 0.67$) , and preoperative VASn <5 had a small but not significant increase in average NDI and VASn at 2 years postoperatively (NDI: 29±18 to 30±21); ($p = 0.35$); (VASn: 2.3±1.9 to 3.1±2.9) ; ($p = 0.67$). Inclusion of C3 within the laminoplasty construct (n=52) did not have a negative effect on NDI or VASn at 2 years postoperatively (NDI: 34.2±19.9 to 30.6±20.7); ($p = 0.22$); (VASn 3.6±3.1 to 3.1±3.1); ($p = 0.38$). Similarly, in constructs including C7 (n= 37), there was no negative effect found on NDI or VASn at 2 years postoperatively (NDI: 36.0±22.6 to 31.8±21.3); ($p = 0.23$) (VASn: 4.8±2.9 to 3.3±3.2); ($p = 0.09$).

Conclusion: Our study shows that cervical laminoplasty does not lead to a significant increase in NDI or VASn in patients presenting with cervical myelopathy with concomitant neck pain. Thus, cervical laminoplasty can be a viable non-fusion alternative for multi-level cervical stenosis in the setting of cervical myelopathy with associated neck pain.

PAPER 62

Cervical Spine Surgery following COVID-19 Infection: When is it Safe to Proceed?

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Introduction: COVID-19 has been shown to adversely affect multiple organ systems, yet little is known about its effect on perioperative complications after spine surgery or the optimal timing of cervical spine surgery after an infection. We utilized the NIH National COVID Cohort Collaborative (N3C) database to characterize the risk profile in patients undergoing spine surgery during multiple time windows following COVID-19 infection.

Materials and Methods: We queried the National COVID Cohort Collaborative, a database of 17.4 million persons with 6.9 million COVID-19 cases, for patients undergoing cervical spine surgery. Patients were stratified into those with an initial documented COVID-19 infection within three time periods: 0-2 weeks, 2-6 weeks, or 6-12 weeks prior to surgery. All analyses were performed in the N3C Data Enclave Palantir platform.

Results: A total of 28,525 patients who underwent anterior approach cervical spine surgery and 45,408 patients who underwent posterior approach cervical spine surgery were included. Results are shown in Figure 1. Patients who underwent surgery within 2 weeks of their COVID-19 diagnosis had a significantly increased risk for venous thromboembolic events, sepsis, 30-day mortality, and one-year mortality compared to patients who were COVID negative during the same period, irrespective of anterior or posterior approach. The risk of acute kidney injury was elevated in anterior, but not posterior approach surgeries during this period. Among patients undergoing surgery between 2 and 6 weeks after COVID-19 infection, 30-day mortality risk remained elevated in patients undergoing a posterior approach only, while the risk of all other complications returned to normal. Patients undergoing surgery between 6 and 12 weeks from date of COVID-19 infection did not show significantly elevated rates of any complication analyzed.

Conclusion: Patients undergoing either anterior or posterior cervical spine surgery within 2 weeks from initial COVID-19 diagnosis are at increased risk for perioperative venous thromboembolic events, sepsis, and mortality. Elevated perioperative complication risk does not persist beyond 2 weeks, except for 30-day mortality in posterior approach surgeries. Based on these results it may be warranted to postpone non-urgent spine surgeries for at least 2 weeks following a COVID-19 infection, and counsel patients of increased perioperative complication risk when urgent surgery is required.

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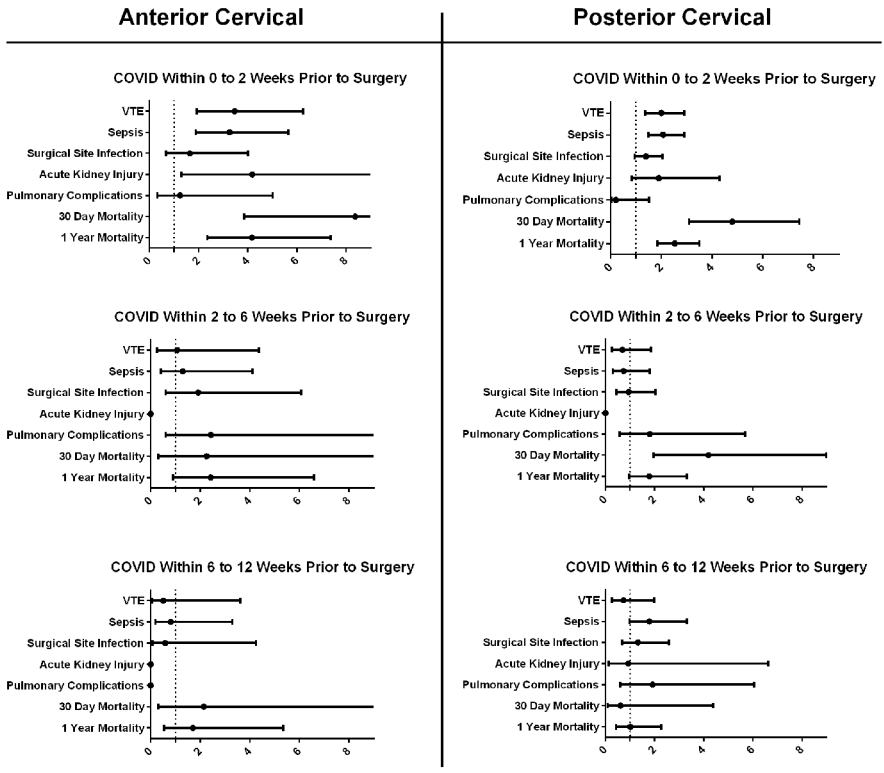

Figure 1: Odds ratios for postoperative complications in patients with a confirmed COVID-19 diagnosis compared to controls without a positive COVID-19 test for the 90 days prior to surgery. Error bars represent 95% confidence interval.

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Anatomic Study of Cervical Neuroforaminal Dimensions, Interpedicular Distance, and Disc Space Height from C2-T1 Using Computed Tomography of 1,000 Patients

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Introduction: While radiographic parameters for diagnosis of central cervical canal stenosis are well-described, parameters for diagnosis of cervical neuroforaminal stenosis (NFS) are not well-defined.[1–3] As there remains a lack of normative guidelines for cervical neuroforaminal dimensions (NFD), so too does there remain a lack of criterion for measurement of NFS. Moreover, the normative relationship between cervical neuroforaminal dimensions (NFD), interpedicular distance (IPD), and disc space height (DSH) remains unknown.[4] The purpose of this study was to use computed tomography (CT) of young patients without spinal pathology to establish normative radiographic measurements of cervical NFD, IPD, and DSH, and to analyze the associations among these measurements, accounting for patient demographic and anthropometric characteristics.

Materials and Methods: We reviewed CT imaging of 1,000 patients between 18 and 35 years of age without spinal pathology to measure cervical NFD, defined as follows: foraminal height, sagittal anterior-to-posterior width, and area. Anterior, middle, and posterior DSH, and IPD were also measured. Patient weight, height, sex, race, and ethnicity were recorded. Interobserver reliability was assessed via the intraclass correlation coefficient (ICC) two-way mixed model on absolute agreement.[5,6] To assess associations among radiographic, demographic, and anthropometric variables, stepwise-, backward-, and forward-method multivariate linear regression models with zero-order and partial correlations were analyzed. Differences in NFD, IPD, and DSH based on sex, race, and ethnicity were assessed using two-way analysis of covariance (ANCOVA) with anthropometric covariates, estimated marginal means, and type III sum-of-square specification. Measurement differences among disc levels were analyzed using ANOVA with post-hoc Bonferroni and Tukey corrections.

Results: Both left- and right-sided NFD followed bimodal distribution patterns moving caudally from C2-T1, whereas DSH measurements exhibited multimodal distribution patterns and IPD demonstrated a unimodal distribution clustered at the lower cervical spine (see Table 1). Significant differences were observed for all NFD, DSH, and IPD measurements across disc levels (see Table 2). Significant differences were observed in NFD, DSH, and IPD measurements with respect to patient sex (see Table 3) and race and ethnicity (see Table 4) taking into consideration patient demographic and anthropometric characteristics. The African American cohort demonstrated the smallest NFD, DSH, and IPD measurements, followed by the Hispanic cohort, followed by the Caucasian cohort (see Table 5). Weak correlations were observed between patient height and NFD, DSH, and IPD measurements across all levels from C2 - T1, though patient weight did not correlate with any radiographic measurement. Weak-to-moderate correlations were observed among NFD, DSH, and IPD measurements across all

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levels from C2 - T1 (see Table 6).

Conclusion: This study describes 70,800 DSH, NFD, and IPD measurements from C2 - T1 using CT imaging of young patients without spinal pathology. Findings from this study may provide normative guidelines necessary to establish the foundation for diagnosis of cervical neuroforaminal stenosis. Surprisingly, this study found no strong, or even moderate, correlations between normative NFD, DSH, and IPD measurements across all levels from C2 - T1. Patient sex, ethnicity, and height are associated with NFD, DSH, and IPD, though patient weight is not.

Table 1. Mean (SD) Cervical Neural Foraminal Dimensions, Disc Space Height, and Interpedicular Distance

Disc Level	Left NFD			Right NFD			DSH			C3 - C7 IPD		
	Width	Height	Area	Width	Height	Area	Anterior	Middle	Posterior	Mean (SD)	Min	Max
C2 - C3	6.9 (1.6)	9.4 (2.7)	65.0 (23.6)	7.1 (1.6)	9.4 (3.7)	64.6 (23.8)	2.4 (.8)	4.0 (1.1)	2.0 (.8)	24.2 (1.5)	22.0	31.0
C3 - C4	6.4 (1.6)	8.6 (2.4)	54.7 (18.4)	6.3 (1.5)	8.5 (1.6)	55.1 (19.6)	2.5 (.9)	4.3 (1.0)	2.0 (1.5)	25.2 (1.7)	22.5	30.1
C4 - C5	6.5 (1.4)	9.0 (1.6)	57.9 (19.0)	6.50 (1.4)	8.8 (1.6)	58.2 (19.5)	2.6 (1.0)	4.1 (1.0)	2.0 (.8)	25.8 (1.9)	22.5	31.9
C5 - C6	6.4 (1.4)	9.5 (3.3)	59.9 (18.3)	6.6 (1.4)	9.5 (5.1)	60.3 (19.4)	2.8 (1.1)	4.1 (1.0)	1.9 (.9)	26.2 (1.9)	23.0	31.8
C6 - C7	6.6 (1.3)	9.6 (1.8)	58.7 (17.0)	6.8 (1.4)	9.7 (2.9)	60.7 (20.3)	2.9 (1.1)	4.4 (2.2)	1.8 (1.0)	25.4 (1.9)	22.5	32.0
C7 - T1	6.7 (1.4)	9.7 (2.0)	57.7 (19.0)	6.8 (1.4)	9.6 (1.9)	58.2 (18.9)	2.3 (1.0)	3.7 (1.0)	1.4 (.8)	*	*	*

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Table 2. Differences in Cervical DSH, NFD, and IPD Measurements based on Disc Level

Level of Reference	Level of Comparison	Mean Difference (Reference - Comparison)																			
		Left NFD Width		*Left NFD Height*		*Left NFD Area*		*Right NFD Width*		*Right NFD Height*		*Right NFD Area*		*Anterior DSH*		*Middle DSH*		*Posterior DSH*		*C3 - C7 IPD*	
		MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*
C2 - C3	C3 - C4	**0.6**	**<.001**	**0.8**	**<.001**	**10.1**	**<.001**	**0.8**	**<.001**	**0.9**	**<.001**	**9.5**	**<.001**	**-0.2**	**0.040**	**-0.3**	**0.010**	-0.1	1.000	**-1.0**	**<.001**
	C4 - C5	**0.5**	**<.001**	**0.4**	**0.050**	**6.9**	**<.001**	**0.6**	**<.001**	**0.6**	**0.010**	**6.4**	**<.001**	**-0.3**	**<.001**	-0.1	1.000	-0.1	1.000	**-1.6**	**<.001**
	C5 - C6	**0.6**	**<.001**	-0.1	1.000	**4.8**	**<.001**	**0.5**	**<.001**	-0.1	1.000	**4.3**	**0.000**	**-0.5**	**<.001**	-0.1	1.000	0.0	1.000	**-2.0**	**<.001**
	C6 - C7	**0.3**	**0.000**	-0.2	1.000	**6.1**	**<.001**	**0.3**	**0.010**	-0.3	1.000	**3.9**	**0.010**	**-0.6**	**<.001**	**-0.4**	**<.001**	**0.2**	**0.010**	**-1.2**	**<.001**
	C7 - T1	**0.3**	**0.010**	-0.3	0.570	**7.1**	**<.001**	**0.3**	**0.020**	-0.2	1.000	**6.3**	**<.001**	0.0	1.000	**0.3**	**<.001**	**0.5**	**<.001**	*	*
C3 - C4	C2 - C3	**-0.6**	**<.001**	**-0.8**	**<.001**	**-10.1**	**<.001**	**-0.8**	**<.001**	**-0.9**	**<.001**	**-9.5**	**<.001**	**0.2**	**0.040**	**0.3**	**0.010**	0.1	1.000	**1.0**	**<.001**
	C4 - C5	-0.1	1.000	-0.4	0.120	-3.2	0.060	-0.2	0.370	-0.3	1.000	-3.1	0.120	-0.2	0.210	0.2	0.530	0.0	1.000	**-0.6**	**<.001**
	C5 - C6	-0.1	1.000	**-0.9**	**<.001**	**-5.3**	**<.001**	**-0.3**	**0.010**	**-1.0**	**<.001**	**-5.2**	**<.001**	**-0.3**	**<.001**	0.2	0.630	0.1	1.000	**-1.0**	**<.001**
	C6 - C7	**-0.3**	**0.010**	**-1.0**	**<.001**	**-4.1**	**0.000**	**-0.5**	**<.001**	**-1.2**	**<.001**	**-5.6**	**<.001**	**-0.4**	**<.001**	-0.2	0.470	**0.2**	**<.001**	-0.3	0.196
	C7 - T1	**-0.3**	**0.000**	**-1.1**	**<.001**	**-3.1**	**0.090**	**-0.5**	**<.001**	**-1.1**	**<.001**	-3.1	0.110	0.2	0.010	**0.6**	**<.001**	**0.5**	**<.001**	*	*
C4 - C5	C2 - C3	**-0.5**	**<.001**	**-0.4**	**0.050**	**-6.9**	**<.001**	**-0.6**	**<.001**	**-0.6**	**0.010**	**-6.4**	**<.001**	**0.3**	**<.001**	0.1	1.000	0.1	1.000	**1.6**	**<.001**
	C3 - C4	0.1	1.000	0.4	0.120	3.2	0.060	0.2	0.370	0.3	1.000	3.1	0.120	0.2	0.210	-0.2	0.530	0.0	1.000	**0.6**	**<.001**
	C5 - C6	0.1	1.000	**-0.5**	**0.010**	-2.1	0.950	-0.1	1.000	**-0.7**	**0.000**	-2.1	1.000	-0.1	0.490	0.0	1.000	0.1	1.000	**-0.4**	**0.006**
	C6 - C7	-0.2	0.730	**-0.6**	**<.001**	-0.8	1.000	**-0.3**	**0.010**	**-0.9**	**<.001**	-2.5	0.500	**-0.2**	**<.001**	**-0.3**	**<.001**	**0.2**	**<.001**	**0.4**	**0.020**
	C7 - T1	-0.2	0.230	**-0.7**	**<.001**	0.2	1.000	**-0.3**	**0.000**	**-0.8**	**<.001**	0.0	1.000	**0.3**	**<.001**	**0.4**	**<.001**	**0.5**	**<.001**	*	*
C5 - C6	C2 - C3	**-0.6**	**<.001**	0.1	1.000	**-4.8**	**<.001**	**-0.5**	**<.001**	0.1	1.000	**-4.3**	**0.000**	**0.5**	**<.001**	0.1	1.000	0.0	1.000	**2.0**	**<.001**
	C3 - C4	0.1	1.000	**0.9**	**<.001**	**5.3**	**<.001**	**0.3**	**0.010**	**1.0**	**<.001**	**5.2**	**<.001**	**0.3**	**<.001**	-0.2	0.630	-0.1	1.000	**1.0**	**<.001**
	C4 - C5	-0.1	1.000	**0.5**	**0.010**	2.1	0.950	0.1	1.000	**0.7**	**0.000**	2.1	1.000	0.1	0.490	0.0	1.000	-0.1	1.000	**0.4**	**0.006**
	C6 - C7	-0.2	0.100	-0.1	1.000	1.3	1.000	-0.2	0.460	-0.2	1.000	-0.4	1.000	-0.1	0.710	**-0.3**	**<.001**	**0.2**	**0.020**	**0.7**	**<.001**
	C7 - T1	**-0.3**	**0.020**	-0.2	1.000	2.2	0.680	-0.2	0.200	-0.1	1.000	2.0	1.000	**0.5**	**<.001**	**0.4**	**<.001**	**0.5**	**<.001**	*	*
C6 - C7	C2 - C3	**-0.3**	**0.000**	0.2	1.000	**-6.1**	**<.001**	**-0.3**	**0.010**	0.3	1.000	**-3.9**	**0.010**	**0.6**	**<.001**	**0.4**	**<.001**	**-0.2**	**0.010**	**1.2**	**<.001**
	C3 - C4	**0.3**	**0.010**	**1.0**	**<.001**	**4.1**	**0.000**	**0.5**	**<.001**	**1.2**	**<.001**	**5.6**	**<.001**	**0.4**	**<.001**	0.2	0.470	**-0.2**	**<.001**	0.3	0.196
	C4 - C5	0.2	0.730	**0.6**	**<.001**	0.8	1.000	**0.3**	**0.010**	**0.9**	**<.001**	2.5	0.500	**0.2**	**<.001**	**0.3**	**<.001**	**-0.2**	**<.001**	**-0.4**	**0.020**
	C5 - C6	0.2	0.100	0.1	1.000	-1.3	1.000	0.2	0.460	0.2	1.000	0.4	1.000	0.1	0.710	**0.3**	**<.001**	**-0.2**	**0.020**	**-0.7**	**<.001**
	C7 - T1	0.0	1.000	-0.1	1.000	1.0	1.000	0.0	1.000	0.1	1.000	2.4	0.550	**0.6**	**<.001**	**0.7**	**<.001**	**0.3**	**<.001**	*	*
C7 - T1	C2 - C3	**-0.3**	**0.010**	0.3	0.570	**-7.1**	**<.001**	**-0.3**	**0.020**	0.2	1.000	**-6.3**	**<.001**	0.0	1.000	**-0.3**	**<.001**	**-0.5**	**<.001**	*	*
	C3 - C4	**0.3**	**0.000**	**1.1**	**<.001**	3.1	0.090	**0.5**	**<.001**	**1.1**	**<.001**	3.1	0.110	**-0.2**	**0.010**	**-0.6**	**<.001**	**-0.5**	**<.001**	*	*
	C4 - C5	0.2	0.230	**0.7**	**<.001**	-0.2	1.000	**0.3**	**0.000**	**0.8**	**<.001**	0.0	1.000	**-0.3**	**<.001**	**-0.4**	**<.001**	**-0.5**	**<.001**	*	*
	C5 - C6	**0.3**	**0.020**	0.2	1.000	-2.2	0.680	0.2	0.200	0.1	1.000	-2.0	1.000	**-0.5**	**<.001**	**-0.4**	**<.001**	**-0.5**	**<.001**	*	*
	C6 - C7	0.0	1.000	0.1	1.000	-1.0	1.000	0.0	1.000	-0.1	1.000	-2.4	0.550	**-0.6**	**<.001**	**-0.7**	**<.001**	**-0.3**	**<.001**	*	*

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

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Table 3. Comparison of Left- Versus Right-Sided Cervical NFD Measurements from C2-T1

Disc Level	Neuroforaminal Measurement	Mean Difference	*p*	Correlation	*p*
C2-C3	*Width*	-0.1	0.151	0.592	<.001
	Height	0.0	0.903	0.219	<.001
	Area	-0.1	0.824	0.717	<.001
C3-C4	*Width*	0.1	0.226	0.659	<.001
	Height	0.0	0.671	0.383	<.001
	Area	0.1	0.226	0.659	<.001
C4-C5	*Width*	0.03	0.485	0.605	<.001
	Height	0.05	0.686	0.265	<.001
	Area	-0.51	0.356	0.710	<.001
C5-C6	*Width*	-0.1	0.006	0.633	<.001
	Height	-0.1	0.749	0.112	0.001
	Area	-0.8	0.167	0.690	<.001
C6-C7	*Width*	-0.1	0.086	0.606	<.001
	Height	-0.1	0.282	0.308	<.001
	Area	-2.1	0.002	0.585	<.001
C7-T1	*Width*	-0.1	0.170	0.634	<.001
	Height	0.1	0.479	0.452	<.001
	Area	-0.6	0.385	0.619	<.001

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Table 4. Differences in NFD, DSH, and IPD Measurements based on Patient Sex

Measurement			Male		Female		Mean Difference (Male - Female)	95% Confidence Interval		*p-value*
			Mean	SD	Mean	SD		Lower Bound	Upper Bound	
C2 - C3	*Left NFD*	*Width*	6.9	1.6	7.2	1.6	-0.3	-0.5	0.0	**0.021**
		Height	10.1	3.2	8.8	1.7	1.3	0.9	1.7	**<.001**
		Area	72.3	23.7	57.8	19.7	14.5	11.2	17.7	**<.001**
	Right NFD	*Width*	6.9	1.7	7.3	1.5	-0.3	-0.6	-0.1	**0.010**
		Height	10.1	4.4	8.9	1.7	1.2	0.7	1.7	**<.001**
		Area	72.1	24.2	58.3	20.5	13.8	10.5	17.1	**<.001**
	DSH	*Anterior*	2.6	0.9	2.2	0.9	0.4	0.3	0.5	**<.001**
		Middle	4.3	1.0	3.9	1.1	0.4	0.2	0.6	**<.001**
		Posterior	2.1	0.9	1.9	0.9	0.2	0.1	0.4	**<.001**
	IPD	*C3*	24.4	1.7	23.8	1.2	0.6	0.3	0.9	**<.001**
C3 - C4	*Left NFD*	*Width*	6.2	1.6	6.6	1.5	-0.4	-0.6	-0.1	**0.003**
		Height	9.1	2.9	8.3	1.5	0.9	0.5	1.2	**<.001**
		Area	59.1	18.9	51.3	16.2	7.8	5.2	10.4	**<.001**
	Right NFD	*Width*	6.1	1.6	6.6	1.5	-0.5	-0.7	-0.3	**<.001**
		Height	9.1	1.7	8.3	1.4	0.8	0.6	1.1	**<.001**
		Area	60.3	19.6	51.4	17.5	9.0	6.2	11.8	**<.001**
	DSH	*Anterior*	2.8	1.0	2.3	0.9	0.5	0.3	0.6	**<.001**
		Middle	4.5	1.0	4.1	1.0	0.5	0.3	0.6	**<.001**
		Posterior	2.3	1.8	1.9	0.8	0.4	0.2	0.6	**<.001**
	IPD	*C4*	25.4	1.7	24.7	1.5	0.6	0.3	1.0	**<.001**
C4 - C5	*Left NFD*	*Width*	6.4	1.4	6.7	1.5	-0.3	-0.5	-0.1	**0.006**
		Height	9.4	1.8	8.8	1.6	0.7	0.4	0.9	**<.001**
		Area	62.9	19.5	53.9	16.8	9.0	6.3	11.7	**<.001**
	Right NFD	*Width*	6.4	1.4	6.6	1.4	-0.3	-0.5	-0.1	**0.012**
		Height	9.3	1.7	8.8	4.4	0.4	0.0	0.9	0.070
		Area	63.8	20.2	53.8	17.0	9.9	7.1	12.8	**<.001**
	DSH	*Anterior*	3.0	1.1	2.4	0.9	0.6	0.5	0.8	**<.001**

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		Middle	4.4	1.0	4.1	2.7	0.4	0.1	0.7	**0.013**
		Posterior	2.2	0.9	1.9	0.8	0.2	0.1	0.4	**<.001**
	IPD	*C5*	26.1	1.9	25.2	1.6	0.9	0.6	1.2	**<.001**
C5 - C6	*Left NFD*	*Width*	6.3	1.5	6.6	1.3	-0.3	-0.5	-0.1	**0.003**
		Height	9.9	4.1	9.1	1.6	0.7	0.3	1.2	**0.002**
		Area	63.8	19.1	56.7	16.5	7.2	4.5	9.9	**<.001**
	Right NFD	*Width*	6.3	1.4	6.9	1.4	-0.6	-0.8	-0.3	**<.001**
		Height	9.6	1.9	9.5	6.9	0.1	-0.6	0.8	0.790
		Area	64.5	20.1	57.6	18.8	6.9	4.0	9.8	**<.001**
	DSH	*Anterior*	3.2	1.1	2.4	1.0	0.8	0.6	1.0	**<.001**
		Middle	4.4	1.0	4.0	1.0	0.5	0.3	0.6	**<.001**
		Posterior	2.1	0.9	1.9	0.8	0.1	0.0	0.3	**0.043**
	IPD	*C6*	26.5	1.9	25.7	1.6	0.8	0.5	1.1	**<.001**
C6 - C7	*Left NFD*	*Width*	6.5	1.3	6.8	1.5	-0.2	-0.4	0.0	**0.024**
		Height	10.0	2.0	9.3	1.8	0.6	0.3	0.9	**<.001**
		Area	62.5	18.0	56.2	16.5	6.4	3.8	8.9	**<.001**
	Right NFD	*Width*	6.6	1.4	7.0	1.5	-0.4	-0.6	-0.2	**<.001**
		Height	10.0	2.0	9.5	3.7	0.5	0.0	0.9	**0.033**
		Area	65.4	21.2	57.3	19.0	8.1	5.1	11.2	**<.001**
	DSH	*Anterior*	3.4	1.2	2.4	1.0	1.0	0.8	1.1	**<.001**
		Middle	4.8	2.6	4.2	1.0	0.6	0.3	0.9	**<.001**
		Posterior	1.9	1.1	1.8	0.9	0.0	-0.1	0.2	0.655
	IPD	*C7*	25.7	1.9	25.0	1.6	0.7	0.4	1.1	**<.001**
C7 - T1	*Left NFD*	*Width*	6.8	1.4	6.6	1.4	0.2	0.0	0.4	**0.028**
		Height	10.2	2.0	9.2	1.9	1.0	0.7	1.3	**<.001**
		Area	63.5	19.6	52.9	17.1	10.6	7.8	13.3	**<.001**
	Right NFD	*Width*	6.8	1.4	6.7	1.4	0.1	-0.1	0.3	0.503
		Height	10.2	2.0	9.1	1.7	1.0	0.8	1.3	**<.001**
		Area	64.5	19.9	52.9	16.9	11.6	8.9	14.4	**<.001**
	DSH	*Anterior*	2.6	1.0	2.1	0.9	0.5	0.4	0.7	**<.001**
		Middle	3.9	1.0	3.7	1.0	0.2	0.1	0.4	**0.005**
		Posterior	1.6	0.8	1.5	0.8	0.1	0.0	0.2	0.092

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.

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Table 5. Differences in NFD, DSH, and IPD Measurements based on Patient Race and Ethnicity

Measurement			African American		Caucasian		Hispanic		Asian		Other	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C2 - C3	Left NFD	Width	6.8	2.0	7.1	1.5	7.0	1.5	7.1	1.5	7.6	1.8
		Height	9.3	1.8	9.9	1.9	9.5	3.3	9.3	1.8	9.4	1.5
		Area	63.1	20.6	70.5	21.8	64.9	24.1	62.6	25.5	59.0	22.4
	Right NFD	Width	6.8	1.6	7.1	1.5	7.1	1.6	7.4	1.9	7.8	1.8
		Height	9.2	1.9	9.8	1.9	9.6	4.5	9.3	2.1	9.1	1.5
		Area	61.1	20.9	70.7	21.9	65.8	24.1	59.1	27.6	61.7	27.9
	DSH	Anterior	2.4	0.9	2.7	0.9	2.3	0.9	2.3	0.9	2.5	0.8
		Middle	3.9	1.1	4.3	1.3	4.0	1.0	3.9	1.1	4.2	1.0
		Posterior	2.1	1.0	2.1	1.0	1.9	0.9	1.9	0.8	1.9	0.9
	IPD	C3	24.0	1.6	24.6	1.7	24.0	1.5	24.2	1.6	24.5	1.2
C3 - C4	Left NFD	Width	6.3	1.8	6.4	1.5	6.4	1.6	6.6	1.3	7.0	1.3
		Height	8.4	1.7	9.1	3.7	8.7	1.7	8.7	1.5	8.8	2.1
		Area	51.5	16.1	58.7	16.5	55.9	19.1	54.2	18.4	51.1	17.7
	Right NFD	Width	6.2	1.6	6.3	1.6	6.4	1.5	6.3	1.7	6.6	2.2
		Height	8.6	1.7	8.9	1.6	8.7	1.7	8.7	1.5	8.3	1.4
		Area	52.3	17.2	59.4	18.4	56.9	19.5	52.5	23.7	46.1	18.7
	DSH	Anterior	2.5	1.0	2.7	1.0	2.5	1.0	2.3	0.9	2.5	0.9
		Middle	4.1	1.0	4.5	1.0	4.3	1.0	4.3	1.1	4.5	1.0
		Posterior	2.1	0.8	2.2	0.9	2.1	1.8	1.9	0.8	2.0	1.0
	IPD	C4	25.0	1.4	25.5	1.8	25.0	1.6	24.8	1.8	25.5	1.1
C4 - C5	Left NFD	Width	6.4	1.6	6.6	1.6	6.5	1.4	6.5	1.6	6.7	1.5
		Height	8.7	1.7	9.4	1.8	9.1	1.7	9.0	1.9	9.5	2.1
		Area	54.5	17.9	61.8	18.9	59.1	18.9	53.4	18.6	58.1	18.4
	Right NFD	Width	6.3	1.4	6.4	1.4	6.5	1.4	6.7	1.5	6.5	1.7
		Height	8.7	1.5	9.6	5.8	9.0	1.7	8.6	1.7	8.7	1.3
		Area	57.0	17.3	62.8	18.3	59.2	20.0	54.3	27.6	53.0	18.0
	DSH	Anterior	2.7	1.1	2.9	1.1	2.7	1.0	2.3	0.8	2.7	1.0
		Middle	4.2	1.0	4.3	1.0	4.3	2.5	4.1	1.0	4.1	1.0
		Posterior	2.2	0.9	2.1	0.8	2.0	0.9	1.8	0.7	2.1	0.8
	IPD	C5	25.7	1.7	26.2	2.0	25.6	1.8	25.7	1.7	26.1	1.3

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C5 - C6	Left NFD	Width	6.4	1.5	6.3	1.4	6.5	1.4	6.3	0.8	7.1	1.5
		Height	9.0	1.6	9.6	1.7	9.7	4.1	9.2	1.6	9.5	1.7
		Area	57.3	15.6	63.4	17.9	61.0	19.0	50.9	14.2	58.8	21.8
	Right NFD	Width	6.7	1.6	6.4	1.4	6.6	1.4	7.0	1.5	7.0	1.3
		Height	9.9	8.9	9.9	6.2	9.4	2.0	9.1	2.1	9.3	1.5
		Area	59.2	16.8	64.4	18.6	61.3	20.3	56.5	31.4	57.5	18.3
	DSH	Anterior	2.8	1.1	3.1	1.2	2.8	1.1	2.6	1.1	2.8	1.0
		Middle	4.2	0.9	4.3	1.0	4.2	1.0	4.1	1.1	4.3	0.9
		Posterior	2.3	0.9	2.0	0.9	25.9	1.8	1.6	0.5	2.0	0.7
	IPD	C6	26.1	1.8	26.6	1.8	1.9	0.9	26.3	2.6	25.9	1.3
C6 - C7	Left NFD	Width	6.7	1.7	6.6	1.2	6.7	1.4	6.2	1.4	7.3	1.1
		Height	9.3	1.7	9.8	1.7	9.8	2.0	8.9	1.8	9.5	2.0
		Area	56.2	15.4	63.2	16.8	59.9	18.0	50.8	15.1	56.0	23.0
	Right NFD	Width	6.8	1.7	6.6	1.3	6.8	1.4	6.9	1.8	7.3	1.7
		Height	9.4	1.9	10.0	1.9	9.9	3.5	9.4	2.1	9.7	2.1
		Area	58.3	16.7	65.8	20.7	61.7	20.8	56.3	31.3	56.6	19.5
	DSH	Anterior	2.9	1.2	3.2	1.2	2.9	1.2	2.6	1.3	3.1	1.0
		Middle	4.3	1.1	4.5	1.1	4.6	2.6	4.3	1.2	4.7	0.8
		Posterior	2.0	0.8	1.8	0.9	1.8	1.1	1.5	0.9	1.7	0.7
	IPD	C7	25.3	1.8	25.8	1.9	25.2	1.8	25.4	1.9	25.6	1.5
C7 - T1	Left NFD	Width	6.5	1.5	6.8	1.4	6.7	1.4	6.5	1.5	6.5	1.1
		Height	9.4	1.8	10.2	2.0	9.8	2.1	9.1	1.9	9.3	1.9
		Area	53.1	16.4	64.1	19.4	58.4	19.0	52.1	20.0	53.0	21.9
	Right NFD	Width	6.7	1.6	6.8	1.5	6.8	1.3	6.5	1.1	7.0	1.2
		Height	9.3	1.4	9.9	1.9	9.8	2.0	9.4	2.2	9.4	1.6
		Area	54.6	15.7	62.8	19.2	59.6	19.9	57.5	28.1	51.3	15.5
	DSH	Anterior	2.3	0.9	2.6	1.1	2.3	1.0	2.3	1.1	2.5	0.8
		Middle	3.9	1.0	3.7	1.1	3.8	1.0	4.0	1.0	3.9	0.9
		Posterior	1.8	0.8	1.5	0.8	1.5	0.8	1.4	0.7	1.4	0.8

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Table 6. Mean Differences in NFD, DSH, and IPD Measurements among African American, Caucasian, Hispanic, and Asian Cohorts

Disc Level	Reference	Comparison	Mean Difference (Reference - Comparison)																			
			Left NFD Width		Left NFD Height		Left NFD Area		Right NFD Width		Right NFD Height		Right NFD Area		Anterior DSH		Middle DSH		Posterior DSH		IPD	
			MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*	MD	*p*
C2 – C3	*African American*	*Caucasian*	-0.3	0.542	-0.6	0.297	**-7.4**	**0.029**	-0.3	0.31	-0.6	0.556	**-9.6**	**0.002**	**-0.3**	**0.007**	**-0.4**	**0.009**	0	1	**-0.6**	**0.034**
	African American	*Hispanic*	-0.2	0.809	-0.2	1	-1.8	1	-0.3	0.272	-0.4	0.996	-4.7	0.199	0.1	1	-0.2	0.633	0.2	0.071	-0.1	1
	African American	*Asian*	-0.3	1	0.1	1	0.5	1	-0.6	1	-0.1	1	1.9	1	0.0	1	0.0	1	0.2	1	-0.2	1
	Caucasian	*African American*	0.3	0.542	0.6	0.297	**7.4**	**0.029**	0.3	0.31	0.6	0.556	**9.6**	**0.002**	**0.3**	**0.007**	**0.4**	**0.009**	0	1	**0.6**	**0.034**
	Caucasian	*Hispanic*	0.1	1	0.4	0.32	**5.6**	**0.021**	0	1	0.2	1	4.9	0.056	**0.4**	**<.001**	**0.2**	**0.033**	**0.3**	**0.006**	**0.5**	**0.008**
	Caucasian	*Asian*	0.0	1	0.6	1	7.9	1	-0.2	1	0.5	1	11.6	0.398	0.4	0.918	0.4	1	0.2	1	0.4	1
	Hispanic	*African American*	0.2	0.809	0.2	1	1.8	1	0.3	0.272	0.4	0.996	4.7	0.199	-0.1	1	0.2	0.633	-0.2	0.071	0.1	1
	Hispanic	*Caucasian*	-0.1	1	-0.4	0.32	**-5.6**	**0.021**	0	1	-0.2	1	-4.9	0.056	**-0.4**	**<.001**	**-0.2**	**0.033**	**-0.3**	**0.006**	**-0.5**	**0.008**
	Hispanic	*Asian*	-0.1	1	0.2	1	2.3	1	-0.3	1	0.3	1	6.7	1	-0.1	1	0.1	1	0.0	1	-0.1	1
	Asian	*African American*	0.3	1	-0.1	1.0	-0.5	1.0	0.6	1.0	0.1	1.0	-1.9	1.0	0.0	1	0.0	1	-0.2	1	0.2	1
	Asian	*Caucasian*	0.0	1	-0.6	1.0	-7.9	1.0	0.2	1.0	-0.5	1.0	-11.6	0.4	-0.4	0.918	-0.4	1	-0.2	1	-0.4	1
	Asian	*Hispanic*	0.1	1	-0.2	1.0	-2.3	1.0	0.3	1.0	-0.3	1.0	-6.7	1.0	0.1	1	-0.1	1	0.0	1	0.1	1
C3 - C4	*African American*	*Caucasian*	-0.1	1	**-0.8**	**0.036**	**-7.2**	**0.004**	-0.1	1	-0.3	0.391	**-7**	**0.008**	-0.2	0.556	**-0.4**	**0.012**	0	1	-0.5	0.158
	African American	*Hispanic*	-0.1	1	-0.3	0.694	-4.4	0.092	-0.2	1	-0.1	1	-4.6	0.087	0	1	-0.2	0.264	0	1	0.1	1
	African American	*Asian*	-0.3	1	-0.3	1.0	-2.7	1.0	-0.1	1.0	-0.1	1.0	-0.2	1.0	0.3	1	-0.2	1	0.3	1	0.2	1
	Caucasian	*African American*	0.1	1	**0.8**	**0.036**	**7.2**	**0.004**	0.1	1	0.3	0.391	**7**	**0.008**	0.2	0.556	**0.4**	**0.012**	0	1	0.5	0.158
	Caucasian	*Hispanic*	0	1	0.4	0.147	2.8	0.255	-0.1	1	0.2	0.811	2.4	0.464	0.2	0.201	0.2	0.191	0.1	1	**0.6**	**0.005**
	Caucasian	*Asian*	-0.2	1	0.4	1.0	4.5	1.0	0.0	1.0	0.2	1.0	6.9	1.0	0.4	0.746	0.2	1	0.3	1	0.7	1
	Hispanic	*African American*	0.1	1	0.3	0.694	4.4	0.092	0.2	1	0.1	1	4.6	0.087	0	1	0.2	0.264	0	1	-0.1	1
	Hispanic	*Caucasian*	0	1	-0.4	0.147	-2.8	0.255	0.1	1	-0.2	0.811	-2.4	0.464	-0.2	0.201	-0.2	0.191	-0.1	1	**-0.6**	**0.005**
	Hispanic	*Asian*	-0.2	1	0.0	1.0	1.7	1.0	0.0	1.0	0.1	1.0	4.4	1.0	0.3	1	0.0	1	0.2	1	0.1	1
	Asian	*African American*	0.3	1	0.3	1.0	2.7	1.0	0.1	1.0	0.1	1.0	0.2	1.0	-0.3	1	0.2	1	-0.3	1	-0.2	1
	Asian	*Caucasian*	0.2	1	-0.4	1.0	-4.5	1.0	0.0	1.0	-0.2	1.0	-6.9	1.0	-0.4	0.746	-0.2	1	-0.3	1	-0.7	1
	Asian	*Hispanic*	0.2	1	0.0	1.0	-1.7	1.0	0.0	1.0	-0.1	1.0	-4.4	1.0	-0.3	1	0.0	1	-0.2	1	-0.1	1
C4 - C5	*African American*	*Caucasian*	-0.2	0.629	**-0.7**	**0.001**	**-7.3**	**0.005**	-0.1	1	-0.9	0.084	**-5.7**	**0.049**	-0.2	0.296	-0.1	1	0.1	0.908	-0.5	0.246
	African American	*Hispanic*	-0.2	1	-0.4	0.082	-4.6	0.087	-0.2	0.549	-0.3	1	-2.2	0.895	0	1	-0.1	1	0.2	0.059	0.1	1
	African American	*Asian*	-0.2	1	-0.4	1.0	1.1	1.0	-0.4	1.0	0.1	1.0	2.7	1.0	0.4	1	0.1	1	0.4	0.633	-0.1	1
	Caucasian	*African American*	0.2	0.629	**0.7**	**0.001**	**7.3**	**0.005**	0.1	1	0.9	0.084	**5.7**	**0.049**	0.2	0.296	0.1	1	-0.1	0.908	0.5	0.246
	Caucasian	*Hispanic*	0.1	1	0.3	0.105	2.7	0.322	-0.1	0.965	0.6	0.133	3.5	0.132	0.2	0.075	0	1	0.1	0.425	**0.6**	**0.01**
	Caucasian	*Asian*	0.0	1	0.4	1.0	8.4	0.6	-0.3	1.0	1.1	1.0	8.4	0.8	0.6	0.263	0.2	1	0.3	1	0.4	1
	Hispanic	*African American*	0.2	1	0.4	0.082	4.6	0.087	0.2	0.549	0.3	1	2.2	0.895	0	1	0.1	1	-0.2	0.059	-0.1	1
	Hispanic	*Caucasian*	-0.1	1	-0.3	0.105	-2.7	0.322	0.1	0.965	-0.6	0.133	-3.5	0.132	-0.2	0.075	0	1	-0.1	0.425	**-0.6**	**0.01**
	Hispanic	*Asian*	0.0	1	0.1	1.0	5.6	1.0	-0.2	1.0	0.4	1.0	4.9	1.0	0.4	1	0.2	1	0.2	1	-0.2	1

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	Asian	*African American*	0.2	1	0.4	1.0	-1.1	1.0	0.4	1.0	-0.1	1.0	-2.7	1.0	-0.4	1	-0.1	1	-0.4	0.633	0.1	1
	Asian	*Caucasian*	0.0	1	-0.4	1.0	-8.4	0.6	0.3	1.0	-1.1	1.0	-8.4	0.8	-0.6	0.263	-0.2	1	-0.3	1	-0.4	1
	Asian	*Hispanic*	0.0	1	-0.1	1.0	-5.6	1.0	0.2	1.0	-0.4	1.0	-4.9	1.0	-0.4	1	-0.2	1	-0.2	1	0.2	1
	African American	*Caucasian*	0.1	1	-0.6	0.455	**-6**	**0.023**	0.2	0.521	-0.1	1	-5.2	0.092	-0.3	0.071	-0.1	1	0.2	0.12	-0.5	0.221
	African American	*Hispanic*	-0.1	1	-0.7	0.211	-3.7	0.204	0.1	1	0.5	1	-2	1	0	1	0	1	**0.4**	**<.001**	0.1	1
	African American	*Asian*	0.1	1	-0.2	1.0	6.4	1.0	-0.3	1.0	0.8	1.0	2.8	1.0	0.2	1	0.1	1	0.7	0.024	-0.2	1
	Caucasian	*African American*	-0.1	1	0.6	0.455	**6**	**0.023**	-0.2	0.521	0.1	1	5.2	0.092	0.3	0.071	0.1	1	-0.2	0.12	0.5	0.221
	Caucasian	*Hispanic*	-0.2	0.503	-0.1	1	2.3	0.47	-0.2	0.734	0.5	0.75	3.2	0.213	**0.3**	**0.008**	0.1	0.811	0.1	0.222	**0.6**	**0.004**
C5 - C6	*Caucasian*	*Asian*	0.0	1	0.4	1.0	12.5	0.0	-0.6	1.0	0.9	1.0	8.0	1.0	0.5	0.919	0.2	1	0.5	0.348	0.3	1
	Hispanic	*African American*	0.1	1	0.7	0.211	3.7	0.204	-0.1	1	-0.5	1	2	1	0	1	0	1	**-0.4**	**<.001**	-0.1	1
	Hispanic	*Caucasian*	0.2	0.503	0.1	1	-2.3	0.47	0.2	0.734	-0.5	0.75	-3.2	0.213	**-0.3**	**0.008**	-0.1	0.811	-0.1	0.222	**-0.6**	**0.004**
	Hispanic	*Asian*	0.2	1	0.5	1.0	10.1	0.2	-0.4	1.0	0.4	1.0	4.8	1.0	0.2	1	0.1	1	0.3	1	-0.4	1
	Asian	*African American*	-0.1	1	0.2	1.0	-6.4	1.0	0.3	1.0	-0.8	1.0	-2.8	1.0	-0.2	1	-0.1	1	-0.7	0.024	0.2	1
	Asian	*Caucasian*	0.0	1	-0.4	1.0	-12.5	0.0	0.6	1.0	-0.9	1.0	-8.0	1.0	-0.5	0.919	-0.2	1	-0.5	0.348	-0.3	1
	Asian	*Hispanic*	0.0	1	-0.5	1.0	-10.1	0.2	0.4	1.0	-0.4	1.0	-4.8	1.0	-0.2	1	-0.1	1	-0.3	1	0.4	1
	African American	*Caucasian*	0.1	1	-0.5	0.116	**-7**	**0.004**	0.2	0.944	-0.5	0.439	**-7.5**	**0.009**	-0.3	0.154	-0.2	1	0.2	0.231	-0.5	0.208
	African American	*Hispanic*	0	1	-0.5	0.104	-3.7	0.175	0	1	-0.4	0.605	-3.4	0.407	0	1	-0.3	0.638	0.2	0.116	0.1	1
	African American	*Asian*	0.5	1	0.5	1.0	5.4	1.0	-0.1	1.0	0.1	1.0	2.1	1.0	0.3	1	0.0	1	0.5	0.477	-0.1	1
	Caucasian	*African American*	-0.1	1	0.5	0.116	**7**	**0.004**	-0.2	0.944	0.5	0.439	**7.5**	**0.009**	0.3	0.154	0.2	1	-0.2	0.231	0.5	0.208
	Caucasian	*Hispanic*	-0.1	1	0	1	3.3	0.106	-0.1	0.716	0.1	1	4.1	0.077	**0.3**	**0.035**	-0.1	1	0	1	**0.5**	**0.017**
C6 - C7	*Caucasian*	*Asian*	0.4	1	0.9	0.4	12.3	0.0	-0.3	1.0	0.6	1.0	9.5	0.6	0.5	0.585	0.1	1	0.3	1	0.4	1
	Hispanic	*African American*	0	1	0.5	0.104	3.7	0.175	0	1	0.4	0.605	3.4	0.407	0	1	0.3	0.638	-0.2	0.116	-0.1	1
	Hispanic	*Caucasian*	0.1	1	0	1	-3.3	0.106	0.1	0.716	-0.1	1	-4.1	0.077	**-0.3**	**0.035**	0.1	1	0	1	**-0.5**	**0.017**
	Hispanic	*Asian*	0.5	1	0.9	0.4	9.0	0.3	-0.1	1.0	0.5	1.0	5.4	1.0	0.3	1	0.3	1	0.3	1	-0.1	1
	Asian	*African American*	-0.5	1	-0.5	1.0	-5.4	1.0	0.1	1.0	-0.1	1.0	-2.1	1.0	-0.3	1	0.0	1	-0.5	0.477	0.1	1
	Asian	*Caucasian*	-0.4	1	-0.9	0.4	-12.3	0.0	0.3	1.0	-0.6	1.0	-9.5	0.6	-0.5	0.585	-0.1	1	-0.3	1	-0.4	1
	Asian	*Hispanic*	-0.5	1	-0.9	0.4	-9.0	0.3	0.1	1.0	-0.5	1.0	-5.4	1.0	-0.3	1	-0.3	1	-0.3	1	0.1	1
	African American	*Caucasian*	-0.3	0.209	**-0.8**	**0.005**	**-11**	**<.001**	-0.1	1	**-0.6**	**0.022**	**-8.2**	**0.002**	-0.3	0.051	0.1	0.74	**0.3**	**0.038**	*	*
	African American	*Hispanic*	-0.2	0.444	-0.4	0.205	**-5.3**	**0.033**	-0.1	1	**-0.5**	**0.041**	-5	0.057	0	1	0.1	0.976	**0.3**	**0.016**	*	*
	African American	*Asian*	0.0	1	0.2	1.0	1.0	1.0	0.2	1.0	-0.2	1.0	-2.9	1.0	-0.1	1	-0.1	1	0.4	0.85	*	*
	Caucasian	*African American*	0.3	0.209	**0.8**	**0.005**	**11**	**<.001**	0.1	1	**0.6**	**0.022**	**8.2**	**0.002**	0.3	0.051	-0.1	0.74	**-0.3**	**0.038**	*	*
C7 - T1	*Caucasian*	*Hispanic*	0.1	1	0.4	0.114	**5.7**	**0.002**	0	1	0.1	1	3.1	0.211	**0.3**	**0.019**	0	1	0	1	*	*
	Caucasian	*Asian*	0.3	1	1.0	0.4	12.0	0.1	0.3	1.0	0.5	1.0	5.3	1.0	0.2	1	-0.3	1	0.1	1	*	*
	Hispanic	*African American*	0.2	0.444	0.4	0.205	**5.3**	**0.033**	0.1	1	**0.5**	**0.041**	5	0.057	0	1	-0.1	0.976	**-0.3**	**0.016**	*	*
	Hispanic	*Caucasian*	-0.1	1	-0.4	0.114	**-5.7**	**0.002**	0	1	-0.1	1	-3.1	0.211	**-0.3**	**0.019**	0	1	0	1	*	*
	Hispanic	*Asian*	0.2	1	0.6	1.0	6.3	1.0	0.3	1.0	0.4	1.0	2.1	1.0	0.0	1	-0.2	1	0.1	1	*	*
	Asian	*African American*	0.0	1	-0.2	1.0	-1.0	1.0	-0.2	1.0	0.2	1.0	2.9	1.0	0.1	1	0.1	1	-0.4	0.85	*	*
	Asian	*Caucasian*	-0.3	1	-1.0	0.4	-12.0	0.1	-0.3	1.0	-0.5	1.0	-5.3	1.0	-0.2	1	0.3	1	-0.1	1	*	*
	Asian	*Hispanic*	-0.2	1	-0.6	1.0	-6.3	1.0	-0.3	1.0	-0.4	1.0	-2.1	1.0	0.0	1	0.2	1	-0.1	1	*	*

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.

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Table 7. Correlation Matrix among Patient Anthropometric Factors and Cervical NFD, DSH, and IPD†

Measurement			Left NFD			Right NFD			Disc Space Height			IPD	Height	Weight	BMI
			Width	Height	Area	Width	Height	Area	Anterior	Middle	Posterior				
C2 - C3	Left NFD	Width	1.000	.065	-.041	.592	.000	-.049	.007	-.034	-.018	.179	.010	-.082	-.089
		Height	.065	1.000	.393	.009	.219	.324	.200	.195	.222	.025	.406	.168	.026
		Area	-.041	.393	1.000	-.127	.252	.717	.263	.333	.287	.146	.414	.145	-.002
	Right NFD	Width	.592	.009	-.127	1.000	-.032	-.069	-.075	-.063	-.053	.112	-.038	-.107	-.104
		Height	.000	.219	.252	-.032	1.000	.261	.163	.114	.149	-.007	.153	.089	.013
		Area	-.049	.324	.717	-.069	.261	1.000	.284	.341	.295	.134	.404	.113	-.015
	DSH	Anterior	.007	.200	.263	-.075	.163	.284	1.000	.483	.468	.146	.304	.075	-.073
		Middle	-.034	.195	.333	-.063	.114	.341	.483	1.000	.512	.133	.283	.043	-.090
		Posterior	-.018	.222	.287	-.053	.149	.295	.468	.512	1.000	.063	.137	.038	-.001
	IPD	C3	.179	.025	.146	.112	-.007	.134	.146	.133	.063	1.000	.227	.063	-.072
C3 - C4	Left NFD	Width	1.000	.014	-.027	.659	-.013	-.093	.024	-.051	-.044	.251	-.099	-.143	-.026
		Height	.014	1.000	.494	-.075	.383	.273	.139	.183	.136	.068	.279	.160	.026
		Area	-.027	.494	1.000	-.106	.410	.711	.300	.382	.223	.161	.342	.104	-.024
	Right NFD	Width	.659	-.075	-.106	1.000	-.009	-.051	-.011	-.071	-.064	.165	-.096	-.129	-.018
		Height	-.013	.383	.410	-.009	1.000	.616	.235	.281	.216	.111	.352	.136	-.008
		Area	-.093	.273	.711	-.051	.616	1.000	.324	.419	.224	.166	.325	.082	-.019
	DSH	Anterior	.024	.139	.300	-.011	.235	.324	1.000	.499	.330	.144	.250	.026	-.077
		Middle	-.051	.183	.382	-.071	.281	.419	.499	1.000	.336	.134	.223	.005	-.102
		Posterior	-.044	.136	.223	-.064	.216	.224	.330	.336	1.000	.100	.184	.154	.078
	IPD	C4	.251	.068	.161	.165	.111	.166	.144	.134	.100	1.000	.195	.064	-.110
C4 - C5	Left NFD	Width	1.000	.063	.005	.605	.071	-.027	-.089	-.020	-.033	.196	-.065	-.088	-.051
		Height	.063	1.000	.618	.039	.265	.422	.174	.122	.260	.087	.314	.203	.070
		Area	.005	.618	1.000	-.044	.204	.710	.322	.152	.267	.149	.318	.116	-.022
	Right NFD	Width	.605	.039	-.044	1.000	.026	-.055	-.120	-.028	-.085	.164	-.093	-.130	-.147
		Height	.071	.265	.204	.026	1.000	.310	.127	.078	.162	.125	.312	.120	.056
		Area	-.027	.422	.710	-.055	.310	1.000	.356	.170	.296	.107	.278	.071	-.053
	DSH	Anterior	-.089	.174	.322	-.120	.127	.356	1.000	.301	.465	.123	.272	-.011	-.139
		Middle	-.020	.122	.152	-.028	.078	.170	.301	1.000	.270	.018	-.007	-.031	-.046
		Posterior	-.033	.260	.267	-.085	.162	.296	.465	.270	1.000	.135	.153	.121	.092
	IPD	C5	.196	.087	.149	.164	.125	.107	.123	.018	.135	1.000	.281	.071	-.049
C5 - C6	Left NFD	Width	1.000	.053	.014	.633	.029	-.019	-.137	-.075	.030	.152	-.052	.009	.029
		Height	.053	1.000	.219	.022	.112	.238	.089	.105	.070	-.064	.311	.116	.086
		Area	.014	.219	1.000	-.033	.154	.690	.365	.303	.271	.089	.360	.150	.007
	Right NFD	Width	.633	.022	-.033	1.000	-.025	.002	-.157	-.081	-.060	.130	-.071	-.041	-.013
		Height	.029	.112	.154	-.025	1.000	.222	.079	.056	.073	-.038	.010	.012	-.016
		Area	-.019	.238	.690	.002	.222	1.000	.365	.370	.266	.044	.280	.073	-.014
	DSH	Anterior	-.137	.089	.365	-.157	.079	.365	1.000	.629	.347	.121	.333	-.012	-.151
		Middle	-.075	.105	.303	-.081	.056	.370	.629	1.000	.489	.032	.270	.049	-.065
		Posterior	.030	.070	.271	-.060	.073	.266	.347	.489	1.000	.040	.114	.288	.284
	IPD	C6	.152	-.064	.089	.130	-.038	.044	.121	.032	.040	1.000	.291	.067	-.020
C6 - C7	Left NFD	Width	1.000	.107	.065	.606	-.017	-.054	-.140	-.068	.045	.145	-.042	.055	.100
		Height	.107	1.000	.635	.013	.308	.307	.109	.044	.091	.021	.269	.181	.066
		Area	.065	.635	1.000	-.037	.330	.585	.315	.132	.233	.125	.340	.188	.076
	Right NFD	Width	.606	.013	-.037	1.000	.005	-.016	-.126	-.045	.010	.081	-.095	-.005	.078
		Height	-.017	.308	.330	.005	1.000	.382	.148	.076	.126	-.066	.215	.187	.105
		Area	-.054	.307	.585	-.016	.382	1.000	.335	.139	.176	.072	.289	.131	.025
	DSH	Anterior	-.140	.109	.315	-.126	.148	.335	1.000	.349	.261	.121	.424	.047	-.088
		Middle	-.068	.044	.132	-.045	.076	.139	.349	1.000	.167	-.003	.246	.032	-.067
		Posterior	.045	.091	.233	.010	.126	.176	.261	.167	1.000	.025	.092	.258	.294
	IPD	C7	.145	.021	.125	.081	-.066	.072	.121	-.003	.025	1.000	.250	.025	-.035
C7 - T1	Left NFD	Width	1.000	.144	.219	.634	.055	.154	-.006	.028	-.046	*	.137	-.033	-.037
		Height	.144	1.000	.717	.081	.452	.414	.151	.184	.067	*	.285	.112	-.007
		Area	.219	.717	1.000	.103	.398	.619	.296	.171	.160	*	.330	.121	.004
	Right NFD	Width	.634	.081	.103	1.000	.088	.161	-.053	-.021	-.090	*	.120	-.061	-.029
		Height	.055	.452	.398	.088	1.000	.687	.120	.202	.043	*	.335	.179	.036
		Area	.154	.414	.619	.161	.687	1.000	.258	.196	.127	*	.325	.135	.030
	DSH	Anterior	-.006	.151	.296	-.053	.120	.258	1.000	.433	.341	*	.209	-.063	-.153
		Middle	.028	.184	.171	-.021	.202	.196	.433	1.000	.397	*	.150	.003	-.067
		Posterior	-.046	.067	.160	-.090	.043	.127	.341	.397	1.000	*	.142	.256	.196
C2 – T1	Left NFD	Width	1.000	.078	.051	.629	.029	-.002	-.070	-.044	-.023	.125	-.021	-.050	-.015
		Height	.078	1.000	.466	.029	.238	.318	.131	.101	.107	.005	.295	.146	.040
		Area	.051	.466	1.000	-.023	.251	.681	.291	.197	.225	.071	.348	.135	.005
	Right NFD	Width	.629	.029	-.023	1.000	.014	.011	-.101	-.055	-.067	.076	-.048	-.079	-.040
		Height	.029	.238	.251	.014	1.000	.339	.125	.085	.096	.002	.141	.095	.021
		Area	-.002	.318	.681	.011	.339	1.000	.308	.222	.217	.048	.315	.100	-.008
	DSH	Anterior	-.070	.131	.291	-.101	.125	.308	1.000	.410	.347	.181	.296	.010	-.111
		Middle	-.044	.101	.197	-.055	.085	.222	.410	1.000	.301	.042	.137	.010	-.060
		Posterior	-.023	.107	.225	-.067	.096	.217	.347	.301	1.000	.055	.131	.174	.153
	IPD	C3 - C7	.125	.005	.071	.076	.002	.048	.181	.042	.055	1.000	.234	.053	-.059

† Values in bold denote $p < .05$

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

PAPER 64

Dynamic Radiographs are Unreliable to Assess Arthrodesis following Cervical Fusion: A Modeled Radiostereometric Analysis of Cervical Motion

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Introduction: The utility of flexion-extension radiographs in clinical practice remains in question due to poor reliability of the parameters utilized to measure motion. The purpose of the present study was to utilize an idealized cervical spine model to determine whether the parallax effect or changes in the position of the spine relative to the x-ray generator influence intervertebral motion parameters on dynamic cervical spine radiographs.

Materials and Methods: A cervical spine model with tantalum beads inserted into the tip of each spinous process was utilized to measure interspinous process distance on plain radiographs (IPD). The model was then manipulated to alter the generator angle and generator distance, and the IPD was measured. The impact of individual and combined changes in these parameters on IPD was assessed. Multivariate analysis was performed to identify independent drivers of variability in IPD measurements.

Results: Isolated changes in the generator distance and generator angle and combined changes in these parameters led to significant changes in the measured IPD at each intervertebral level in neutral, flexion, and extension, which, in many instances, exceeded an absolute change of >1mm or >2mm. Multivariate analysis revealed that generator distance and generator angle are both independent factors impacting IPD measurements that have an additive effect.

Conclusion: In an idealized cervical spine model, small clinically feasible changes in spine position relative to the x-ray generator produced substantial variability in interspinous process distance measurements, with absolute changes that often exceeded established cutoffs for determining the presence of pathologic motion across a fused segment. This study further reinforces that motion assessment on dynamic radiographs is not a reliable method for determining the presence of an arthrodesis unless these sources of variability can be consistently eliminated.

TABLE 5. Coefficients for Interspinous Process Distance

Variable	Coefficient	95% Confidence Interval	P value
Generator Angle	-0.04	-0.05 - -0.03	**<0.001**
Generator Distance	0.21	0.14 - 0.29	**<0.001**
Position of the Spine (Flexion)	2.7	-6.38 - -5.17	**<0.001**
Position of the Spine (Extension)	-5.8	2.12 - 3.32	**<0.001**

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Table 6: Combined Impact of Generator Distance and Angle on Interspinous Process Distance (mm*) at C6-7 in the Neutral Position

	+4cm	0cm	-4cm
+30°	31.5 ± 0.5	30.8 ± 0.6	30.2 ± 0.3
+25°	31.8 ± 0.2	31.3 ± 0.1	30.7 ± 0.5
+20°	32.2 ± 0.2	31.8 ± 0.2	31.0 ± 0.1
+15°	33.1 ± 0.4	31.5 ± 0.2	31.0 ± 0.3
+10°	32.9 ± 0.1	32.2 ± 0.3	31.6 ± 0.2
+5°	33.4 ± 0.3	32.7 ± 0.4	31.8 ± 0.6
0°	34.1 ± 0.4	32.9 ± 0.6	32.2 ± 0.3
-5°	34.4 ± 0.5	32.8 ± 0.5	32.6 ± 0.5
-10°	35.0 ± 0.4	33.6 ± 0.4	32.9 ± 0.3
-15°	35.0 ± 0.5	34.1 ± 0.3	32.9 ± 0.3
-20°	34.9 ± 0.3	34.4 ± 0.3	33.5 ± 0.1
-25°	35.6 ± 0.4	34.5 ± 0.2	33.6 ± 0.3
-30°	36.2 ± 0.4	34.9 ± 0.4	34.4 ± 0.3

†Continuous variables are represented as mean ± standard deviation.
*Abbreviations: millimeters (mm)
Boxes shaded in blue represent values that differ by ≥1mm from baseline. Boxes shaded in orange represent values that differ by ≥2mm from baseline. The box shaded in yellow represents the baseline measurement at C6-7.

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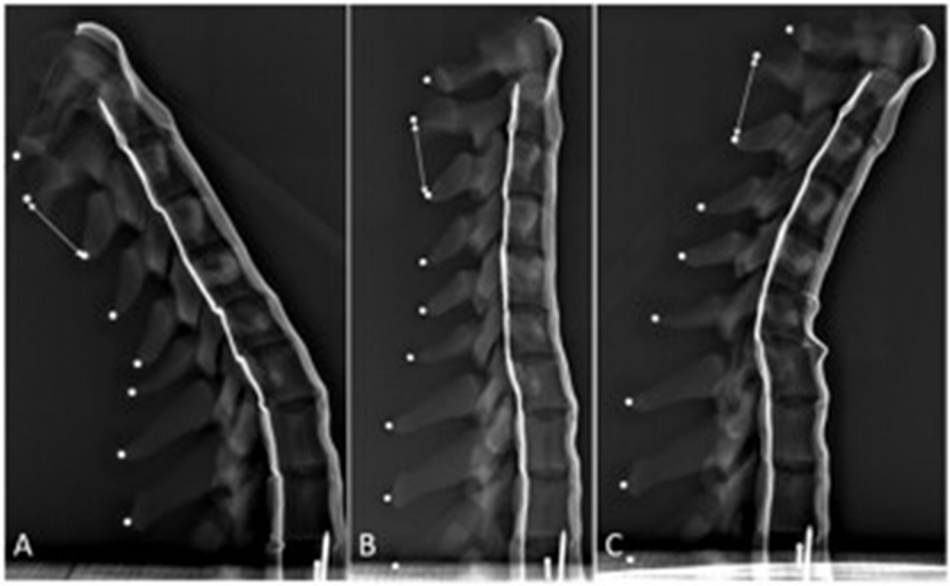
Figure 1:



PAPER 65

Adjunctive Use of Bone Growth Stimulation Increases Cervical Spine Fusion Rates in Patients at Risk for Pseudarthrosis

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Introduction: Multi-level disease, prior failed fusion, diabetes, nicotine use, and osteoporosis are factors that may decrease the likelihood of a successful cervical spine fusion, the result of which leads to prolonged pain, reduced function, and overall decreased quality of life. Studies have shown that adjunctive use of pulsed electromagnetic field (PEMF) stimulation devices can be used to improve spine fusion rates, particularly in subjects that are at risk for pseudarthrosis. The purpose of this study was to evaluate the cervical spine fusion status in subjects with one or more risk factors for nonunion, comparing subjects that received PEMF treatment compared to subjects that did not receive PEMF treatment.

Materials and Methods: Data from a multicenter prospective study of subjects undergoing cervical spine fusion and were treated with PEMF was compared to a "matched" retrospective cohort of subjects that underwent cervical spine fusion but were not treated with PEMF bone stimulation. In the prospective arm, subjects undergoing cervical spine fusion surgery were identified for enrollment based on having 1 or more of the following risk factors for pseudoarthrosis: multilevel (2 or more levels) fusion, prior failed cervical spine fusion, diabetes, osteoporosis, or nicotine use. The subjects were required to wear the device for 4 hours/day for 6 months following surgery. Fusion status was assessed at 12 months postop using a combination of x-rays and/or CT. In order to be classified as a successful fusion, all treated levels needed to be graded as fused. A different cohort of cervical spine fusion patients that were prescribed postop PEMF, but did not receive PEMF treatment (reasons include insurance denial, refused PEMF treatment, other) were retrospectively enrolled and compared to PEMF treated subjects.

Results: Both cohorts had similar gender and BMI characteristics (treated group was 53.8% female vs. 55.3% female for control; treated group had a BMI of 30.0kg/m^2 vs. 30.2kg/m^2 for control). The treated group was older compared to control (61.0yr and 55.9yr respectively, $p<0.05$). At baseline, subjects in the PEMF treated group had a significantly higher average number of risk factors for nonunion (1.8 for treated group vs. 1.1 for control, $p<0.001$), and significantly higher average number of surgical levels (2.8 for treated group vs. 2.0 for control, $p<0.005$). At 12 months post-op, subjects in the PEMF treated group (n=161) had a 90.1% fusion rate, compared to a 65.4% fusion rate for the control group (n=26) ($p<0.001$).

Conclusion: Adjunctive use of PEMF stimulation provides significant improvements in cervical spine fusion rates in subjects having risk factors for pseudarthrosis. When compared to control subjects that did not use the PEMF device, treated subjects had improved fusion outcomes despite being older, having more risk factors for pseudarthrosis, and undergoing more complex surgical procedures.

PAPER 66

MRI Vertebral Bone Quality Correlates with Interbody Cage Subsidence After Anterior Cervical Discectomy and Fusion

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Introduction: Many risk factors have been reported for subsidence of interbody cages in anterior cervical discectomy and fusion (ACDF). MRI Vertebral Bone Quality (VQB) is a relatively new radiographic parameter that can be easily obtained from pre-operative MRI and has been shown to correlate with measurements of bone density such as DXA and CT Hounsfield Units. The purpose of the study was to evaluate VBQ as a predictor of interbody subsidence and to determine threshold values that portend increased risk of subsidence.

Materials and Methods: We performed a retrospective review of patients who underwent one- to three-level ACDF using titanium interbodies with anterior plating between the years 2018 and 2020. VBQ was measured on pre-operative sagittal T1 MRI by two independent reviewers. Subsidence measurements were performed by two independent reviewers on CT scans obtained 6 months postoperatively. Subsidence was then classified as mild if subsidence into the inferior and superior endplate were both ≤2 mm, moderate if the worst subsidence into the inferior or superior endplate was between 2 to 4 mm, or severe if the worst subsidence into the inferior or superior endplate was ≥4 mm.

Results: Eight-five fusion levels in forty-four patients were included in the study. There were 32 levels (38%) with moderate subsidence and 12 levels with severe subsidence (14%). The average VBQ score in those patients with severe subsidence was significantly higher than those without subsidence (3.80 vs 2.40, $P < 0.01$). A threshold value of 3.2 was determined to be optimal for predicting subsidence (AUC = 0.99) and had sensitivity of 100% and a specificity of 94.1% in predicting subsidence. Interobserver reliability of VBQ measurement was excellent with ICC=0.94 (95% CI: 0.89 – 0.97).

Conclusion: VBQ strongly correlates with subsidence of interbody grafts after ACDF. A threshold VBQ score value of 3.2 has excellent sensitivity and specificity for predicting subsidence. Spine surgeons can use VBQ as a readily available screening tool to identify patients at higher risk for subsidence.

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	No Subsidence (N=34)	Subsidence (N=10)	Total (N=44)	p value
Age	55.2 (12.0)	60.6 (11.9)	56.5 (12.1)	0.23
Female sex	21 (61.8%)	3 (30.0%)	24 (54.5%)	0.15
Smoking	5 (14.7%)	0 (0.0%)	5 (11.4%)	0.57
Diabetes	5 (14.7%)	2 (20.0%)	7 (15.9%)	0.65
CKD	1 (2.9%)	1 (10.0%)	2 (4.5%)	0.41
Chronic steroid use	1 (2.9%)	0 (0.0%)	1 (2.3%)	1.00
Inflammatory arthritis	1 (2.9%)	0 (0.0%)	1 (2.3%)	1.00
BMI	29.6 (6.6)	30.3 (2.0)	29.8 (5.8)	0.62
Diagnosis				0.45
Myelopathy	9 (26.5%)	4 (40.0%)	13 (29.5%)	
Myeloradiculopathy	1 (2.9%)	0 (0.0%)	1 (2.3%)	
Radiculopathy	22 (64.7%)	4 (40.0%)	26 (59.1%)	
Spinal stenosis	1 (2.9%)	0 (0.0%)	1 (2.3%)	
Spondylosis	1 (2.9%)	2 (20.0%)	3 (6.8%)	
VBQ CSF Score	2.4 (0.5)	3.8 (0.3)	2.7 (0.8)	**< 0.01**
VBQ Blank Score	33.7 (22.6)	16.5 (14.1)	29.8 (22.0)	**< 0.01**
Lowest BMD t-score	-0.927 (1.271)	0.880 (1.143)	-0.919 (1.227)	0.95
Average HU of superior and inferior VB levels	326.2 (70.7)	327.8 (70.8)	326.5 (69.5)	0.76
Longus colli AP diameter at C5/6 (mm)	7.9 (2.5)	7.3 (3.0)	7.8 (2.5)	0.75
Longus Colli Area at C5/6 (mm^2)	60.8 (29.2)	37.5 (14.6)	57.5 (28.6)	0.08
Hounsfield units, Longus colli at C5/6	55.7 (12.7)	58.2 (8.5)	56.0 (12.1)	0.68
# of ACDF levels				**0.01**
1	13 (38.2%)	1 (10.0%)	14 (31.8%)	
2	16 (47.1%)	3 (30.0%)	19 (43.2%)	
3	5 (14.7%)	6 (60.0%)	11 (25.0%)	

PAPER 67

Pulsed Electromagnetic Fields (PEMF) Used as an Adjunct to Cervical Spine Fusion

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Introduction: Prior studies show that pulsed electromagnetic field (PEMF) stimulation promotes bone healing, and can be an especially valuable tool to help overcome biological deficiencies in patients at risk for nonunion. The present study examined the efficacy and safety of PEMF when used as an adjunct to cervical arthrodesis up to 12 months follow-up.

Materials and Methods: A prospective multicenter clinical trial (NCT 03177473) was conducted at 11 clinical sites across the USA. Subjects undergoing cervical spine fusion with 1 or more risk factors for nonunion were identified for enrollment. Risk factors for nonunion included multilevel (2 or more levels) fusion, prior failed cervical spine fusion, diabetes, osteoporosis, or smoking. Subjects undergoing cervical spinal fusion were required to wear the PEMF device for 4 hours/day for 6 months post-op.

The primary outcome measure was fusion status at the 12 month follow-up period. Fusion status was determined at the 12 month visit using anterior/posterior, lateral, and flexion/extension radiographs and computed tomography. Patient reported outcomes including Neck Disability Index (NDI), health related quality of life (EQ-5D and SF-36) and visual analog scale for pain (VAS neck and arm pain) were collected as secondary outcome measures.

Results: Out of 160 subjects, 144 (90.0%) were graded as fused (all levels) at the 12 month visit. Over half of the subjects (55.6%) had 2 or more risk factors for pseudarthrosis. Fusion success was 91.7% (n=55/60) for subjects with a single risk factor, 89.0% (n=89/100) for subjects with 2 or more risk factors and 90.9% (n=20/22) for subjects with 3 or more risk factors. Significant improvements in NDI, arm pain, and neck pain were observed compared to baseline scores ($p<0.001$) along with improvements in SF-36 and EQ-5D ($p < 0.001$). A compliance rate of 85.0% (SD 24.1) was observed at 3 months and 78.3% (SD 26.2) at 6-months in subjects who had successful cervical fusion. A total of 715 AEs were reported with the majority of AEs considered mild (n=451, 63.1%) and unexpected (n=568, 79.4%).

Conclusion: The PEMF bone growth stimulator device is a valuable adjunctive tool to aid in cervical spine fusion healing, especially in challenging populations. Subjects in this study experienced favorable fusion rates of 90% and significant improvement in patient reported outcomes despite having elevated comorbidity and/or complex surgeries.

PAPER 68

Decreased Opioid Use After Anterior Cervical Discectomy and Fusion during 2014-15 to 2018-19: The Influence of State Policies

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Introduction: In the early 2000s, opioids were widely used to manage chronic pain. However, due to the increasing number of opioid-related deaths, the Department of Health and Human Services declared a public health emergency regarding the rampant use of opioids in 2017. As a result, many states passed legislation limiting opioid prescriptions for pain treatment. The aim of this study was to understand the effect of legislation on the opioid crisis and opioid prescriptions before and after a common spinal procedure, anterior cervical discectomy and fusion.

Materials and Methods: The study used 151 individual patient records in the PearlDiver database and divided patients into two major cohorts based on when they underwent ACDF. The pre-policy group consisted of patients who underwent ACDF (CPT codes 22551 and 22554) during 2014-2015, while the post-policy group consisted of patients who underwent ACDF during 2018-2019, after most states had passed policies limiting opioid prescribing practices. The number of patients receiving opioid prescriptions and the morphin-milli-equivalent (mme) of opioid prescriptions were compared between the two time points for each policy group 365 days after the respective surgeries.

Results: Out of the 250,209 patients who underwent ACDF in the PearlDiver database, 44,779 had the procedure during 2014-2015, and 39,744 had the procedure during 2018-2019. Twelve out of the fifty states did not pass a state law or policy reducing the opioid prescription limit during the years 2016 to 2018. The remaining thirty-eight states had at least one law or policy passed during that same timespan.

The percentage of patients receiving opioid prescriptions decreased from the pre-policy group (46%) to the post-policy group (42%) (Odds Ratio = 0.85, $p < 0.0001$). In 2014-2015, there was a higher percentage of patients prescribed opioids in states that implemented a policy (47%) compared to those that did not (45%) (Odds Ratio = 0.93, $p = 0.0035$). This difference remained in 2018-2019 (Odds Ratio = 0.94, $p = 0.0231$).

The average mme of opioid prescriptions in the post-policy group (814 ± 1499) was significantly lower than the average mme in the pre-policy group (1069 ± 1052) (Cohen's $d = 0.20$, $p < 0.0001$). In both 2014-2015 and 2018-2019, states that passed a law had significantly higher average mme of opioid prescriptions compared to states that did not pass a policy ($p < 0.0001$ and $p = 0.0224$, respectively). However, the effect size of each difference was negligible (Cohen's $d = 0.06$ and Cohen's $d = 0.02$, respectively).

Conclusion: This study found a significant decrease in the amount of opioids prescribed from 2014 to 2018, regardless of state law or legislation on prescribing practices. The authors suggest that this decrease may be due to increased awareness surrounding the dangers of opioids and a state of public health emergency. The study also recommends promoting physician education and awareness on opioid-related morbidity and mortality as a way to reduce opioid prescribing.

PAPER 69

How Much Money Do You Actually Save Your Hospital When You Choose a Posterior Foraminotomy Instead of an ACDF for Cervical Radiculopathy?

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Thomas Jefferson University Hospital[1] Drexel University[2] Rothman Orthopaedic Institute[3]

Introduction: To our knowledge, a comparison of the true intraoperative costs of anterior cervical fusion (ACDF) vs. posterior cervical foraminotomy (PCF) has never been done. Given that many patients with cervical radiculopathy are a candidate for either procedure, we sought to address this knowledge gap. We used time-driven activity-based costing (TDABC) to compare the total intraoperative cost for the two procedures at a large academic institution.

Materials and Methods: Total cost was divided into direct (personnel and supply costs) and indirect costs (personnel and overhead costs). Individual costs were obtained by direct observation, electronic medical records, and through querying multiple departments (business operations, sterile processing, plant operations, and pharmacy). Timestamps for personnel and material resources were documented, in conjunction with process mapping of the surgeries. Total intraoperative costs were estimated for all single-level ACDFs and PCFs from 2017 to 2022. Regression analyses were performed to identify factors associated with total cost.

Results: A total of 256 and 32 patients underwent single-level ACDFs and PCF for cervical radiculopathy, respectively. The average total intraoperative cost for ACDFs was $7,574 ± $3,175 versus $3,062 ± $547 for PCF. For ACDFs, supply cost (69% for ACDFs vs. 33% for PCF) was the major contributor, while personnel cost (67% for PCF vs. 31% for ACDFs) constituted most of the cost incurred during PCFs. Supply cost, particularly implant cost ($3,818 ± $2,316), appeared to influence cost variability in ACDFs, while personnel cost ($2,051 ± $419) seemingly explained cost variability in PCFs. On linear regression analysis, ACDFs (β coefficient: $4,685 ± $575, $p<0.001$), males ($p=0.03$), and patients with commercial insurance ($p=0.01$) had significantly higher total costs when controlled for age, comorbidities, and smoking status.

Conclusion: TDABC is a feasible methodology for estimating differences in true intraoperative costs between ACDFs and PCFs for cervical radiculopathy. The major cost contributors were supply and personnel costs. Implant cost appeared to influence total cost variability in ACDFs, while personnel costs seemingly explained cost variability among PCFs. ACDFs were associated with an additional $4,685 ± $575 of total intraoperative cost as compared to PCFs. Males and patients with commercial insurance were also associated with significantly higher total costs.

PAPER 70

How Does the Cervical Spinal Cord Run After Cervical Laminoplasty? Additional Risk Factor Analysis for Spinal Cord Alignment Deterioration After Cervical Laminoplasty

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Introduction: Previous research has shown that cervical laminoplasty has two effects: direct spinal cord decompression and indirect decompression by the posterior shifting of the spinal cord. Theoretically, spinal cord alignment should be routed straight to maintain the shortest distance after cervical laminoplasty. To our knowledge, no reports exist on how spinal cord alignments change before and after cervical laminoplasty, and this study aims to address this gap in knowledge. Additional risk factors were analyzed for spinal cord alignment deterioration after laminoplasty.

Materials and Methods: We retrospectively analyzed 346 patients who underwent cervical laminoplasty between 2011 and 2020. The K-line (a line connecting the midpoints of the spinal canal at the C2 and C7 level) on the MRI scan was drawn on the pre- and post-operative T2W mid-sagittal image. The distances from this line to the anterior and posterior margins of the spinal cord were then measured at each level from C3 to C6. If the center-to-posterior margin distance is longer than the center-to-anterior margin distance, the spinal cord has a kyphotic curvature.

Patients were divided into three groups according to the curvature of their spinal cords before and after laminoplasty: Lordosis to lordosis (Group A), lordosis to kyphosis (Group B), and kyphosis to kyphosis (Group C). We compared Groups A and B to determine the risk factors for spinal cord alignment deterioration following surgery. Functional improvement and cord expansion were assessed in patients with pre-operative kyphotic spinal cord alignment (Group C).

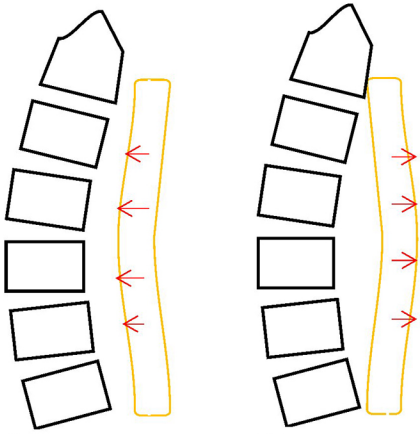
Results: Among the 346 patients analyzed, 245, 68, and 33 patients were in Groups A, B, and C, respectively. There was a significant difference between the subjects in Groups A and B with respect to the cervical alignment before and after surgery (14.9 vs 10.2, 11.1 vs 2.8; $p < 0.05$, $p = 0.01$). In addition, there was a significant difference depending on the laminectomy of C3 (54.2% vs 77.7%, $p < 0.05$) and the decompression level (3.1 vs 3.4, $p < 0.05$). Post-operative cord expansion was prominent in Group A (1.45 vs 0.1, $p < 0.01$). In Group C, the mean pre- and post-operative cord diameters were 31 mm and 34 mm, respectively. The spinal cord expansion was definite and showed an improvement in the Japanese Orthopedic Association (JOA) score after laminoplasty in each group.

Conclusion: Even if the spinal cord alignment before surgery was kyphotic, this study confirmed that neurological improvement was seen after cervical laminoplasty. It is assumed that this is the effect of direct decompression of laminoplasty, even if the posterior shifting of the cord is insufficient. However, to obtain an indirect decompression with lordotic cord alignment after laminoplasty, it should be performed on patients with lordotic cervical alignment, decompression level should be minimized, and C3 dome laminectomy rather than C3 laminectomy should be considered wherever possible.

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

PAPER 70 continued

Figure 1.



The K-line on the MRI scan was drawn on the pre- and post-operative T2W mid-sagittal image. The distances from this line to the anterior and posterior margins of the spinal cord were then measured at each level from C3 to C6. If the center-to-posterior margin distance is longer than the center-to-anterior margin distance, the spinal cord has a kyphotic curvature (**B**). On the contrary, if the center-to-anterior margin distance is longer than the center-to-posterior margin distance, the spinal cord has a lordotic curvature (**A**).

PAPER 71

Impact of Frailty and Cervical Radiographic Parameters on Postoperative Dysphagia Following Anterior Cervical Spine Surgery: mFI-11, T1 slope, Change in Cervical lordosis, and C3/4 surgery

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Hospital for Special Surgery[1]

Introduction: Postoperative dysphagia is a common complication after anterior cervical spinal surgery (ACSS). Frailty, characterized by increased vulnerability to adverse outcomes and mortality, has been associated with perioperative surgical complications in spine surgery. Understanding the risks in frail patients undergoing ACSS is crucial for decision-making in cervical spine surgery. However, few studies have identified the impact of frailty on postoperative dysphagia after ACSS. The purpose of this study was to investigate the effect of frailty and other clinical and radiographic parameters on postoperative dysphagia.

Materials and Methods: Patients who underwent anterior cervical discectomy and fusion or cervical disc replacement for the treatment of degenerative cervical spine pathology between June 2017 and Oct 2022 were included.

The primary outcome was postoperative dysphagia which was assessed by the eat assessment tool-10 (EAT-10). Patients with ≥3 points on EAT-10 were diagnosed with dysphagia. Clinical data included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) class, and Charlson comorbidity index (CCI). Operative data included surgical time (min), surgical levels, anterior cervical plate use, recombinant human bone morphogenetic protein-2 use, and topical steroid use in the surgical field. Preoperative frailty was retrospectively assessed by the modified frailty index -11 (mFI-11). The radiographic parameters included C0-2 angle, C2-7angle, C2-7 SVA, C2 slope, T1 slope, and disc height on standing X-rays (Fig). Patient reported outcome measures (PROMs) included Neck Disability Index (NDI) and 12-Item Short Form Survey Physical and Mental Component Score (SF-12 PCS and MCS).

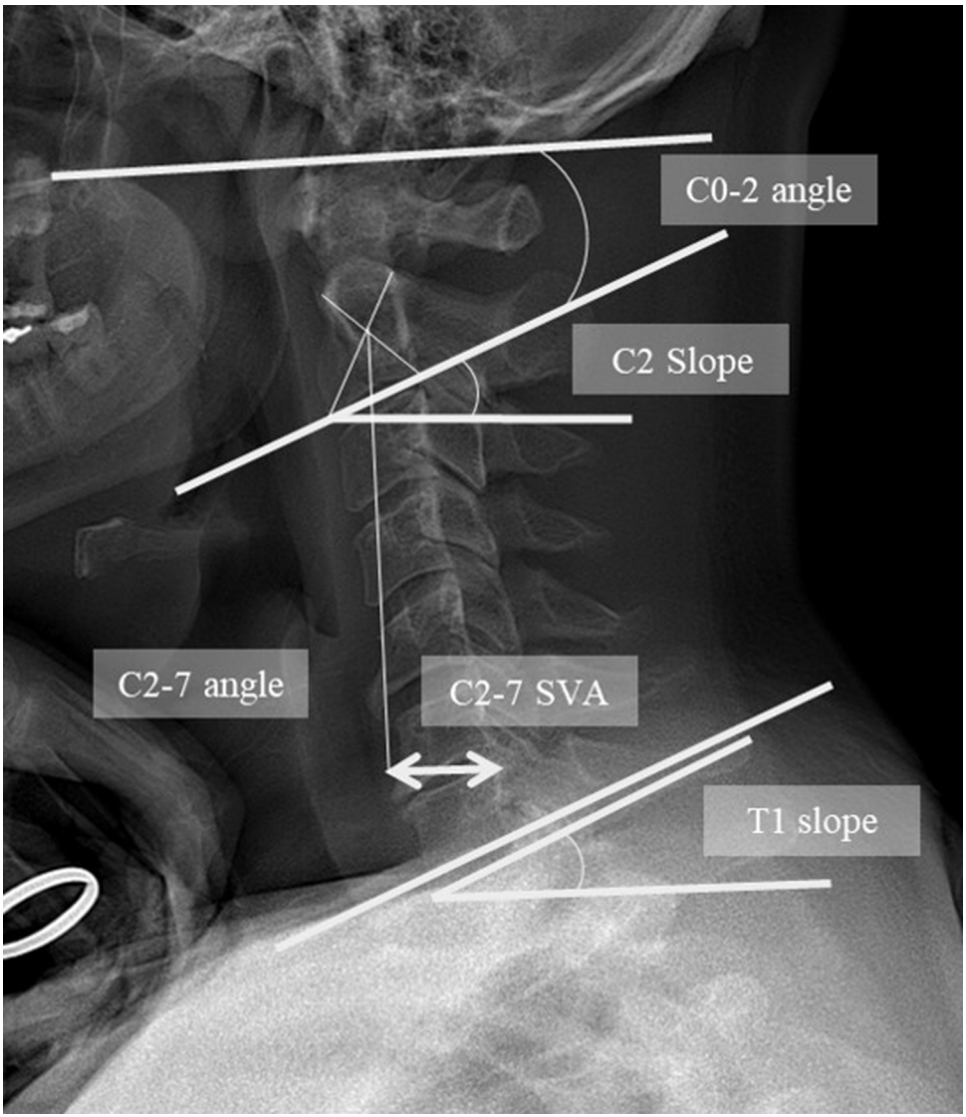
Two postoperative periods were defined - early (2-6 weeks) and late (1 to 2 years), where the EAT-10, radiographic parameters, and PROMs were assessed. Patients were divided into two groups – dysphagia, non-dysphagia. After univariable analysis, a multivariable logistic regression was performed to identify factors associated with postoperative dysphagia and to calculate an adjusted odds ratio (aOR). Correlation analysis was performed between dysphagia status and PROMs.

Results: 95 patients (mean age, 52.5 years) were included. Postoperative dysphagia occurred in 31 patients (32.6%). Multivariable logistic regression analysis suggested mFI-11 (aOR, 2.94; CI, 1.12-7.72; p=0.028), T1 slope (aOR, 1.12; CI, 1.03-1.21; p=0.006), surgery at C3/4 (aOR 6.71; CI 1.02-44.19; P=0.048), and the change of C2-7 angle between preoperative and early postoperative periods (aOR, 1.09; CI, 1.02-1.16; p = 0.007) were significantly associated with the postoperative dysphagia. The mFI-11 showed a tendency for higher aOR for dysphagia even during the late postoperative period (aOR, 2.21; CI, 0.90-5.41; p=0.083), although it was not statistically significant. The EAT-10 score had a significant correlation with NDI (Early, 0.41; Late,

PAPER 71 continued

0.38) and SF-12MCS (Early, -0.35; Late, -0.40) during the early and late postoperative periods.

Conclusion: Frailty was a significant factor associated with postoperative dysphagia, especially in the early postoperative period. Postoperative dysphagia showed a correlation with clinical outcomes even in the short as well as long term.



POSTER 1

Impact of Educational Background on Preoperative Disease Severity and Postoperative Outcomes Among Patients with Cervical Spondylotic Myelopathy

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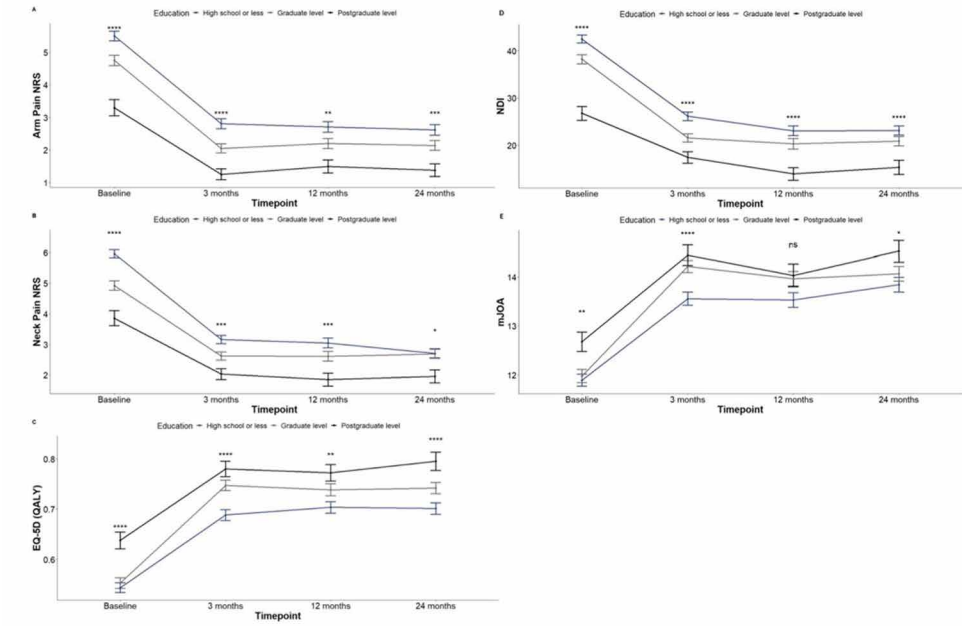
Introduction: Patient education level has been suggested to correlate with health literacy and disease perception as well as socioeconomic status (SES) and access to health care. The association of educational level with disease severity has yet to be described in patients with cervical spondylotic myelopathy (CSM).

Materials and Methods: The CSM dataset of the Quality Outcomes Database (QOD) was utilized in this study to identify patients undergoing surgical management of CSM from January 2016 to December 2018. Education level was grouped as high school or below, graduate-level, and post-graduate level. The association of education level with baseline disease severity was assessed. Patient-reported outcome measures (PROMs) included the North American Spine Society surgical satisfaction scale, Neck Disability Index (NDI), modified Japanese Orthopedic Association score (mJOA), arm and neck pain as numeric rating scale (NRS), and quality-adjusted life-years (QALY).

Results: Among 1,141 patients with CSM included, 509 (44.6%) had an education level of high school or below. The three groups were significantly different in terms of SES index, proportion of smokers, symptom duration > 3 months, and baseline PROMs. In multivariable analyses, lower education level was associated with symptom duration of > 3 months, higher arm pain NRS, and higher neck pain NRS. All groups reported similar surgical satisfaction and minimal clinically important differences across all measures, except for neck pain.

Conclusion: Patients with CSM reporting a lower educational level tended to present with longer symptom duration, more disease-inflicted disability, higher pain scores, and lower QALY scores. These patients are a potentially vulnerable subpopulation, and their health literacy and access to care should be prioritized.

POSTER 1 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.

POSTER 2

The Relationship Between Osteopenia and Subsidence Following Anterior Cervical Discectomy and Fusion

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Icahn School of Medicine[1]

Introduction: Subsidence is a common complication following ACDF, referring to the sinking of a graft or cage into a vertebral body[1]. Subsidence can cause a reduction in disc height, disruption of sagittal alignment, nonunion, and foraminal stenosis[2]. Some studies have shown that osteoporosis is associated with an increased risk of complications including subsidence[3]. The 33rd urpose of this study was to further evaluate the relationship between osteopenia and anterior segmental subsidence.

Materials and Methods: This was a retrospective cohort study performed using data from 2016-2021 at an academic tertiary care center. Anterior segmental subsidence was calculated by subtracting the immediate postoperative anterior disc height from the long-term postoperative anterior disc height. Disc height measurements were made on lateral cervical radiographs from both the immediate postoperative period and the final follow-up (greater than 6 months) postoperatively. Osteopenia diagnosis was based on prior diagnosis or dual-energy x-ray absorption bone density scan results. T-scores of less than -1.5 were defined as osteopenic. Univariable analysis was used to investigate the relationship between prior osteopenia diagnosis and segmental subsidence. Multivariable analysis was used to further investigate this relationship, controlling for age, sex, smoking status, and cage type.

Results: This study included 131 patients with a total of 244 levels fused. Average age for the entire cohort was 53.6 (SD 10.9) years old. Patients underwent either one-level (n=41, 31%), two-level (n=67, 51%) or three-level (n=23, 18%) fusions. Patients received allograft (n=68, 52%), titanium (n=22, 17%), PEEK (n=27, 21%), ceramic (n=11, 8%) and zero-profile (n=3, 2%) cages. Of the 131 patients, 27 (21%) had a prior diagnosis of osteopenia. The mean age was 59.5 (SD 9.0) for patients with prior diagnosis of osteopenia, while it was lower at 52.1 (SD 10.9) for patients without prior diagnosis of osteopenia. Mean follow up for osteopenia patients was 495 (SD 272) days, and 434 (SD 294) days for patients without osteopenia. With univariable linear regression, we observed no significant difference in anterior subsidence based on a diagnosis of osteopenia (p=0.633). In a multivariable linear regression model (beta=-0.002; CI [-0.051, 0.046]), osteopenia was not significantly correlated with anterior segmental subsidence (p=0.926).

Conclusion: In our retrospective review of radiographic data, we found that prior diagnosis of osteopenia was not significantly correlated with anterior segmental subsidence. Our results suggest that whether a patient is more or less likely to see subsidence following ACDF is multifactorial and cannot be evaluated due to prior osteopenia diagnosis alone.

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Figure

Table 1: Univariable linear regression. N = 244. Per-level radiographic data based on prior diagnosis of osteopenia. Outcome measure is segmental subsidence.

	Osteopenia (n = 58)	No Osteopenia (n = 186)	P-value
Final ADH	0.64 (0.14)	0.69 (0.14)	0.047
Final PDH	0.54 (0.13)	0.54 (0.12)	0.750
Percent ADH Change	-16.98 (16.28)	-17.27 (16.29)	0.905
Anterior Subsidence	0.14 (0.14)	0.15 (0.15)	0.633
Posterior Subsidence	0.12 (0.10)	0.12 (0.12)	0.751
Segmental Lordosis Change	-0.66 (3.72)	-0.73 (3.85)	0.896
Final Segmental Lordosis	4.11 (3.18)	4.71 (3.10)	0.203
Inferior Density	412.75 (183.57)	458.08 (189.22)	0.336
Superior Density	521.54 (230.97)	526.24 (178.49)	0.926

POSTER 3

Geographical and Specialty-Specific Variation in the Utilization of Laminoplasty for Cervical Myelopathy

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Introduction: Cervical myelopathy is a common and progressive disorder affecting the cervical spine. Surgical intervention persists as the gold standard treatment for those with moderate-to-severe disease, with both anterior and/or posterior-based surgical approaches as acceptable strategies. Although the optimal surgical approach remains debatable, the inclusion of motion-preserving treatments has become more prevalent in decision-making. When considering posterior-based surgery, isolated laminectomy, laminectomy and fusion, and laminoplasty are the main options. Laminectomy with fusion offers superior correction for patients with sagittal deformity, however, laminoplasty is a motion-preserving and potentially safer alternative without fusion-related complications especially in patients without sagittal imbalance. Recent literature suggests that laminoplasty offers similar if not superior outcomes and a lower risk of adjacent segment disease for certain pathologies. Despite the positive outcomes associated with laminoplasty, the majority of patients presenting with cervical myelopathy continue to be treated with arthrodesis. Here, we explore how geographic and specialty-specific differences may influence the utilization of laminoplasty to treat cervical myelopathy.

Materials and Methods: This was a retrospective cohort study in a large, national administrative database. All patients with cervical myelopathy who underwent ACDF, cervical disc replacement, laminectomy, fusion, or laminoplasty were included in the study. We identified all patients with a diagnosis of myelopathy who underwent these surgical procedures using CPT codes. We further divided patients based on the geographical location associated with the procedure claim into Northeast (NE), South (SO), Midwest (MW), and West (WE). Additionally, we divided the surgical records based on the specialty of the surgeon: neurosurgery or orthopaedic spine surgery. Chi-squared test was used for statistical analysis and significance.

Results: We identified 117,301 patients with a diagnosis of cervical myelopathy, of which 2,710 (2.3%) underwent laminoplasty and 114,591 (97.7%) underwent ACDF, laminectomy alone, laminectomy and fusion, or cervical disc arthroplasty. Of the laminoplasty cases, 1,561 (57.6%) were performed by orthopaedic spine surgeons compared to 1,149 (42.4%) by neurosurgeons. In comparison, for the other cervical spine procedures, 33,391 (29.1%) were performed by orthopaedic surgeons and 81,200 (70.9%) were performed by neurosurgeons ($p<0.001$). Geographically, 508 (18.8%) of the laminoplasties were performed in the NE, 1,005 (37.1%) in the SO, 889 (32.8%) in the MW, and 308 (11.4%) in the WE. Regarding the other cervical spine surgeries, 21,547 (18.8%) of the laminoplasties were in the NE, 51,020 (44.5%) in the SO, 27,999 (24.4%) in the MW, and 14,025 (12.2%) in the WE ($p<0.001$).

Conclusion: Laminoplasty has emerged as a safe and effective treatment option for cervical myelopathy. Despite the abundance of established evidence regarding the advantages of laminoplasty, widespread utilization in the United States is not well defined. Our results suggest

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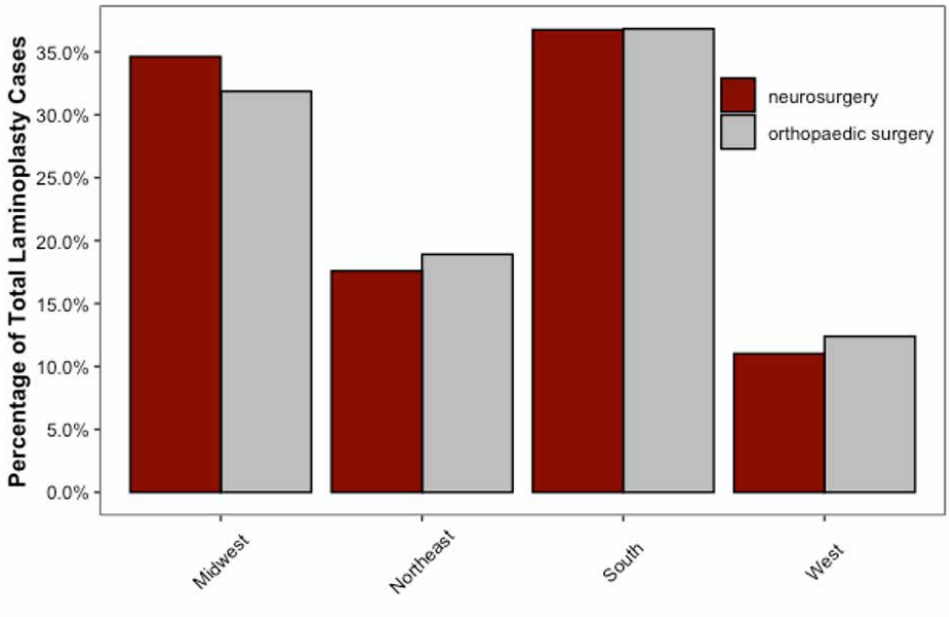
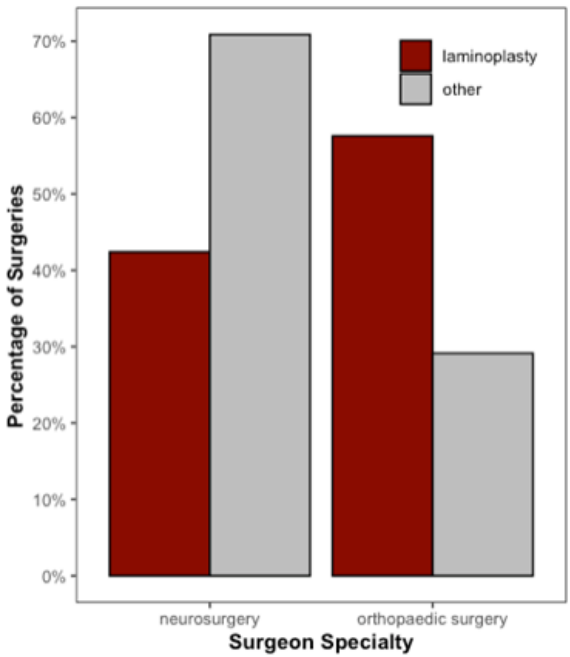
a geographical and training-specific variation in the utilization of laminoplasty. We found that surgeons who underwent orthopaedic training were more likely to perform laminoplasty compared to surgeons with a neurosurgery training background. Additionally, we found greater utilization of laminoplasty in the MW, and lowest utilization in the South, which could be the result of regional training differences. The drivers of these geographic- and specialty-related differences in utilization of laminoplasty should be further explored.

Laminoplasty vs Other C-Spine Surgeries for Myelopathy						
		Laminoplasty		Other Sx		p-value
		n	%	n	%	
	Total Patients	2710		114591		
Age	15 to 19	0		38	0.03	<0.001
	20 to 24	0		123	0.11	
	25 to 29	0		496	0.43	
	30 to 34	21	0.77	1753	1.53	
	35 to 39	30	1.11	3999	3.49	
	40 to 44	79	2.92	7176	6.26	
	45 to 49	176	6.49	11208	9.78	
	50 to 54	295	10.89	15673	13.68	
	55 to 59	423	15.61	18232	15.91	
	60 to 64	472	17.42	17933	15.65	
	65 to 69	425	15.68	14798	12.91	
	70 to 74	452	16.68	13520	11.80	
	75 to 79	281	10.37	8510	7.43	
	80 to 84	46	1.70	1132	0.99	
Region	MW	889	32.80	27999	24.43	<0.001
	NE	508	18.75	21547	18.80	
	SO	1005	37.08	51020	44.52	
	WE	308	11.37	14025	12.24	
Gender	Female	981	36.20	57328	50.03	<0.001
	Male	1729	63.80	57263	49.97	
Year	2011	198		9171		0.46
	2012	257		11048		
	2013	291		12900		
	2014	321		13780		
	2015	306		13595		
	2016	302		12568		
	2017	271		11741		
	2018	321		12219		
	2019	361		14203		
	2020	82		3366		
Specialty	NSGY	1149	42.40	81200	70.86	<0.001
	Ortho	1561	57.60	33391	29.14	
Paymen Plan	Cash	<11		131		
	Commercial	1874		81680		
	Government	27		2403		
	Medicaid	101		6355		
	Medicare	669		22947		
	Unknown	30		1075		
Service Location	INPATIENT	2497		79049		<0.001
	OFFICE	<11		199		
	OUTPATIENT	211		35231		
	Unknown	<11		102		

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.

POSTER 3 continued





Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

POSTER 4

Readmission After Ambulatory Cervical Spine Surgery: Common Reasons and Risk Factors

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Introduction: The exponential growth of the United States healthcare expenditure has prompted a shift towards value-based healthcare with greater emphasis on cost efficiency. Recently, a major avenue for cost reduction has been the continual shift towards performing surgical procedures in the outpatient setting. While many studies have compared outcomes and costs between outpatient vs. inpatient spine surgery, few studies have aimed to improve appropriate patient selection for spine surgery in the ambulatory setting. An important concern with ambulatory spine surgery is the risk of early readmission, which would effectively negate the cost efficiency benefit associated with outpatient surgery; thus, readmission prevention is central to healthcare cost sustainability. Therefore, the objectives of this study are to (1) describe the incidence and timing of 30-day unplanned readmission after ambulatory cervical spine surgery, (2) evaluate the common reasons for readmission, and (3) identify the independent preoperative risk factors for readmission in this population.

Materials and Methods: Patients who underwent ambulatory cervical spine surgery, including anterior cervical discectomy and fusion (ACDF), cervical disc replacement (CDR), cervical laminotomy, cervical laminectomy, and posterior cervical fusion were identified in the 2015-2020 National Surgical Quality Improvement Program (NSQIP) database. The primary outcome of 30-day readmission was defined as any unplanned readmissions after the initial postoperative discharge. The timing of readmissions (days from index procedure) was recorded. Reasons for readmission were identified based on International Classification of Diseases 9th or 10th revision diagnosis codes. The occurrence of an unplanned readmission was tested for association with each of the baseline patient factors and comorbidities using multivariable Poisson regression with robust error variance.

Results: A total of 33,092 patients were identified. ACDF (52.8%) and posterior cervical fusion (33.3%) were the most common procedures performed. There were 1,116 readmissions in total, yielding an overall incidence rate of 3.37% within 30-days following surgery. The average time from index surgery to readmission was 10.3 ± 8.1 days. The three most common surgical site-related reasons for readmission included uncontrolled pain (12.9%), postoperative hematoma/seroma (7.8%), and dysphagia (6.2%). The most common non-surgical site-related reasons included gastrointestinal (5.3%), neurological (4.2%), and pulmonary complications (3.8%). In the final multivariable model, the independent risk factors for readmission included older age (55-64 years: odds ratio [OR] 1.280, p=0.033; ≥65 years: OR 2.085, p<0.001), BMI ≥35 (OR 1.348, p=0.004), functional dependence (OR 2.262, p<0.001), diabetes (OR 1.260, p=0.001), smoker (OR 1.225, p=0.006), COPD (OR 1.434, p=0.001), and steroid use (OR 1.501, p<0.001).

Conclusion: This study highlights the common reasons and risk factors for readmission following ambulatory cervical spine surgery. The most common surgical site-related reasons for readmission included uncontrolled pain, recurrence of disc herniation or major symptom, and postoperative hematoma/seroma. Common non-surgical site-related reasons included

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gastrointestinal, neurological, and cardiovascular complications. Risk factors for readmission included age ≥55, BMI ≥35, functional dependence, diabetes, smoker, COPD, and steroid use. Consideration of these factors may be critical in identifying appropriate candidates for ambulatory cervical spine surgery and in order to minimize the occurrences of unplanned readmissions.

Table 1. Baseline Patient Characteristics

Characteristic	Number	Percent
***N* of cases**	33,092	
Median age (IQR)	57.0 (19.0)	
<45	5,553	16.8%
45-54	8,281	25.0%
55-64	9,174	27.7%
≥65	10,084	30.5%
Sex		
Male	18,096	54.7%
Female	14,996	45.3%
Race and Ethnicity		
Non-Hispanic White	28,290	85.5%
Non-Hispanic Black	2,809	8.5%
Hispanic	1,131	3.4%
Asian	618	1.9%
BMI category		
<25	5,747	17.4%
25-29	10,976	33.2%
30-34	9,003	27.2%
≥35	7,366	22.3%
Comorbidities		
Functional dependence	281	0.8%
ASA class ≥3	14,642	44.2%
Diabetes mellitus	5,608	16.9%
Smoker	7,281	22.0%
COPD	1,317	4.0%
Congestive heart failure	82	0.2%
Hypertension	16,469	49.8%
Steroid use	1,244	3.8%

IQR, interquartile range. BMI, body mass index. ASA, American Society of Anesthesiologists. COPD, chronic obstructive pulmonary disease.

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Table 2. Reasons for Readmissions after Ambulatory Cervical Spine Surgery

Reason	Number	% of Readmissions	% of Total Cohort
Total Cohort	33,092	-	-
Total 30-day readmissions	1,116	-	3.37%
Surgical site-related	517	46.3%	1.56%
Uncontrolled pain	144	12.9%	0.44%
Postoperative hematoma or seroma	87	7.8%	0.26%
Dysphagia	69	6.2%	0.21%
Wound complications	65	5.8%	0.20%
Recurrence of disc herniation or major symptom	57	5.1%	0.17%
CSF leakage	39	3.5%	0.12%
Nerve injury	29	2.6%	0.09%
Prosthesis-related complications	27	2.4%	0.08%
Non-surgical site-related	402	36.0%	1.21%
Gastrointestinal complications	59	5.3%	0.18%
Neurological complications	47	4.2%	0.14%
Pulmonary complications	42	3.8%	0.13%
Generalized weakness/fatigue	34	3.0%	0.10%
Cardiovascular complications	34	3.0%	0.10%
Sepsis/infections	30	2.7%	0.09%
Thoracolumbar spinal pathology	27	2.4%	0.08%
Unrelated orthopedic complications	24	2.2%	0.07%
Renal/genitourinary complications	21	1.9%	0.06%
Metabolic/endocrine/nutritional abnormalities	18	1.6%	0.05%
Thromboembolic complications	15	1.3%	0.05%
Falls	11	1.0%	0.03%
Medication/substance complications	9	0.8%	0.03%
Urinary retention	9	0.8%	0.03%
Hemorrhage	8	0.7%	0.02%
Psychiatric complications	5	0.4%	0.02%
Malignancy	1	0.1%	0.00%
Other complications	8	0.7%	0.02%
Missing readmission reason	197	17.7%	0.60%

CSF, cerebrospinal fluid.

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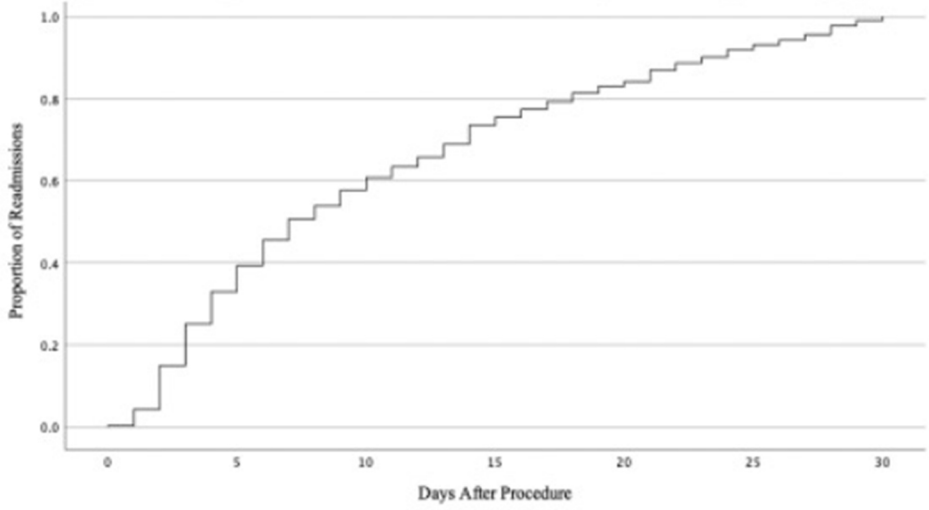
Table 3. Independent Risk Factors for Readmission after Ambulatory Cervical Spine Surgery

Characteristic	Odds Ratio	95% Confidence Interval	*p*-value
Age			
<45	Reference	-	-
45-54	1.110	0.877 - 1.405	0.386
55-64	1.280	1.020 - 1.606	0.033
≥65	2.085	1.667 - 2.607	<0.001
Race and Ethnicity			
Non-Hispanic White	Reference	-	-
Non-Hispanic Black	1.129	0.929 - 1.373	0.223
Hispanic	0.979	0.706 - 1.357	0.898
Asian	0.425	0.213 - 0.847	0.015
BMI category			
<25	Reference	-	-
25-29	1.088	0.899 - 1.317	0.385
30-34	1.197	0.985 - 1.453	0.070
≥35	1.348	1.101 - 1.651	0.004
Functional dependence			
No	Reference	-	-
Yes	2.262	1.603 - 3.191	<0.001
Diabetes mellitus			
No	Reference	-	-
Yes	1.260	1.095 - 1.449	0.001
Smoker			
No	Reference	-	-
Yes	1.225	1.060 - 1.416	0.006
COPD			
No	Reference	-	-
Yes	1.434	1.156 - 1.779	0.001
Steroid use			
No	Reference	-	-
Yes	1.501	1.187 - 1.897	<0.001

BMI, body mass index. COPD, chronic obstructive pulmonary disease.

POSTER 4 continued

Figure 1. Timing of Readmissions after Ambulatory Cervical Spine Surgery



POSTER 5
WITHDRAWN

POSTER 6
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POSTER 7
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POSTER 8
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POSTER 9

Could Double Crush Syndrome Play a Role in Persisting Symptoms Following Cervical Fusion or Disc Replacement?

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Introduction: When noninvasive treatment options for cervical radiculopathy do not resolve symptoms, cervical decompression and fusion (ACDF/PCDF) or cervical total disc replacement (cTDR) are popular surgical options. However, postoperatively, patients may have residual upper extremity pain, numbness, or tingling. These persistent symptoms can warrant further treatment if not resolved. Upper extremity entrapment neuropathy can present clinically with similar symptoms to cervical radiculopathy, including muscle weakness as well as pain following the ulnar nerve distribution.

Literature on double crush syndrome (DCS) states that damage to a nerve at one site may impair the overall health and function of the nerve so that it becomes more susceptible to compression at other sites. There has been controversy over the etiology, pathophysiology, and overall applicability of the DCS[2]. Diagnosis of DCS is difficult, since multiple sites of compression may result in vague, non-classical symptoms.

How often does DCS get missed on examination or mistaken for cervical radiculopathy alone? This analysis aims to evaluate the relationship between upper extremity entrapment neuropathy and cervical radiculopathy. This data may suggest that DCS is more prevalent than expected and could be the reason behind persistent postoperative symptoms. The data examines outcomes with both cervical and upper extremity diagnoses, as well as which is treated first. This may provide clinicians with evidence to evaluate patient for DCS, as outcomes may differ for patients with concurrent cervical radiculopathy and upper extremity entrapment neuropathy.

Materials and Methods: This analysis was performed with data from the Pearldiver database to analyze insurance claims of all the patients who underwent anterior or posterior cervical fusions, cTDR, and ulnar nerve release or injection. Patients with diagnoses of cervical radiculopathy, carpal tunnel, cubital tunnel, and ulnar neuropathy were included.

Results: Our surgical population group was comprised of patients diagnosed with both cervical radiculopathy and upper extremity entrapment neuropathy who have been followed for 5 years.

The data showed that while 4.54% of cervical radiculopathy patients have a concurrent neuropathy of the upper extremity, 7.26% of neuropathy patients had concurrent cervical radiculopathy.

7.98% of cTDR patients underwent a nerve release or injection after surgery. 11.78% of ACDF and PCDF patients underwent a nerve release or injection after surgery.

0.23% of patients went on to undergo an ACDF or PCDF after a nerve release or injection. 0.26% of patients went on to undergo a cTDR after a nerve release or injection.

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0.55% of all patients with concurrent cervical radiculopathy and upper extremity entrapment neuropathy underwent surgery (ACDF, PCDF, cTDR) within 5 years following a nerve release or injection.

Conclusion: In conclusion, a nerve release or injection to treat the symptoms of upper extremity entrapment neuropathy may be a valuable option in those with both cervical radiculopathy and upper extremity entrapment neuropathy. These patients avoided cervical surgery ~99% of the time. ACDF and PCDF patients are also more likely to have a nerve release or injection after surgery compared to cTDR patients. This preliminary data may suggest physicians to consider treating neuropathy before cervical surgery in patients who have concurrent conditions.

POSTER 10

Comparison of Clinical, Radiographic and Patient-Reported Outcomes for Patients Undergoing Multi-Level Anterior Cervical Discectomy and Fusion

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Introduction: One- and two- level anterior cervical discectomy and fusions (ACDFs) are safe and effective procedures with strong clinical evidence of efficacy and similar safety profiles. However, three- and four-level ACDFs are less common with less data on clinical outcomes. Due to the paucity of literature on three and four level ACDFs, this study aims to analyze clinical, patient reported, and radiographic outcomes for three or four- level ACDFs.

Materials and Methods: Ninety-five adult patients who underwent three or four-level ACDF at a tertiary care medical center over a 10-year period were retrospectively reviewed. Changes in Neck Disability Index (NDI) scores, 8-item short-form physical component summary (PCS-8) and mental component summary (MCS-8) scores, clinical improvement, radiographic outcomes, rates of pseudoarthrosis, adjacent segment disease (ASD), dysphonia/dysphagia, and rehospitalization/reoperation were analyzed.

Results: Ninety-five patients met criteria and were included in the analysis. Eighty-six patients underwent a three-level and nine underwent a four-level procedure. Seventeen patients (16 three-level, 1 four-level) also underwent a concurrent corpectomy. Minimum and average follow-up times for three-level procedures were 10.1 and 27.6 months respectively, and for four-level procedures were 11.6 and 19.1 months respectively. The pre-operative and one-year mean NDI for three-level procedures was 22.6 and 13.2 respectively, and for four-level procedures was 25.1 and 18.8 respectively (minimum clinically important difference (MCID of 7.5)[1]. The average PCS-8/MCS-8 pre-operatively and at one year for three level procedures was 33.7/48.6 and 51.9/42.9 respectively, and for four level procedures was 30.4/43.1 and 35.5/45.0 respectively (MCID of 6 for PCS-8 and 5 for MCS-8)[2]. Thirty (31.6%) patients had dysphagia postoperatively, which resolved at 6 months for all but 2 (2.1%) patients. Ten (10.5%) had dysphonia postoperatively, which resolved at 1 year for all but 1 (1.1%) patient. In the three-level cohort, 17 (19.8%) patients had symptomatic pseudoarthrosis and 11 (12.8%) had symptomatic ASD. In the four-level cohort, 4 (44.4%) patients had symptomatic pseudoarthrosis and 1 (11.1%) had symptomatic ASD. In the three-level cohort, 15 (17.4%) patients received re-operations (1-iliac crest site infection, 1-cervical incision site infection, 3-ASD, 10-pseudoarthrosis). In the four-level cohort, no patients received a re-operations.

Conclusion: Our data demonstrates that rates of radiographic pseudoarthrosis for three-level ACDFs were found to be significantly higher than previous findings in a similar study (38.4% vs 20.9%, p = .0231) and no significant difference for four-level ACDFs (66.7% vs 46.7%, p = .3563)[3]. Despite this, patient reported outcomes improved after three- or four- level ACDFs at each follow-up. Of note, our current smoker population (27.9%) is significantly (p<.0001) higher than those present in comparable studies (6.7%). Despite our high smoking population, rates of pseudoarthrosis and ASD were not found to be significant between our two populations of smokers vs non- or former smokers (p=.1304 and p=.1690 respectively). Future studies include

POSTER 10 continued

prospectively analyzing which preoperative factors impact surgical outcomes in patients undergoing three- or four- level ACDFs, as well retrospectively analyzing patients undergoing one or two level ACDFs to investigate the relationship betweeen pre-operative smoking status and the necessity for increased number of multi-level fusions or indcidence of re-operation.

Table 1
Radiographic outcomes: Rates of pseudoarthrosis and Adjacent Segment Disease in patients with adequate follow-up (>=10 Month Post-op)

	3 Level ACDF	4 Level ACDF	P-Value
Rate of Pseudoarthrosis			
Present in Patient[1]	38.4% (33/86)	66.7% (6/9)	.0503
By Intervertebral Level[2]	25.2% (61/242)	41.2% (14/34)	.0250
Symptomatic	19.8% (17/86)	44.4% (4/9)	.0448
Rate of Adjacent Segment Disease			
Segment Above	8.1% (7/86)	14.3% (1/9)	.3800
Segment Below	8.1% (7/86)	33.3% (3/9)	.0096
Both Segments Above and Below	1.2% (1/86)	14.3% (1/9)	.0240
Symptomatic	4.7% (4/86)	11.1% (1/9)	.2045

1 - Proportion of patients with radiographic pseudoarthrosis at any level
2 - Proportion of intervertebral levels operated upon with radiographic evidence of pseudoarthrosis at either adjacent endplate

Table 2.
Baseline Demographics. Data presented as mean ± standard deviation or n (%). ACDF, anterior discectomy and fusion; BMI, body mass index; CCI, Charlson comorbidity index.

Variable	ACDF 3-Level (n = 86)	ACDF 4-Level (n=9)	P-Value
Age	56.5 ± 10.5	57.4 ± 7.3	1
Sex			
Female	52 (60.5)	6 (66.7)	.358
Male	34 (39.5)	3 (33.3)	.5075
BMI	30.13 ± 7.98	27.7 ± 7.0	.443
Smoking Status			
Nonsmoker	37 (43.02)	2 (22.2)	.114
Former Smoker	29 (33.7)	3 (33.3)	.491
Current Smoker	20 (23.3)	4 (44.4)	.082
CCI	2.45 ± 2.18	2.67 ± 2.12	.939
Pre-operative Diagnosis			
Radiculopathy	48 (55.8)	3 (33.3)	.099
Myelopathy	65 (75.6)	8 (88.9)	.184
Myeloradiculopathy	33 (38.4)	2 (22.2)	.170
Cervicalgia	56 (65.1)	4 (44.4)	.111

POSTER 11

Facet Resection in Posterior Cervical Foraminotomy: Is More than 50% Resection Really Incompatible?

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Introduction: Since the implementation of biomechanical experiments using an in vitro model, previous research has suggested that facet resection during posterior cervical foraminotomy (PCF) should not exceed 50% to maintain postoperative stability. However, to date, there has been no investigation regarding the potential increase in instability associated with facet resection beyond 50%. Furthermore, recent data have cast doubt on whether resection of more than 50% of the facet can still be considered unstable. This study aimed to investigate the effects of facet resection exceeding 50% during PCF.

Materials and Methods: We conducted a retrospective review of 65 patients who had undergone unilateral PCF for cervical radiculopathy and were followed up for more than 2 years. The patients were categorized into two groups based on the amount of resection: group O (over-resection group, resection > 50%) and group C (control group, resection ≤ 50%). A chi-square test was employed to compare the bone bridge formation between the two groups. In addition, a regression analysis was conducted on 162 segments to assess the relationship between the amount of facet resection and four outcome variables: segmental instability, range of motion (ROM), disc height, and foraminal restenosis.

Results: Group O demonstrated a significantly lower segmental ROM compared to group C (p=.005), while there were no significant differences between the groups in terms of clinical outcomes, cervical ROM, or alignment. The chi-square test did not show a significant difference in bone bridge formation between groups O and C; however, the former exhibited a notably higher number of fully formed bone bridges than the latter (p=.350). Additionally, the regression analysis results revealed a significant negative correlation between the degree of facet resection and postoperative disc height (β=-.196, p=.013), indicating that greater facet resection was associated with a greater reduction in disc height after the surgery.

Conclusion: The group O did not exhibit any adverse clinical or radiological outcomes, except for a decrease in segmental ROM. Furthermore, there was no significant difference in radiographic changes according to the extent of resection for each segment, except for disc height changes at 2-year follow-up. Contrary to conventional understanding, facet resection of more than 50% did not appear to cause significant issues, but rather led to spontaneous fusion, potentially resulting in a decrease in ROM.

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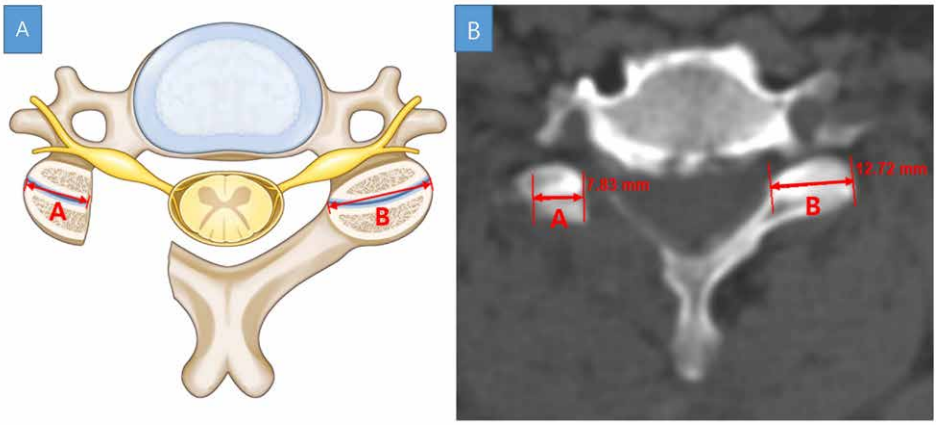
[Figure 1] The amount of facet resection was quantified by measuring the width of the facets before and after resection on the coronal planes. CT scans (A) and schematics (B).



- The amount of facet resection (%) = (1 - A/B) x 100

[Table a] Comparison of clinical outcomes among groups.

		Over-resection group (N=51)	Control group (N=14)	p-value
Neck pain VAS	Preoperative	2.20 ± 0.38	2.00 ± 0.85	.822
	Posteoperative_6m	2.00 ± 0.38	1.40 ± 0.85	
	Postoperative _2Y	2.44 ± 0.50	1.40 ± 1.11	
Arm pain VAS	Preoperative	4.46 ± 0.50	5.40 ± 1.14	.307
	Posteoperative_6m	2.50 ± 0.51	0.80 ± 1.16	
	Postoperative _2Y	3.19 ± 0.55	2.20 ± 1.25	
NDI	Preoperative	10.95 ± 1.57	9.20 ± 3.06	.486
	Posteoperative_6m	6.79 ± 1.26	5.60 ± 2.47	
	Postoperative _2Y	5.21 ± 1.06	6.80 ± 2.06	

VAS, visual analogue scale; NDI, neck disability index; m, months; Y, years.

Statistical analyses were performed by repetitive measures analysis (RMA).

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[Table b] Comparison of radiological outcomes among groups

	Group	Mean	S.D.	t	p-value
Segmental alignment changes_6M	Over-resection (> 50%) (N=51)	-0.80	5.29	.383	.703
	Control (≦ 50%) (N=14)	-0.21	4.26		
Segmental alignment changes_2Y	Over-resection	-0.27	5.15	.465	.644
	Control	0.43	4.45		
Cervical alignment changes_6M	Over-resection	-0.69	8.03	-1.242	.219
	Control	-3.79	9.14		
Cervical alignment changes_2Y	Over-resection	-0.29	8.16	-1.21	.231
	Control	-3.50	10.82		
Segmental ROM changes_6M	Over-resection	-3.33	10.54	2.015	.05
	Control	0.79	5.29		
Segmental ROM changes_2Y	Over-resection	-6.84	13.37	2.967**	.005
	Control	0.43	5.92		
Cervical ROM changes_6M	Over-resection	-4.98	17.14	-0.152	.88
	Control	-5.79	19.10		
Cervical ROM changes_2Y	Over-resection	-9.37	21.54	.688	.494
	Control	-5.07	17.29		

Segmental alignment changes: [neutral segmental angle (SA)_6M or 2Y] - [neutral SA_preoperative]

Cervical alignment changes: [neutral cervical lordosis angle (CL)_6M or 2Y] - [neutral CL_preoperative]

Segmental ROM changes: [(flexion SA-extension SA)_6M or 2Y] - [(flexion SA-extension SA)_preoperative]

Cervical ROM changes: [(flexion CL-extension CL)_6M or 2Y] - [(flexion CL-extension CL)_preoperative]

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[Table c] Comparison of bone bridge formation among groups.

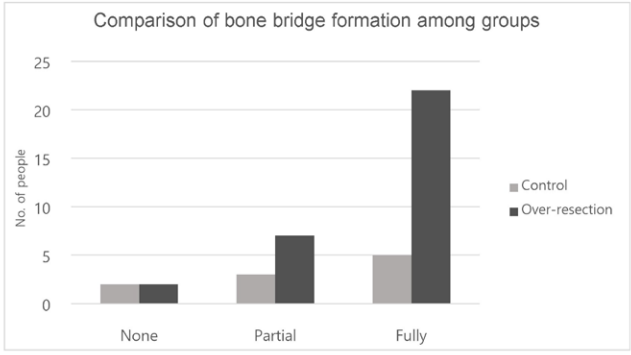
Unit: Frequency (%)

		Over-resectcion group	Control group	Total	X^2	p-value
Bone bridge formation	None	2(6.5)	2(20.0)	4(9.8)	2.098	.350
	Partial	7(22.6)	3(30.0)	10(24.4)		
	Fully	22(71.0)	5(50.0)	27(65.9)		
Total		31(100.0)	10(100.0)	41(100.0)		

None, None; Partial, Partially present; Fully, Fully present.

Statistical analyses were performed by Chi-squared test.

[Figure 2] Comparison of bone bridge formation among groups.



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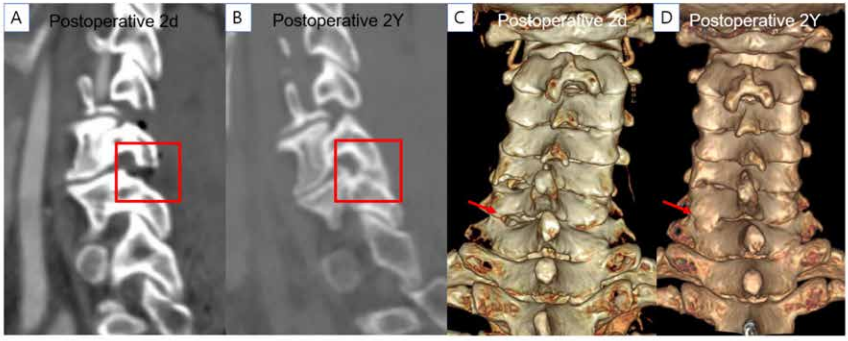
[Table d] Comparison of segment-specific radiological outcomes based on extent of facet joint resection.

IV	DV	B	S.E.	β	t	p-value
Disc height chages_6M	(constant)	-.059	.256		-.231	.818
	facetectomy	-.003	.005	-.044	-.552	.582
			F= .305 (p>.05), R^2=.002 , D-W= 1.793			
Disc height chages_2Y	(constant)	.498	.475		1.048	.296
	facetectomy	-.022	.009	-.196	-2.519*	.013
			F= 6.346 (p<.05), R^2=.038 , D-W= 1.062			
Gliding distance changes_6M	(constant)	-.168	.897		-.187	.852
	facetectomy	-.006	.016	-.029	-.360	.719
			F= .130 (p>.05), R^2=.001 , D-W= .891			
Gliding distance changes_2Y	(constant)	-.480	.928		-.518	.605
	facetectomy	-.005	.017	-.023	-.286	.775
			F= .082 (p>.05), R^2=.001 , D-W= .984			
ISPD changes_6M	(constant)	-2.446	1.327		-1.843	.067
	facetectomy	.012	.024	.041	.515	.607
			F= .265 (p>.05), R^2=.002 , D-W= 1.651			
ISPD changes_2Y	(constant)	-4.945	1.519		-3.255	.001
	facetectomy	.025	.027	.072	.916	.361
			F= .839 (p>.05), R^2=.005 , D-W= 1.315			
Foraminal restenosis	(constant)	10.989	.240		.097	.039
	facetectomy	.150	.098	.154	1.532	.129
			F= 2.346 (p>.05), R^2=.024 , D-W= 1.386			

*p<.05 IV, independent value; DV, dependent value; ISPD, interspinous process distance.
Statistical analyses were performed by simple linear regression analysis.

[Figure 3] Formation of bone bridge. These images are CT scans taken two days and two years after a posterior cervical foraminotomy was performed on a 57-year-old male patient diagnosed with C-radiculopathy at the C5-6-7, Lt level. Images A and B show sagittal CT scans indicating the formation of a bone bridge at the C6-7 level (red rectangle), while images C and D show CT reconstruction images also indicating the formation of a bone bridge at the C6-7 level (red arrow).



POSTER 12

Machine Learning-based Measurement of the Regional and Global Spinal Parameters Using the Concept of Incidence Angle of Inflection Points

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Introduction: The convolutional neural network (CNN), a subtype of machine learning, is widely used to extract features of image data and a few studies have reported the application to a spinal sagittal analysis recently. For intuitive interpretation of the spinal alignment, incidence angles of the inflection points (IAIPs) had been introduced as useful parameters representing the geometrical relationships between the pelvis and the spine. Therefore, IAIPs were measured using the CNN and the accuracy of thoracolumbar angular parameters derived through geometric relationships was evaluated.

Materials and Methods: For whole spine standing radiographs for parameters measurement, 563 whole spine lateral radiography sheets among 595 high-quality images were analyzed. Endpoints and center of sacrum, L1, T1, and C2 vertebra, and center of femur heads were detected by CNN-based machine learning by 3 layers of the region of interest. And validation of angular parameters was performed on 63 patients of the validation set. The ratio of the training set and the validation set was set at 9:1. The IAIPs, defined as the angle between the extension of pelvic tilt vector line and the perpendicular vector of the upper endplate of each vertebra, represent the geometric summation from the pelvis to each vertebra. And the six test parameters of LL, TK, C27L, L1S, T1S, and C2S were calculated from the proposed equations.

Results: To evaluate the performance of the proposed method, the success rates of parameters, which is the ratio having the mean absolute error of measured results smaller than the error threshold, were high in pelvic incidence and C2 incidence and low in sacral slope and L1 incidence. The proposed method shows efficiency in measuring PI, PT, T1I, C2I, LL, C2-7L, L1S, T1S, and C2S with the detection rate for these angles reaching 80 percentages with an error threshold of 3.5° (Fig. 1). The test results of the method were visualized via Bland–Altman plots for all angles of the entire sagittal parameters, which includes the horizontal lines of mean difference and mean difference ± 1.96 standard deviations (Fig. 2). The mean time required to perform the entire measurement procedure was less than 1 s. And the differences between the value calculated by the proposed formula and the value directly measured by the CNN model were very low as 0.005 as the mean absolute difference value and showed a coefficient of determination value of 1.000 ($p<0.01$).

Conclusion: The CNN-based deep learning algorithm and the concept of IAIPs were able to accurately measure the spinal sagittal parameters. Based on the three pelvic parameters and three incidence angles, the six additional parameters could be estimated accurately. The advantages of machine learning and the concept of IAIPs will be useful tools for large-scale data accumulation of sagittal spinal alignment.

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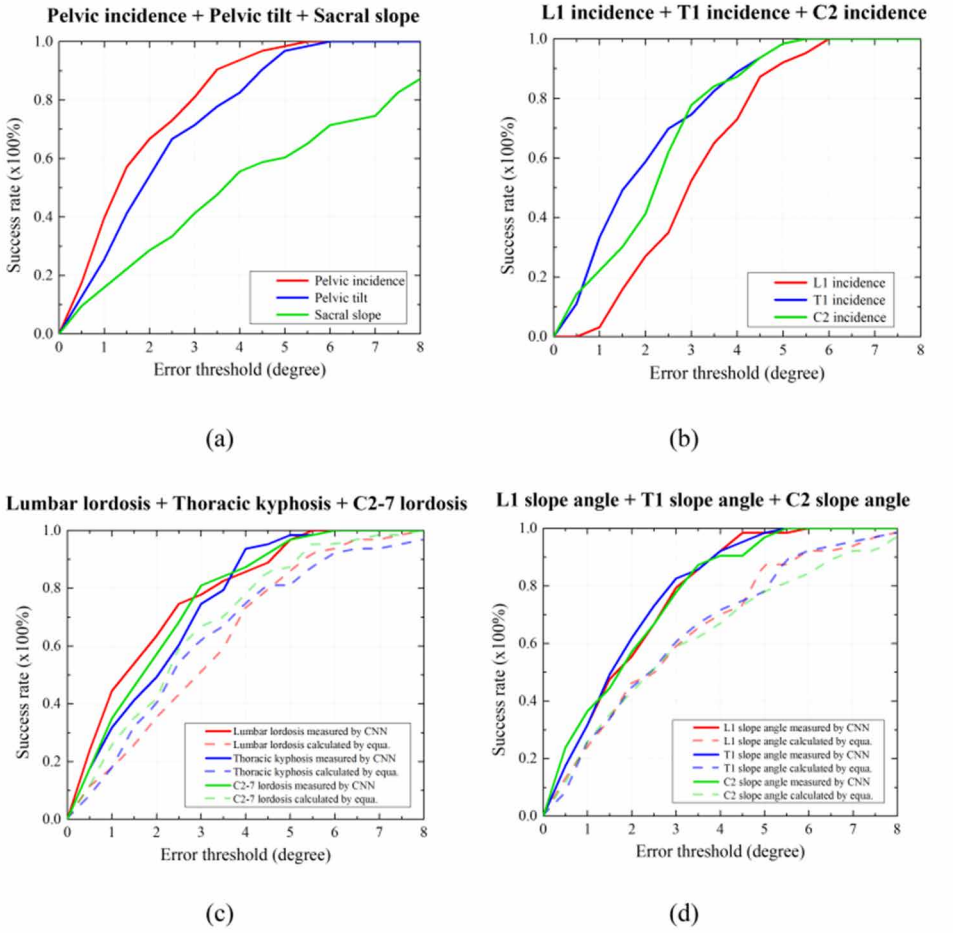

Figure 1: Successful rate for 12 parameters by error threshold. (a) PI, PT, SS measured by CNN; (b) L1I, T1I, C2I measured by CNN; (c) LL, TK, C2-7 measured by CNN and calculated from equations; (d) L1S, T1S C2S measured by CNN and calculated from equations.

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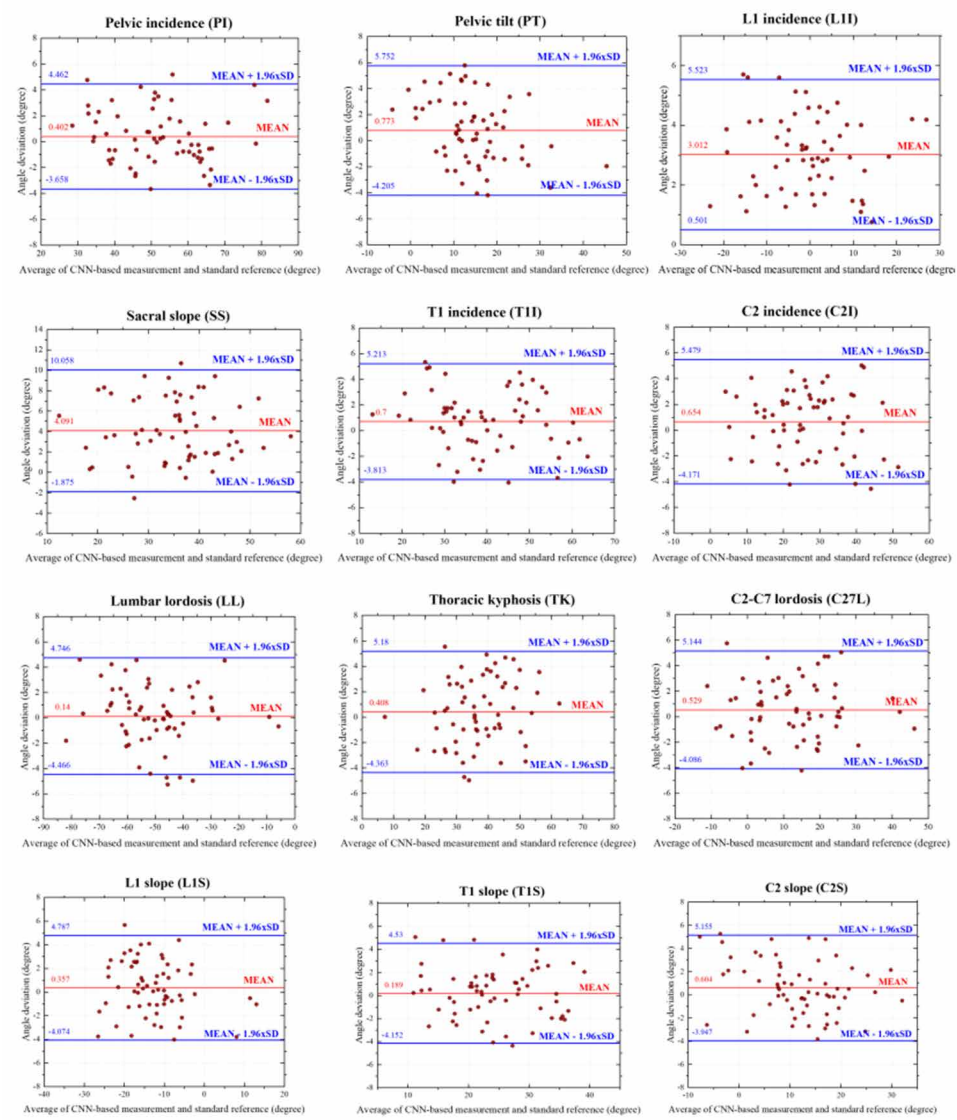

Figure 2: Bland–Altman plots comparing the values of radiographic parameters.

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.

POSTER 13

Posterior Cervical Foraminotomy is a Motion-Preserving Implant-free Alternative to Fusion: A Comparative Biomechanical Study

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Introduction: Surgical cervical spondylotic radiculopathy is currently commonly treated with anterior cervical discectomy and fusion (ACDF) or arthroplasty. However, they both involve permanent implantation of the spacer/plate or the artificial disc. Posterior cervical foraminotomy (PCF) is a motion-preserving implant-free alternative to fusion that involves facetectomy to widen the foramen for the damaged or affected nerve root[1]. It is also amenable to minimally invasive surgical techniques. While arthrodesis and arthroplasty have been studied extensively, PCF has received less attention. The objective of this study is to compare the external and internal biomechanics of PCF with ACDF to provide biomechanical guidance to the surgical extent of facetectomy.

Materials and Methods: A previously validated three-dimensional osteoligamentous finite element model of the human cervical spinal column (C2-T1) was used to simulate minimally invasive left-sided PCF with 50, 75, and 100% facetectomy and ACDF with anterior plating and screws[2]. All surgical simulations were performed at the C5-C6 level (figure 1), the most common surgical level for ACDF[3,4]. The finite element model included all subaxial cervical and T1 vertebrae, intervertebral discs, facet joints, and all anterior and posterior spinal ligaments. Physiological pure moment loading of 2 Nm under flexion, extension, and lateral bending, and in vivo follower force of 75 N was applied to the intact spine. A hybrid loading protocol that matched the range of motion (ROM) of the intact spine was used for the ACDF and PCF models. ROM, disc pressure, and facet forces at the index and adjacent levels for all cases were obtained and were normalized with respect to the intact spine, under flexion, extension, and lateral bending.

Results: ROM: ACDF decreased ROM at the index and increased ROM at the adjacent levels, while all graded PCF responses had an opposite trend: increased motion at the index and decreased motion at adjacent levels. The magnitude of changes depended on the level of resection, spinal level, and loading mode. Motion was greater with more extensive facetectomy especially under left lateral bending (figure 2).

Disc pressure: Disc pressure increased at the index level and decreased at the adjacent levels in extension and lateral bending, which were opposite to the pattern seen after fusion. 100% facetectomy led to over 60% increase in disc pressure with ipsilateral lateral bending.

Facet Load: Fusion led to reduction in facet load at the index level while increasing facet load at both index and adjacent levels. PCF led to increased facet load at both index and adjacent levels in extension and contralateral lateral bending. Ipsilateral lateral bending increased the adjacent facet loads more than contralateral lateral bending. Complete facetectomy led to facet load increases at adjacent levels more than fusion in extension and ipsilateral lateral bending.

Conclusion: PCF is a motion-preserving surgical option. Increasing extent of facetectomy resulted in greater lateral index level motion especially with 75% and 100% facetectomy.

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Complete facetectomy can significantly increase the index level disc pressure and stress both index level and adjacent level facets more so than fusion. Facetectomy should be kept to less than 75% in PCF if possible.

Figure 1

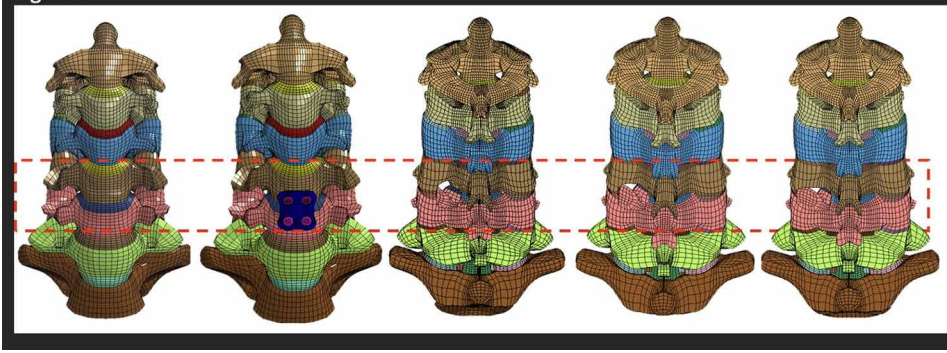
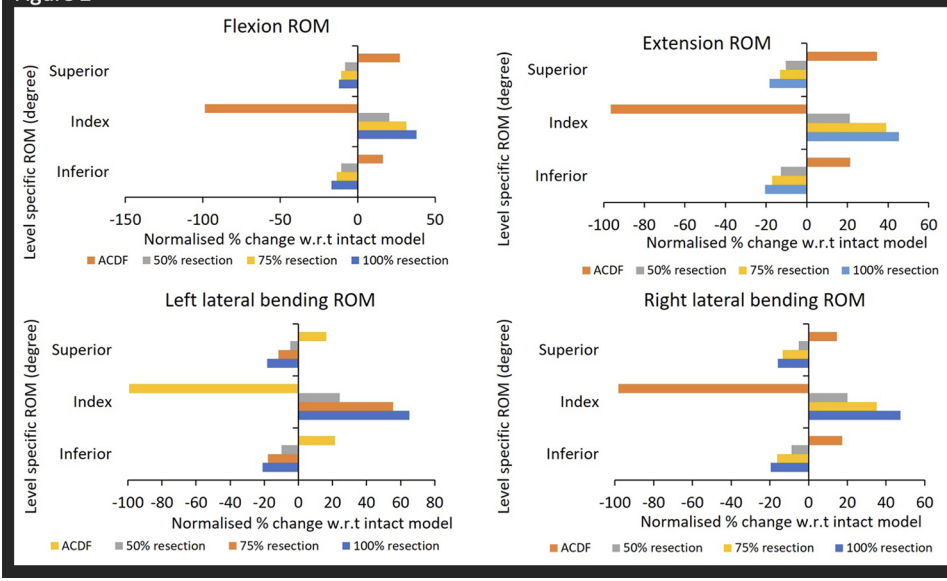


Figure 2



POSTER 14

Intraoperative Ultrasound Using a Linear (Minimally Invasive) Transducer During Anterior Cervical Surgery: Description of a New Technique

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Introduction: Intraoperative ultrasound (IOUS) has been utilized during posterior cervical approaches, but its use has not been described during an anterior cervical approach previously. We hypothesized that a small linear transducer (originally designed for transsphenoidal surgery) can visualize the spinal cord, subarachnoid space, nerve roots, and surrounding structures during anterior cervical approaches and may facilitate judgment of spinal cord and nerve root decompression.

Materials and Methods: IOUS was performed with the bkActive Imaging System (range 2-20 MHz) (BK Medical, Burlington, MA) using the "minimally invasive" transducer (N20P6/9007). Eleven patients underwent anterior cervical surgery (15 levels total) including 1 patient that underwent one-level corpectomy (7 males, 4 females). After discectomy and resection of the posterior longitudinal ligament, IOUS was used to judge the adequacy of central decompression. In addition, IOUS was used to judge the adequacy neural foraminal decompression after foraminotomy in 10 levels and uncinectomy in 5 levels (Figure 1). If indicated by IOUS, additional central or neural foraminal decompression was completed. Visualization of subarachnoid space surrounding the spinal cord and CSF pulsatility within the nerve root sleeve served as the criteria for adequate spinal cord and nerve root decompression, respectively.

Results: IOUS influenced surgical management in 5 of 15 levels of anterior cervical cases (33.3%). IOUS identified persistent nerve root compression in 3 cases (20%), including after foraminotomy (1 case) and uncinectomy (2 cases), and prompted additional osteophyte or soft tissue removal. A planned uncinectomy was aborted after IOUS demonstrated adequate CSF pulsatility within the nerve root sleeve. Additional central decompression behind the cranial-most vertebral body was performed following corpectomy in one patient after IOUS demonstrated persistent compression cranial to the corpectomy bed (Figure 2). Incidentally, IOUS was able to visualize subarachnoid space ventral to the spinal cord before takedown of the posterior longitudinal ligament in a case without spinal cord compression on preoperative MRI. IOUS was also able to visualize the position of the vertebral artery on standard brightness and doppler modes. In addition to the figures provided, an operative video with surgical and real-time IOUS footage is available to demonstrate the technique and results.

Conclusion: The neural elements and their relationships to normal and pathological structures can be visualized with IOUS using a small minimally invasive transducer during anterior cervical spine procedures and can facilitate judgment of the adequacy of spinal cord and nerve root decompression.

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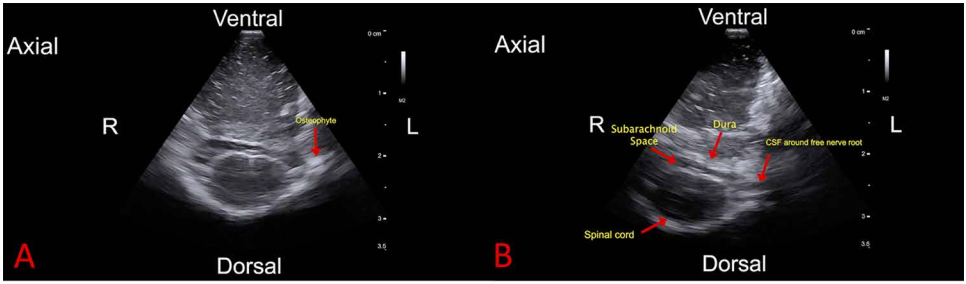

Figure 1. 48-year-old male with left arm pain. A) Short-axis IOUS image demonstrating compression of exiting nerve root due to osteophyte. B) Short-axis IOUS image after foraminotomy demonstrating decompression. of exiting nerve root.

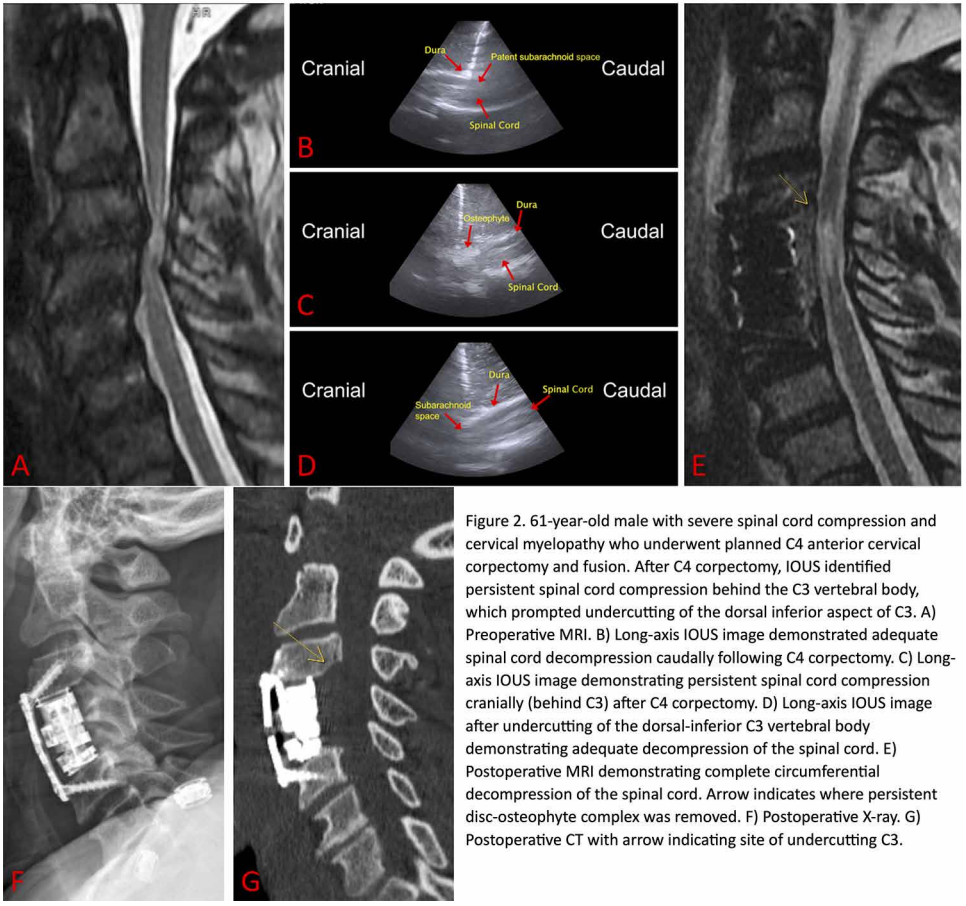

Figure 2. 61-year-old male with severe spinal cord compression and cervical myelopathy who underwent planned C4 anterior cervical corpectomy and fusion. After C4 corpectomy, IOUS identified persistent spinal cord compression behind the C3 vertebral body, which prompted undercutting of the dorsal inferior aspect of C3. A) Preoperative MRI. B) Long-axis IOUS image demonstrated adequate spinal cord decompression caudally following C4 corpectomy. C) Long-axis IOUS image demonstrating persistent spinal cord compression cranially (behind C3) after C4 corpectomy. D) Long-axis IOUS image after undercutting of the dorsal-inferior C3 vertebral body demonstrating adequate decompression of the spinal cord. E) Postoperative MRI demonstrating complete circumferential decompression of the spinal cord. Arrow indicates where persistent disc-osteophyte complex was removed. F) Postoperative X-ray. G) Postoperative CT with arrow indicating site of undercutting C3.

POSTER 15

Preoperative Predictors of Neurological Recovery Following Cervical Laminoplasty for Cervical Myelopathy: A Quality Outcome Database Study

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Introduction: Laminoplasty (LP) is an increasingly popular surgical option for patients with Degenerative Cervical Myelopathy (DCM). Cervical LP increases the volumetric area available for the spinal cord, thereby alleviating myelopathic symptoms while also retaining cervical spine mobility.[1] Questions remain regarding which patient demographic variables might impact neurological recovery following cervical LP. The purpose of our study is to identify which patient characteristics, including those of both demographic and clinical nature, serve as predictors of neurological recovery at 3 months following LP in a large, multicenter prospective registry.

Materials and Methods: A retrospective cohort study was conducted querying data from the Quality Outcomes Database for all adult patients who underwent cervical LP for DCM. Exclusion criteria included concomitant cervical fusion/arthroplasty, multistage surgeries, and patients without baseline or 3-month modified Japanese Orthopedic Association (mJOA) scores. Collected variables included age, body mass index (BMI), sex, insurance status, education, race, smoking status, medical comorbidities, ASA grade, pain medication, and pre-operative neck and arm Visual Analog Scale (NRS) scores for neck and arm pain, neck disability index (NDI) scores, and mJOA scores. Regression analysis was performed considering covariates to predict 3-month mJOA scores, which serves as an indicator of neurological function and severity of myelopathy.

Results: The study included 122 patients with a mean age of 62.8 ± 11.9 and a mean BMI of 30.5 ± 6.9. There were 70 (57.4%) men, and 97 (79.5%) patients were white. 67 (56.3%) patients experienced cervical myelopathic symptoms for less than 12 months. Mean preoperative VAS Neck pain was 4.1 ± 3.1, VAS Arm pain was 3.7 ± 3.4, NDI was 30.1 ± 20.4, and mJOA was 12.5 ± 3.2. Additionally, 65 (53.3%) patients reported motor deficits, and 27 (22.1%) were not able to ambulate independently. Mean mJOA score 3 months following LP was 14.4 ± 2.4. After controlling for baseline covariates, regression analysis showed that higher preoperative mJOA (β=0.35, 95%CI=0.21 – 0.49, $p<0.001$), lower preoperative NDI (β=-0.03, 95%CI= -0.06 – -0.01, p=0.019), lower BMI (β=-0.05, 95%CI= -0.11 – 0.00, p=0.042), greater than high school education attainment (β=0.90, 95%CI= 0.13 – 1.7, p=0.023), and white race (β=1.6, 95%CI= 0.70 – 2.4, $p<0.001$) were all significant predictors of higher 3-month postoperative mJOA scores.

Conclusion: The results of this study suggest there are multiple patient characteristics which may serve as predictors of neurological recovery, as measured by mJOA scores, at 3 months postop following cervical laminoplasty for degenerative cervical myelopathy. These predictors include higher preoperative mJOA, lower preoperative NDI, lower BMI, greater than high school education attainment, and white race. These findings suggest that both patient demographics and baseline functional status play a crucial role in predicting postoperative outcomes following LP. These findings not only will help surgeons better counsel patients regarding

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their odds of neurologic improvement following LP, but also point out an apparent healthcare disparity where non-white patients have a poorer prognosis for neurologic recovery, which should be the target of additional investigation.

POSTER 16

Cost Benefit of Preoperative Mental Health Optimization for Adult Spinal Deformity Surgery

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Introduction: The complexity of adult spinal deformity (ASD) corrective surgery can carry a significant cost burden. Psychological distress can be associated with worsening surgical outcomes and postoperative course. Given that these outcomes influence cost, associations between pre-surgical psychological state, intervention, and cost is warranted.

Materials and Methods: Patients >18yrs with NDI>20%. Patients administered 4 validated self-report instruments: Distress and Risk Assessment Method (DRAM), Fear-Avoidance Beliefs Questionnaire (FABQ), Pain Catastrophizing Scale (PCS), Outcome Expectation question (OEQ). Patients randomized using matched pairs: Sham (placebo educational group receiving six sham treatments then surgery); CBT (treatment by licensed professional prior to surgery). Surveys administered at enrollment. Thresholds were set >17 DRAM, >49/66 FABQ, >30/52 PCS. Subjects who did not meet cutoff were assigned into control group. Those who are above any thresholds placed into either the Sham or CBT group based on a 1:1 randomization. Any who exceeded psychological distress criteria were assigned to DRAM observation only group. Basic demographics and baseline measures HRQLs (NDI, EQ5D, PCS, FABQ) were assessed via descriptive analyses. Cost data valued by CMS.gov DRG. QALYS was calculated using NDI converted to EQ5D using published conversion, with 3% discount to account for life expectancy (78.7 years). Total utility gained calculated by change in utility multiplied by life expectancy. ANOVA and multivariate logistic regression determined predictive factors between cost and cohort groups.

Results: 47 included (53.6years, 49% female, 29.4 kg/m^2). At baseline, average PCS 27.4, FABQ 40, average EQ5D of 9.3, NDI of 25.6. 57.1% had a severe FABQ score, 40.8% severe PCS, 27.7% severe NDI. 17 were CBT, 11 Sham, 10 Control, 9 DRAM. 33 (68.8%) completed 2Y follow-up. Average initial surgical costs were: CBT: $4,722; Sham: $4,720; Control: $4,267; DRAM: $6,052 (p=0.685). Total utility gained was found to be the greatest in DRAM patients (.467), as compared to Sham (0.3712), CBT (0.3510), and Control (0.2349; p=0.029). Control patients with no intervention had lower cost effectiveness ($11,274) compared to the other groups (CBT: $7,043; Sham: $7,224; DRAM: $6,024). CBT trended toward a higher rate of improvement in PCS (56% vs. other groups: 41%, p=0.338), FABQ (50% vs. 28%, p=0.133), NDI (69% vs. 45%, p=0.124), EQ5D (50% vs. 31%, p=0.209), VAS (63% vs. 38%, p=0.114), NRS Neck (56% vs. 38%, p=0.236), and NRS Back (63% vs. 38%, p=0.114). Multivariate analysis found greater odds of increasing cost with higher baseline NDI (OR: 1.22, [1.02, 1.86], p=0.027).

Conclusion: Preoperative patient optimization can overall improve postoperative outcomes and patient satisfaction. This study found that increasing rates of mental health related disability are associated with diminished outcomes and cost effectiveness for cervical deformity surgery. Overall, lowest cost effectiveness was found in those receiving no treatment. With increasing baseline disability predicting greater surgical cost, optimizing patient's mental wellbeing in preoperative period can improve overall outcomes and healthcare burden.

POSTER 17

Cost Benefit Analysis of Preoperative Optimization of Modifiable Health Conditions Prior to Adult Cervical Deformity Surgery

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Introduction: Recent literature has emphasized the importance of frailty in surgical outcomes for adult cervical deformity patients and modifiable health conditions are a known contributor to frailty and overall comorbidity status. Benefits and cost differences to optimizing comorbidities prior to surgical adult cervical deformity correction merits further study.

Materials and Methods: ACD patients with available up to 2-year data were included. Preoperative optimization for osteoporosis was assessed by treatment with an FDA approved drug prior to surgery. Patients were divided into 2 groups: those who had preoperative rehabilitation [Prehab] and those who did not [no Prehab]. Prehab consisted of cognitive behavioral therapy and physical therapy with core, paraspinal and leg strengthening. Nutritional status assessed by ranking patients into quartiles (Q1-Q4) by baseline BMI. Q1 (low BMI) and Q4 (high BMI) were considered not optimized. Patients stratified by optimization in all three groups (Opt) or non-optimized. Cost analysis was based on average Medicare reimbursement while accounting for surgical approach and revision status. Reimbursement consisted of a standardized estimate using regression analysis of Medicare pay-scales for services within a 30 day window. All costs were inflation adjusted to 2022. For QALY analysis, utility was calculated using EQ-5D as previously published. ANCOVA and logistic regression analyses assessed outcomes while accounting for surgical and demographic differences between groups.

Results: 347 ACD patients (average 57.9±12.1 years, 48% female, 29.0±6.82 kg/m2) were included. Multivariate analysis confirmed Prehab patients more likely to improve in ODI (OR .055 [CI .006-.476], p=.008) at 2Y. However, Prehab and no Prehab patients exhibited similar ODI IHS recovery rates from BL to 2Y, P<.05. Total cost for Prehab patients was $59,272 compared to $72,878 for not Prehab, P<.05. Cost effectiveness was determined via cost per QALY: Prehab = $14,463 and not Prehab = $45,515, P<.05. For osteoporosis (85.4% Opt), Opt patients had lower odds of 2Y complications (OR: 0.207 [.086, .498],p<.001) and lower cost ($28,053 vs. $33,171,p=.002) compared to non-optimized patients. Optimized patients were significantly less female (43% vs. 52%, p=.038) and had fewer levels fused (4.14±3.50 vs. 5.21±4.15, p=.002), shorter length of stay (3.96±3.94 vs. 5.12±8.18 days, p=.044), less operative time (261.9±166.6 vs. 315.8±189.7 mins, p=.002), and lower EBL (502.8±950.6 vs. 679.0±965.5 mL, p=.039). Optimized patients had lower cost at 2 years ($33,898.40 vs. $36,861.86, p=.009). Linear regression modeling was significant for optimized BMI predicting lower cost at 2 years with average change of $2963.45 (OR:.45 [1.02,2.89], p=.009).

Conclusion: While preoperative optimization of modifiable health conditions may present greater upfront costs, the longer-term cost savings associated with optimized adult cervical deformity patients may outweigh the initial cost.

POSTER 18

Refining Criteria and Classification of Cervical Kyphosis Considering Compensation Mechanism Based on 'Neck Tilt'; A Separate 'Cone of Economy' for Cervical Spine Balance

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Introduction: Several criteria and classifications for cervical kyphosis (CK) have been proposed, though the majority are based on functional outcomes or morphological grouping and do not directly address compensatory mechanisms. This study evaluated CK using 'neck tilt' (NT)—a constant parameter originating in prior studies—and proposes the 'NT-C2 slope/T1 slope (C2/T1S) classification', which classifies both morphology as well as the presence or failure of compensatory mechanisms.

Materials and Methods: This was a two-center, retrospective review of consecutive patients undergoing surgical management of CK. Preoperative and postoperative radiographic parameters were measured in cervical and full-length entire spine lateral radiographs. We defined cervical decompensation as C2S>T1S, and TL decompensation as C2-SVA in front of NT. Patients were grouped according to the NT-C2/T1S classification (Fig. 1), 1: focal CK, C2ST1S, C2-SVA was posterior to NT, no cervical compensation but intact TL compensation; 3: C2ST1S, global CK, C2-SVA anterior to NT, no cervical or TL compensation. Group 2, 3, and 4 were considered cervical deformity. Parameters were compared between the groups and previous criteria of CK; C2-C7 kyphosis ≥10°, C2-C7 SVA ≥4cm, T1S-CL ≥25°, and classifications by Kim-ISSG and European-CSRS. Statistical significance was considered $p<0.05$.

Results: In total, 106 patients were included (mean age 57.9±14.4years, female 57.6%, prior cervical fusion 33.0%). Pre-operatively, the distribution of patients based on the NT-C2/T1S classification was: group 1 44.3% (n=47), group 2 27.4% (n=29), group 3 13.2% (n=14), group 4 15.1% (n=16). Group 1 showed 1.5 mean kyphotic segments, normal range of C2-C7 angle, C2-7 SVA, C2S, T1S and showed normal cervical and TL compensation. Group 2 showed mean 3.2 kyphotic segments, 20.6° kyphotic C2-7 angle, 11.9° T1S, 29.8° C2S, and a significant increase in T1S and decrease in C2S postoperatively (both $p<0.05$). Group 3 showed mean 1.7 kyphotic segments, 12.8° lordotic C2-C7 angle, 34.5° C2S, and 47.9° T1S. Group 4 showed 3.6 kyphotic segments, 19.9° kyphotic C2-C7 angle, 74.9° C2S, 49.8° T1S, and a significant decrease in C2S post-operatively ($p<0.05$). Overall, NT did significantly change post-operatively among any group (all $p>0.05$) (Table 1). Among all patients in groups 2, 3, and 4 combined, 81.4% met previous CK criteria. (Table 2) The group 2 was compatible with 'focal' type by Kim-ISSG and 'CK-global balance' type by E-CSRS, group 3 with 'cervicothoracic' (Kim-ISSG) and 'cervical lordosis-global imbalance' (E-CSRS) type and group 4 with 'flat neck' (Kim-ISSG) and 'CK-global imbalance' (E-CSRS) type.

Conclusion: This study presented the NT-C2/T1S classification, a refined classification for cervical kyphosis both based on morphology and compensatory mechanisms. This classification implies a separate cone of economy for the cervical spine, based around NT, which was reasonably constant at ~45° both pre- and post-operatively. The NT-C2/T1S classification is intuitive and comprehensive, and integrates cervical kyphosis with

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compensation mechanisms within and outside of the cervical spine. Futures studies will focus on clinical outcomes and implications for surgical decision-making.

Figure 1: Illustration of NT-C2/T1S Classification

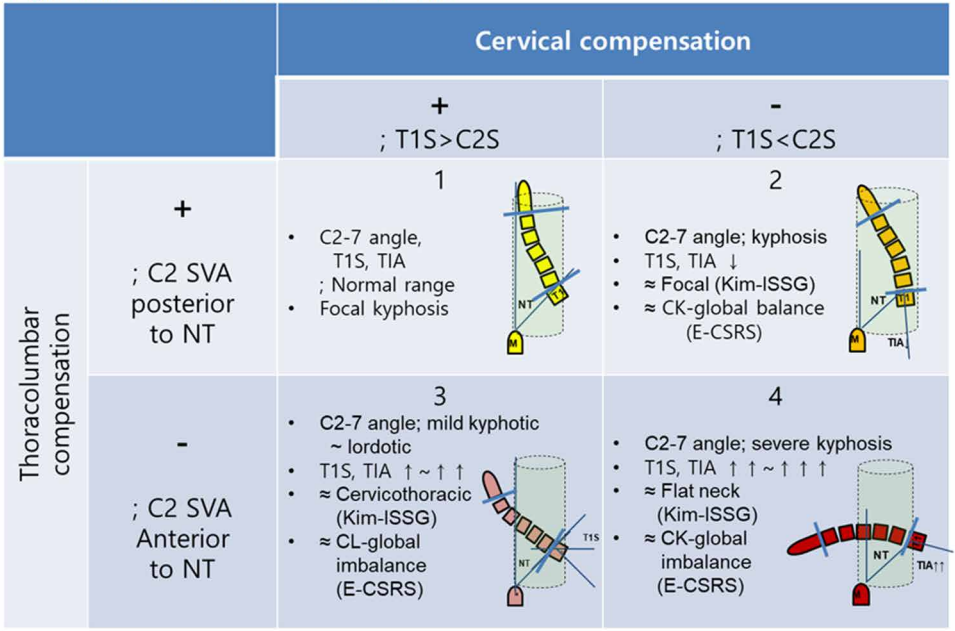

Table 1: Radiographic Parameters By NT-C2/T1S Classification

Variable	All Patients		Group 1		Group 2		Group 3		Group 4	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
C2-C7 Angle	**3.4**	**-6.6** *	-7.6	-10.0	**20.6**	**0.7** *	-12.8	-12.7	**19.9**	**-4.3** *
C2-C7 SVA	**34.9**	**28.4** *	19.3	22.3	28.6	24.6	50.0	36.9	**81.6**	**49.0** *
C7-S1 SVA	**0.9**	**35.3** *	-2.1	10.0	**-22.7**	**13.1** *	50.1	100.1	**12.7**	**75.7** *
C2 Slope	**29.6**	**19.1** *	12.7	13.3	**29.8**	**19.4** *	34.5	23.3	**74.9**	**34.4** *
T1 Slope	27.0	27.0	22.7	24.8	**11.9**	**20.0** *	47.9	35.8	49.8	42.0
Neck Tilt	48.1	47.5	48.9	48.1	50.4	47.4	44.0	45.8	44.8	47.2
Thoracic Inlet Angle	75.1	74.2	71.6	72.9	62.3	67.3	92.0	80.5	95.2	88.8
T4-T12	32.2	33.6	28.6	30.2	23.6	25.0	42.3	43.0	47.2	49.0
L1-S1	-47.9	-45.3	-50.1	-49.4	-47.5	-44.3	-42.3	-40.5	-47.0	-43.1
Sacral Slope	33.2	33.6	36.4	35.3	34.2	34.9	28.3	30.2	26.9	30.7
Pelvic Incidence	48.8	49.4	46.0	46.2	48.8	49.1	53.7	55.9	52.3	51.3

Note: Bolded pre/post pairs and * indicate a statistically significant change from post- vs. pre-operatively ($p<0.05$).

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Table 2: NT-C2/T1S Classification, Comparison to Existing Cervical Deformity Definitions

NT-C2/T1S	C2-C7 Kyphosis ≥10°		C2-C7 SVA ≥40mm		T1S-CL ≥25°		Any Criteria	
Group	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)
All Patients	69.8	30.2	69.8	30.2	53.8	46.2	46.2	53.8
1	100.0	0.0	95.7	4.3	85.1	14.9	80.9	19.2
2	24.1	75.9	82.8	17.2	37.9	62.1	24.1	75.9
3	100.0	0.0	28.6	71.4	35.7	64.3	21.4	78.6
4	37.5	62.5	6.3	93.8	6.3	93.8	6.3	93.8
p-value	<0.0001		<0.0001		<0.0001		<0.0001	

POSTER 19

A MSSIC Study Reveals Non-Modifiable Risk Factors Were Associated with Post-Operative Hematoma following ACDF

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Introduction: Post-operative hematoma (POH) following anterior cervical discectomy (ACDF) is uncommon. Although rare, POH is recognized as a potentially catastrophic post-operative complication. There is limited information as to who is vulnerable. From a large database, the authors sought to identify common modifiable and non-modifiable risk factors for developing POH and its associated clinical outcomes.

Materials and Methods: The Michigan Spine Surgery Improvement Collaborative (MSSIC) is a statewide quality improvement initiative. ACDF cases in MSSIC registry from 2014-2018 were identified. Patients who developed POH (POH) were compared to those who did not (non-POH). Chi-square and t-test analyses were done to compare the two groups in terms of demographics, surgical characteristics, patient reported outcomes (baseline and postoperative PROMIS-PF score), and other postoperative symptoms or complications. All analyses were performed by using SAS 9.4.

Results: Incidence of POH is low. Of the 9,958 cases, it only occurred in 114 cases (1.1%). POH was associated with male gender (1.6% vs 0.7%, p <.001), advanced age (age 59±11 vs 55±11, p <.001), baseline use of anticoagulation (2.3% vs 1.1%, p=.031), previous spine surgery (1.6% vs 0.9%, p=.005) and inpatient procedures (1.3% vs 0.7%, p=.024). POH was also associated with which cervical levels were operated (p<.001), with the highest rates observed in surgeries involving C3-C6 (3.6%) and C3-C5 (3.8%) while the lowest in surgeries involving C5 to C7 (0.5%). Smoking, multi-level surgery, corpectomy and drain use were not associated with hematoma (p>.10 for all). Reports of dysphagia (6.9% vs 29.8%, p <.001), prolonged hoarseness (2.4% vs 9.7%, p <.001) and weakness (5% vs 10.5%, p=.007) were common in the POH group. No significant differences in PROMIS outcomes were observed between POH and the non-POH groups at baseline (p=.232) and post-operatively at 90 days, 1 year, and 2 years (p>.05).

Conclusion: POH is rare. Intrinsic or non-modifiable risk factors identified were gender, age, baseline use of anticoagulation, prior surgery and anatomical exposure. Dysphagia, prolonged hoarseness and weakness were common in the POH group. Discussion: Although intrinsic factors cannot be eliminated, surgical risk factors can be minimized. Our large database review revealed procedures involving C3-C5 and C3-C6 had the highest rate of hematoma compared to more caudal surgeries. Difficulties with exposure as well as vascular anatomy in the upper cervical spine, the cricothyroid arteries bilaterally (Figure 1), could explain this finding. Thorough visual inspection to ensure hemostasis is obtained prior to closure is critical. POH, if left unrecognized put patients at significant risk for this life-threatening postoperative complication. Effective screening targeted at high-risk patients may help in prevention and early detection.

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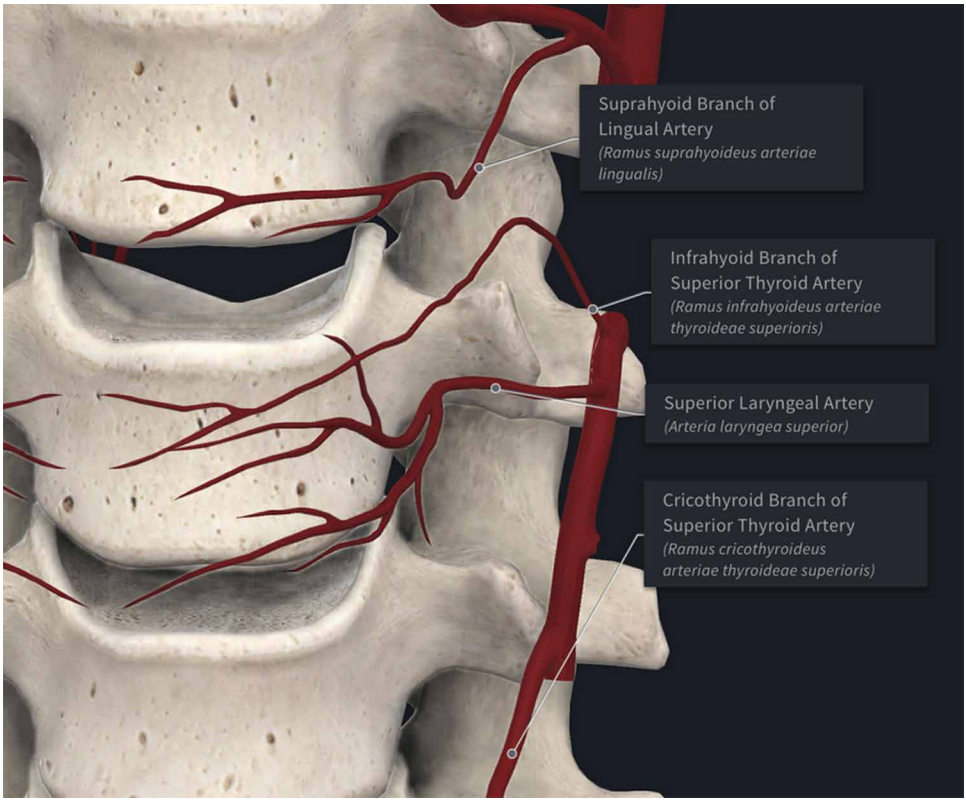

POSTER 20

Differences in Time to Achieve Minimum Clinically Important Difference between Patients Undergoing Anterior Cervical Discectomy and Fusion and Cervical Disc Replacement

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Introduction: Time to minimum clinically important difference (MCID) achievement for patient-reported outcome measures (PROMs) has not been compared in patients undergoing anterior cervical discectomy and fusion (ACDF) versus cervical disc replacement (CDR).

Materials and Methods: PROs of patients undergoing ACDF or CDR were collected preoperatively and postoperatively at 6-week/12-week/6-month/1-year/2-year periods. MCID achievement was calculated through comparison of ΔPROM to previously established values in literature. Time to MCID achievement and predictors for delayed MCID achievement were determined through Kaplan-Meier survival analysis and multivariable Cox regression, respectively.

Results: One hundred and ninety-seven patients were identified, with 118 and 79 undergoing ACDF and CDR, respectively. Kaplan-Meier survival analysis demonstrated faster time to achieve MCID for CDR patients in PROMIS-PF (p=0.006). Early predictors of MCID achievement through Cox regression were CDR procedure, Asian ethnicity, elevated preoperative PROs of VAS neck and VAS arm (HR 1.16-7.28). Workers' compensation was a late predictor of MCID achievement (HR 0.15).

Conclusion: Most patients achieved MCID in physical function, disability, and back pain outcomes within 2 years of surgery. Patients undergoing CDR achieved MCID faster in physical function. Early predictors of MCID achievement were CDR procedure, Asian ethnicity, and elevated preoperative PROs of pain outcomes. Workers' compensation was a late predictor. These findings may be helpful in managing patient expectations.

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Table 1. Demographic and perioperative characteristics

Characteristic	Total (n = 197)	ACDF (n = 118)	CDR (n = 79)	*p-value
Age (years)	48.03±9.71	49.16±9.29	46.34±10.13	**0.046**
Female	40.1% (79)	40.7% (48)	39.2% (31)	0.840
BMI (kg/m^2)	29.75±5.97	30.40±6.48	28.74±4.94	0.061
Ethnicity				0.235
Black	7.1% (14)	8.5% (10)	5.1% (4)	
Asian	2.6% (6)	2.6% (5)	1.3% (1)	
Hispanic	8.2% (18)	11.0% (13)	6.4% (5)	
White	79.6% (156)	74.6% (88)	87.2% (68)	
Other	1.5% (3)	2.5% (3)	0.0% (0)	
Comorbidities				
Smoker	12.2% (24)	14.4% (17)	8.9% (7)	0.243
Hypertension	22.8% (45)	26.3% (31)	17.7% (14)	0.161
Diabetes	10.7% (21)	15.3% (18)	3.8% (3)	**0.011**
ASA Classification				0.456
One	21.7% (38)	20.4% (20)	23.4% (18)	
Two	65.7% (115)	64.3% (63)	67.5% (52)	
Three	12.6% (22)	15.3% (15)	9.1% (7)	
Ageless CCI Score	0.64±0.86	0.75±0.97	0.48±0.64	**0.029**
Insurance Type				0.130
Medicare/Medicaid	3.2% (7)	2.9% (4)	3.7% (3)	
Workers' Comp	26.0% (57)	30.7% (42)	18.3% (15)	
Private	70.8% (155)	66.4% (91)	78.1% (64)	
Spinal Pathology				
Herniated nucleus pulposus	87.3% (172)	79.7% (94)	98.7% (78)	**<0.001**
Central stenosis	60.9% (120)	58.5% (69)	64.6% (51)	0.391
Foraminal stenosis	16.8% (33)	12.7% (15)	22.8% (18)	0.064
Type of surgery				**<0.001**
Index surgery	88.7% (173)	81.9% (95)	98.7% (78)	
Revision surgery	11.3% (22)	18.1% (21)	1.3% (1)	
Number of Instrumented Levels				0.084
One	65.0% (128)	60.2% (71)	72.2% (57)	
Two	35.0% (69)	39.8% (47)	27.9% (22)	
Preoperative PROMs				
VAS Neck	6.04±2.34	6.07±2.18	5.99±2.58	0.798
VAS Arm	5.49±2.66	5.75±2.42	5.11±2.96	0.101
PROMIS-PF	39.64±7.45	38.84±6.93	40.83±8.05	0.067
NDI	39.08±18.85	39.29±18.85	38.78±19.02	0.853
Preoperative symptom duration (days)	277.03±242.75	288.36±268.40	259.74±198.33	0.491
Operative Time (min.)	56.18±15.11	58.58±14.90	52.48±14.77	**0.006**
Estimated Blood Loss (mL)	28.27±9.95	29.09±11.41	26.87±6.62	0.147
Length of Stay (hours)	10.06±8.17	11.29±9.07	8.13±6.10	**0.009**
POD 0 VAS Pain	4.80±2.16	4.99±1.95	4.52±2.42	0.136
POD 0 Narcotic Consumption (OME)	31.62±24.45	39.16±26.00	20.31±16.48	**<0.001**

BMI = Body Mass Index; ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; Workers' Comp = workers' compensation; POD = postoperative day; SD = standard deviation; VAS = Visual analog scale; OME = oral morphine equivalents; PROMs = Patient-reported Outcome Measures; PROMIS PF = Patient-reported Outcomes Measurement Information System Physical Function; ODI = Oswestry Disability Index

*p-value calculated using 1-way ANOVA for continuous variables and Chi-square analysis for categorical variables.

Boldface indicates significance ($p<0.05$).

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

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Table 2. Multivariable Cox regression of factors affecting time to achieve MCID

	PROMIS-PF [HR (95% CI)]	NDI [HR (95% CI)]	VAS Neck [HR (95% CI)]	VAS Arm [HR (95% CI)]
CDR (ref: ACDF)	2.22 (1.33, 3.70)*			
Asian ethnicity			7.28 (1.07, 49.39)	
Workers' Compensation		0.15 (0.03, 0.77)		
Private insurance				
Preoperative PROMs				
VAS Neck			1.28 (1.06, 1.55)	
VAS Arm	1.16 (1.01, 1.33)			1.47 (1.17, 1.86)*

Following variables insignificant on Cox regression and excluded from the table: age, BMI, ASA of 1-3, ageless CCI, gender, smoking status, diabetic status, ethnicities of Black, Hispanic, White, and Other, Medicare/Medicaid, private insurance 1-2 instrumented levels levels, spinal pathologies of central stenosis or foraminal stenosis, symptom duration, preoperative PROMs of PROMIS-PF and NDI and surgery type of index surgery or revision surgery

HR = Hazard Ratio; CI = Confidence Interval; VAS = Visual Analog Scale

*Indicates p-value<0.01.
Filled entries indicate p-value<0.05; Empty entries indicate non-significant values.

POSTER 21

The Influence of Cage Type on Subsidence Following Anterior Cervical Discectomy and Fusion (ACDF) Surgery

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Introduction: A variety of cage types are used to fill the void following anterior cervical discectomy and fusion (ACDF) surgery, which is often complicated by interbody cage subsidence. These cages differ in material composition from allograft and each other, which in turn exert different biomechanical effects. This retrospective cohort study aims to determine the relationships between the use of allograft or interbody cage on subsidence.

Materials and Methods: We conducted a retrospective analysis of radiographs following elective ACDF performed from 2016-2021 at an urban, academic tertiary medical center. Posterior disc height (PDH) and anterior disc height (ADH) measurements were obtained from lateral cervical radiographs at immediate postop (<6 weeks) and long-term postop (> 6 months). Both anterior and posterior cage subsidences were calculated by subtracting the final follow-up postoperative disc height measurements from the immediate postoperative disc height measurements. Cage types included structural allograft, polyetheretherketone (PEEK), titanium, ceramic, and zero-profile. T-tests were used to compare cage type with subsidence.

Results: There were 131 patients and 244 levels fused in this study: 411-level, 67 2-level, and 23 3-level fusions. 68 patients received a structural allograft and 63 received a cage implant: PEEK (27), titanium (22), ceramic (11), and zero-profile (3). The median final follow-up time was 366 (IQR: 239-566) days. Structural allografts were associated with a greater anterior subsidence (p=.016) and posterior subsidence (p=.002) than the cage implant cohort of all subtypes. On multivariate analysis, there was significant association between structural allograft and anterior segmental subsidence (beta=0.385; 95% CI [0.003, 0.768]; p=0.048) and a strong association between structural allograft and posterior segmental subsidence (beta=0.448; 95% CI [0.150, 0.747]; p=0.003).

Conclusion: Some vertebral body settlement can be expected following ACDF. Further subsidence leading to adverse clinical outcomes may be related to spacer selection. We note that using cage implants lead to less long-term subsidence compared to structural allograft. The results from this study can better inform surgeons regarding cage type selection when performing ACDF.

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Table 1: T-test results with Anterior Disc Height (ADH), Posterior Disc Height (PDH), Anterior Subsidence, and Posterior Subsidence measurements in Allograft and Cage subgroups

	Allograft (n=117)	Cage (n=127)	P-value
Immediate ADH (cm)	0.83 (0.15)	0.82 (0.14)	0.696
Final ADH (cm)	0.66 (0.15)	0.69 (0.14)	0.033
Immediate PDH (cm)	0.69 (0.14)	0.64 (0.11)	**0.004**
Final PDH (cm)	0.54 (0.13)	0.54 (0.11)	0.956
Anterior Subsidence (cm)	0.18 (0.14)	0.13 (0.16)	**0.016**
Posterior Subsidence (cm)	0.15 (0.11)	0.10 (0.12)	**0.002**

Table 2. Multivariate linear regression results with structural allograft as predictor variable and controlling for level of fusion (1st, 2nd, 3rd), cervical level (C4, C5, C6, C7), sex, age, smoking status, and osteopenia.

	beta	95% CI	P-value
Anterior Segmental Subsidence	0.385	[0.003, 0.768]	**0.048**
Posterior Segmental Subsidence	0.448	[0.150, 0.747]	**0.003**

POSTER 22

The Effects of Race/Ethnicity on the Epidemiology, Survival and Neurological Outcomes Following Acute Traumatic Spinal Cord Injury: A Retrospective Cohort Study Using Data from the NASCIS-1 Clinical Trial

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Introduction: Prior studies documented the effects of race/ethnicity on demographics and epidemiology of traumatic spinal cord injury (tSCI), as well as their impact on the individuals' quality of life and handicapping after tSCI. However, there is little evidence for any effect of race/ethnicity on other outcomes following tSCI. This study was undertaken to evaluate the influence of race/ethnicity on the individuals' survival and neurological recovery within the first year after acute tSCI.

Materials and Methods: This retrospective cohort study included all 306 cases enrolled in the first National Acute Spinal Cord Injury Study (NASCIS-1), who were grouped into African Americans, non-Hispanic whites, and other races/ethnicities. Outcome measures included survival and neurological recovery (as assessed using the NASCIS motor, pinprick sensory and light-touch sensory scores) within the first year following tSCI. Data on survival with the first year after tSCI was analysed out using Fisher exact test, and Kaplan-Meier curve with log-rank test. Multiple regression analyses were used to evaluate the potential effects of the race/ethnicity on the neurological recovery (i.e. motor recovery, and pinprick and light-touch sensory recovery) at 1 year after tSCI. Those multiple regression analyses were adjusted for major potential confounders including the individuals' sex, age at the tSCI onset, level of tSCI, cause of injury, type of wound, level of consciousness at admission, and total received dose of methylprednisolone.

Results: There were 39 females and 267 males with mean age of 31 years who mostly sustained cervical severe tSCI after motor vehicle accident or fall. The three groups were comparable regarding sex distribution, level and severity of tSCI, level of consciousness, and total received dose of methylprednisolone. African Americans were significantly older than non-Hispanic whites (P=0.0238). African Americans and individuals of other races/ethnicities more often had a tSCI with open wound caused by missile and water-related accidents than non-Hispanic whites (P<0.0001). There no statistically significant differences with regard to the survival rates within the first year after tSCI among the three racial/ethnic groups (P=0.3191; Figure 1). Among the survivors, race/ethnicity did not significantly influence motor recovery (Model: R^2=0.1735; F value=3.36; P=0.0001; race/ethnicity variables: P≥0.6935), pinprick sensory recovery (Model: R^2=0.1223; F value=2.23; P=0.0001; race/ethnicity variables: P≥0.4712) and light-touch sensory recovery (Model: R^2=0.0997; F value=1.76; P=0.0521; race/ethnicity variables: P≥0.3566) at 1 year after acute tSCI, when adjusting for major potential confounders using multiple regression analysis.

Conclusion: The results of this study suggest that some racial/ethnical discrepancies regarding epidemiology of tSCI. Nevertheless, race/ethnicity did not influence survival or neurological recovery at 1 year after tSCI. Those results reinforce the notion that race/ethnicity is not a key determinant for clinical and neurological outcomes after tSCI. However, this does

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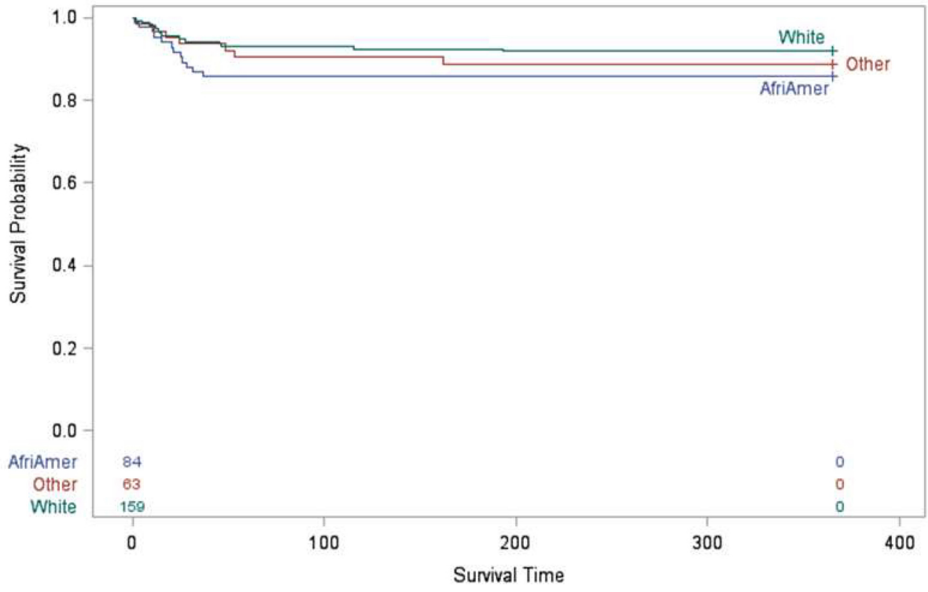
not undermine the fact that there may be significant racial/ethnical disparities with regard to healthcare access in the acute care setting and rehabilitation setting as highlighted by Moore et al in a recent scoping review on traumatic injuries including tSCI. Those important knowledge gaps urge further investigations to further promote health equity in the field of tSCI.

Figure 1. Survival analysis within the first year after acute traumatic spinal cord injury comparing African Americans ("AfriAm"), non-Hispanic whites ("white") and individuals of other races/ethnicities ("other"), using Kaplan-Meier analysis with log-rank test (*P*=0.3191).



POSTER 23

The Effect of Cage Dimensions on Subsidence Following Anterior Cervical Discectomy And Fusion

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Introduction: Anterior cervical discectomy and fusion (ACDF) is the standard treatment for symptomatic cervical myelopathy and radiculopathy. Cage subsidence is a common complication following ACDF which poses clinical complications including decrease in disc height, sagittal alignment disruption, solid fusion prevention, and stenosis of the foramina. Previous studies have analyzed factors that are correlated with subsidence in ACDF, however, cage dimensions and their relation to subsidence have not been thoroughly studied. This study aims to determine how the dimensions of the implanted cage are correlated with subsidence in ACDF.

Materials and Methods: We conducted a retrospective analysis of radiographs following elective ACDF performed from 2016-2021 at an urban, academic tertiary medical center. The radiographic measurements were obtained on lateral cervical radiographs at immediate postop (<6 weeks) and long-term postop (> 6 months). Posterior disc height (PDH), anterior disc height (ADH), cage length, cage height, cage length to vertebral body length ratio, and segmental lordosis were measured. Cage types including structural allograft, PEEK, titanium, ceramic, and zero-profile were also collected. Pearson correlation tests and multivariate logistic regression analyses were used to compare cage dimensions with subsidence and change in segmental lordosis. Each regression model controlled for the level of the fusion, the position of the level with respect to the fusion, cage type, age, sex, smoking history, and osteopenia/osteoporosis history.

Results: There were 131 patients and 244 levels fused in this study: 41 one-level, 67 two-level, and 23 three-level fusions. 68 patients received a structural allograft, 27 received a PEEK cage, 22 titanium, 11 ceramic, and 3 zero-profile. The median final follow-up time was 366 (IQR: 239-566) days. Cage length ($r = 0.238$; $p < 0.001$) and cage height ($r = 0.329$, $p < 0.001$) were positively correlated with anterior subsidence. Scatter plots demonstrating these relationships are shown in Figure 1. Cage length (beta = 0.22; 95% CI: [0.11, 0.33]; $p < 0.001$) and cage height (beta = 0.34; 95% CI: [0.20, 0.47]; $p < 0.001$) were all also significant predictors of anterior segmental subsidence as determined by multivariate analyses (Table 1). The cage-to-vertebral body ratio was not correlated with subsidence and no measured cage dimension had a significant effect on segmental lordosis.

Conclusion: Our results suggest that cage length and height may be associated with anterior subsidence. Increasing length alone, while it may increase the surface area of the cage, might not considerably reduce the stress concentrations between the cage and vertebral body, resulting in subsidence. The results from this study can better inform surgeons about cage selection to minimize subsidence following ACDF.

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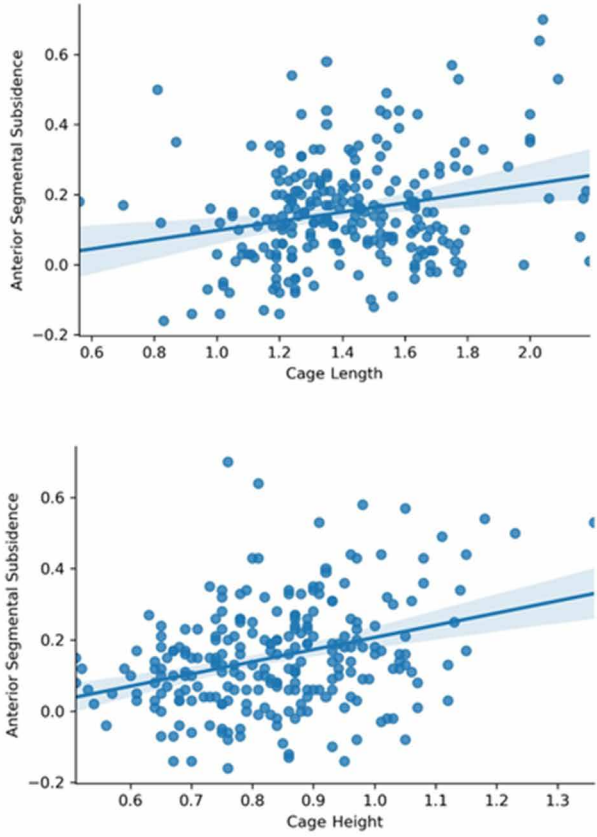

Figure 1: Scatter plots of cage length (top) and cage height (bottom) in relation to anterior segmental subsidence.

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Table 1: Multivariate linear regression results with cage length, cage height, and cage-to-body ratio as the predictors for anterior segmental subsidence, posterior segmental subsidence, and segmental lordosis change.

	Beta	95% CI	P-Value
Cage Length			
Anterior Segmental Subsidence	0.22	(0.11, 0.33)	**<0.001**
Posterior Segmental Subsidence	0.13	(0.04, 0.22)	**0.005**
Segmental Lordosis Change	-0.78	(-3.67, 2.10)	0.594
Cage Height			
Anterior Segmental Subsidence	0.34	(0.20, 0.47)	**<0.001**
Posterior Segmental Subsidence	0.19	(0.08, 0.30)	**<0.001**
Segmental Lordosis Change	-1.84	(-5.39, 1.71)	0.309
Cage-to-Body Ratio			
Anterior Segmental Subsidence	-0.14	(-0.34, 0.05)	0.144
Posterior Segmental Subsidence	-0.05	(-0.20, 0.11)	0.548
Segmental Lordosis Change	-1.13	(-5.94, 3.67)	0.643

POSTER 24

Forty-eight-month Clinical Outcomes of a Prospective, Controlled, Multicenter Study Evaluating Two-level Cervical Disc Arthroplasty with a PEEK-on-ceramic Artificial Disc

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Introduction: Adoption of cervical disc arthroplasty (CDA) continues to increase. These devices continue to evolve in form, function, and materials. We present the data from the most recently FDA approved device for two level CDA. The purpose of this study was to evaluate the safety and efficacy of a PEEK-on-ceramic artificial disc implant used in the treatment of 2-level cervical disc disease at 48 months post-operation.

Materials and Methods: Prospective, non-randomized, multicenter FDA Investigational Device Exemption (IDE) trial evaluating the Simplify® Cervical Artificial Disc (NuVasive, Inc).

Subjects undergoing CDA with 48-month data were included. All patients had 2-level, symptomatic cervical disc disease with radiculopathy and/or myelopathy.

We evaluated subjects clinically for 1) at least 15-point (of 100) improvement in Neck Disability Index (NDI) scores; 2) neurological status; 3) implant, procedure, or implant/procedure associated serious adverse events (SAEs); 4) additional index level surgery; 5) numeric rating scales assessing neck and arm pain intensity; and 6) patient satisfaction.

Subjects were evaluated preoperatively, at hospital discharge, 6 weeks, and 3, 6, 12, 24, 36, and 48 months after surgery. Forty-eight-month CDA data were compared to preoperative and 24-month CDA data to assess the durability of results over time. The non-concurrent ACDF control data were not included in the analysis as these data were only available to 24-months.

Results: 144 subjects (79.1%) were available and completed 48-month follow up. Successful NDI outcome ($\geq$15 points improvement) occurred in 92.9% of subjects at 24-month follow up and 94.4% at 48 months. Mean NDI scores improved from 58.6 pre-operatively to 14.3 at 24 months and 14.4 at 48 months. Neurological status was normal in 93.4% and 94.4% at 24 and 48 months compared to 16.1% pre-operatively. The rate of implant related SAEs through 48 months for all 182 was 2.2% of subjects. Procedure related SAEs occurred in 2.2%. SAEs attributed to both implant and procedure occurred in 2.2%. There were an additional two subsequent surgical interventions (SSIs) at 48 months (3.3%) compared to four (2.2%) at 24 months. Mean neck pain was 7.9 at preop, 1.8 at 24 months, and 1.8 at 48 months. Likewise, mean arm pain improved from a pre-operative mean value of 7.5 to 1.8 at 24 months and 1.5 at 48 months. All preoperative outcome measures in this analysis were significantly improved ($p<0.05$) at 24- and 48-month follow ups. There were no statistical differences ($p>0.05$) between 24- and 48-month follow up for any variable. At 48-months, 94% of subjects responded Definitely True (88%) or Mostly True (6%) to the statement "All things considered I would have the surgery again for the same condition." When asked about their perceived effect

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of surgical treatment, 94% replied they were "Completely Recovered" (56%) or "Much Improved" (38%).

Conclusion: Two level CDA resulted in significant improvements in outcomes at 24 months; these improvements were maintained at 48 months. Patients are overwhelmingly satisfied with their results. These data are consistent with published mid-term results from other 2-level CDA clinical trials and warrant continued follow up of this patient cohort.

POSTER 25

Impact of Prolonged Symptom Duration in Patients with Depressive Symptoms Undergoing Cervical Disc Replacement

Fatima Anwar, BA[1], Timothy Hartman,[1], James Nie, BS[1], Andrea Roca, MA[1], Keith MacGregor, BS[1], Omolabake Oyetayo, BS[1], Eileen Zheng, BS[1], ***Vincent Federico, MD[1],*** *Dustin Massel, MD[1], Arash Sayari, MD[1], Kern Singh, MD[1]*

Rush University Medical Center[1]

Introduction: Symptom duration (SD) prior to surgical intervention may influence outcomes in patients with spine pathology. Depressive symptoms have previously been demonstrated to affect patient perception of surgical outcomes. Our study aims to evaluate the potential impact of preoperative SD on outcomes following cervical disc replacement (CDR) for disc herniation in patients with depressive symptoms.

Materials and Methods: Patient data was retrospectively queried from a single-surgeon registry. Patients with a documented SD who had undergone CDR as indicated for symptomatic disc herniation with preoperative 9-item Patient Health Questionnaire (PHQ-9) scores ≥5 were included. Patients were divided into two cohorts: SD<180 days or SD≥180 days. Patient-reported Outcome Measures (PROMs) were compared preoperatively and at 6-week postoperative and final postoperative follow-up periods between cohorts. Magnitude of improvement in PROMs (ΔPROM) were compared within and between cohorts at 6-weeks (ΔPROM-6W) and final follow-up (ΔPROM-FF). PROMs evaluated included Patient-Reported Outcomes Measurement Information System-Physical Function (PROMIS-PF), Neck Disability Index (NDI), VAS-Neck (VAS-N), VAS-Arm (VAS-A), and PHQ-9. Achievement rates of Minimal Clinically Important Difference (MCID) in each PROM were compared between cohorts.

Results: Fifty patients were included. With the exception of PROMIS-PF at 6-weeks in the SD<180 days cohorts, both cohorts demonstrated significant improvement in all PROMs at 6-weeks and final postoperative periods compared to preoperative baseline (p≤0.019, all). 6-week NDI was superior in the SD<180 days cohort (p=0.039). There were no between group differences in preoperatively or final postoperative PROMs. There were no between group differences in ΔPROM-6W, ΔPROM-FF, or MCID achievement rates for any PROM.

Conclusion: Independent of preoperative SD, patients with depressive symptoms undergoing CDR demonstrated significant improvement in physical function, pain, and mental health following surgical intervention. Patients with a prolonged duration of symptoms demonstrated increased disability at 6-week follow-up. Preoperative SD did not impact outcome parameters of pain or mental health. Patients with depressive symptoms undergoing CDR with a prolonged preoperative duration of symptoms may report increased short-term disability following intervention. These findings may guide both surgeons and patients regarding postoperative expectations.

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Table 1. Patient Demographics

Characteristic	Total (n=50)	SD<180 days (n=20)	SD≥180 days (n=30)	*p-value
Age (mean±SD, years)	44.4±8.9	43.2±8.4	45.1±9.2	0.481
Female Gender	50.0% (25)	60.0% (12)	43.3% (13)	0.248
BMI (mean ± SD, kg/m^2)	28.6±4.9	27.6±6.0	29.3±3.8	0.249
Ethnicity				0.661
Asian	2.0% (1)	5.0% (1)	0.0% (0)	
Black	6.1% (3)	5.0% (1)	6.9% (2)	
Hispanic	6.1% (3)	5.0% (1)	6.9% (2)	
White	85.7% (42)	85.0% (17)	86.2% (25)	
Comorbidities				
Smoker	10.0% (5)	5.0% (1)	13.3% (4)	0.336
Hypertension	18.0% (9)	15.0% (3)	20.0% (6)	0.652
Diabetes	4.0% (2)	0.0% (0)	6.7% (2)	0.239
ASA Score (mean ± SD)	1.9±0.6	1.8±0.6	1.9±0.6	0.435
CCI Score (mean ± SD)	0.7±1.0	0.4±0.8	0.9±1.0	0.056
Insurance Type				0.270
Medicare/Medicaid	4.0% (2)	0.0% (0)	6.7% (2)	
Workers' Comp	22.0% (11)	15.0% (3)	26.7% (8)	
Private	74.0% (37)	85.0% (17)	66.7% (20)	

BMI = Body Mass Index; ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD = Standard Deviations; Workers' Comp = workers' compensation
*p-value calculated using Chi-square analysis for categorical variables or Student's t-test for continuous variables
Boldface indicates significance

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Table 2. Perioperative Characteristics

Characteristic	Total (n=50)	SD<180 days (n=20)	SD≥180 days (n=30)	*p-value
Spinal Pathology				
Herniated Disc(s)	100.0% (50)	100.0% (20)	100.0% (30)	1.000
Central Stenosis	58.0% (29)	45.0% (9)	66.7% (20)	0.128
Foraminal Stenosis	26.0% (13)	20.0% (4)	30.0% (9)	0.430
No. Consecutively Operated Levels				0.797
One	72.0% (36)	70.0% (14)	73.3% (22)	
Two	28.0% (14)	30.0% (6)	26.7% (8)	
Operative Time (min)				
Mean±SD	50.8±11.2	49.2±11.7	51.8±11.0	0.445
Estimated Blood Loss (mL)				
Mean±SD	27.6±7.8	26.7±6.5	28.3±8.6	0.544
Postoperative Length of Stay (hours)				
Mean±SD	8.7±7.3	7.4±5.3	9.4±8.2	0.402
POD 0 VAS Pain	5.1±2.2	4.8±2.3	5.2±2.2	0.623
POD 0 Narcotic Consumption (OME)	21.9±19.1	17.1±17.2	25.0±20.0	0.156

POD = postoperative day of discharge; No.= Number of; SD = standard deviation; VAS = Visual analog scale; OME = oral morphine equivalents
*p-value calculated using Chi-square analysis for categorical variables or Student's t-test for continuous variables
Boldface indicates significance

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Table 3. Patient-reported outcomes measures and minimum clinically important difference

	SD<180 days	†p-value	SD≥180 days	†p-value	*p-value
Pre-Op					
PROMIS-PF	38.3±7.8		36.3±5.7		0.339
NDI	46.2±17.8		52.2±17.0		0.246
VAS-N	6.7±2.3		7.1±1.9		0.485
VAS-A	7.0±2.3		6.6±2.4		0.525
PHQ-9	9.4±4.8		10.3±5.0		0.514
6-week Post-Op					
PROMIS-PF	44.0±8.6	0.081	40.9±7.3	**0.019**	0.317
NDI	23.9±18.8	**<0.001**	40.1±23.0	**0.006**	**0.039**
VAS-N	2.9±2.9	**<0.001**	4.6±3.0	**0.002**	0.112
VAS-A	2.5±3.0	**<0.001**	3.4±3.2	**0.003**	0.404
PHQ-9	4.7±5.2	**0.001**	7.2±6.6	**0.012**	0.250
Final Post-Op					
PROMIS-PF	46.6±9.5	**<0.001**	43.4±8.5	**<0.001**	0.250
NDI	21.9±16.7	**<0.001**	29.5±21.3	**<0.001**	0.195
VAS-N	3.1±2.6	**<0.001**	3.5±2.8	**<0.001**	0.636
VAS-A	2.9±2.5	**<0.001**	3.3±3.3	**0.001**	0.677
PHQ-9	4.9±4.4	**<0.001**	7.3±6.2	**0.007**	0.161
Δ Pre-Op to 6-week Post-Op					
PROMIS-PF	4.8±7.2		4.0±6.6		0.776
NDI	20.5±15.9		12.0±16.7		0.151
VAS-N	4.0±3.5		2.5±3.1		0.218
VAS-A	4.6±3.5		3.2±4.1		0.302
PHQ-9	5.2±4.6		3.5±5.9		0.359
Δ Pre-Op to Final Post-Op					
PROMIS-PF	9.0±7.5		7.4±7.8		0.526
NDI	24.3±22.0		21.1±17.0		0.588
VAS-N	3.6±3.3		3.4±3.0		0.809
VAS-A	4.1±2.9		3.0±4.1		0.338
PHQ-9	4.5±4.1		3.3±5.9		0.436
MCID Achievement					
PROMIS-PF	86.7%		65.2%		0.142
NDI	85.0%		80.0%		0.663
VAS-N	65.0%		68.0%		0.832
VAS-A	50.0%		50.0%		1.000
PHQ-9	10.5%		21.4%		0.329

*p-value calculated using independent samples t-tests for patient-reported outcome measures and chi-square tests for MCID achievement rates
†p-value calculated using paired samples t-tests assessing 6-week PROMs and Final PROMs to Preoperative PROMs
Bolding denotes statistical significance (p<0.05)

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

POSTER 26

Influence of Preoperative Anxiety on Postoperative Clinical Trajectory in Patients Undergoing Cervical Disc Replacement

Fatima Anwar, BA[1], *Timothy Hartman,[1], James Nie, BS[1], Andrea Roca, MA[1], Keith MacGregor, BS[1], Omolabake Oyetayo, BS[1], Eileen Zheng, BS[1], Vincent Federico, MD[1], Dustin Massel, MD[1], Arash Sayari, MD[1], Kern Singh, MD[1]*
Rush University Medical Center[1]

Introduction: No study has established the effect of preoperative anxiety on postoperative outcomes in patients undergoing cervical disc replacement (CDR). We aim to evaluate the impact of preoperative anxiety, measured through the Patient-Reported Outcomes Measurement Information System (PROMIS) Anxiety (PROMIS-A), on patients undergoing CDR.

Materials and Methods: Patients undergoing CDR with preoperative PROMIS-A were stratified into two cohorts: PROMIS-A<55 (lesser anxiety) and PROMIS-A≥55 (greater anxiety). Patient demographics, perioperative characteristics, and patient-reported outcomes (PROs) were collected. PROs of PROMIS Physical Function (PROMIS-PF), PROMIS-A, PROMIS Pain Interference (PROMIS-PI), PROMIS Sleep Disturbance (PROMIS-SD), Patient Health Questionnaire-9 (PHQ-9), Visual Analog Scale (VAS) neck, VAS arm, and Neck Disability Index (NDI) were collected at preoperative and postoperative time points. MCID achievement was calculated through comparison of ΔPROM to previous literature and through effect size. Cohorts were compared using non-parametric inferential statistics.

Results: Forty-six total patients were identified. The lesser anxiety cohort demonstrated significant postoperative improvement in 6- and 12-week PROMIS-PF, 12-week and 6-month PROMIS-A, 6-month PROMIS-PI, 6-week through 6-month PROMIS-SD, 12-week and 6-month VAS neck, 6- and 12-week VAS arm, and 6-week through 6-month NDI ($p \leq 0.043$, all). The greater anxiety cohort demonstrated significant postoperative improvement in 12-week and 6-month PROMIS-PF, 6- and 12-week PROMIS-A, 12-week and 6-month PROMIS-PI, 6- and 12-week PROMIS-SD, all VAS neck, 6- and 12-week VAS arm, and all NDI ($p \leq 0.043$, all). The lesser anxiety cohort demonstrated superior preoperative scores in PROMIS-PF, PHQ-9, and NDI. The lesser anxiety cohort demonstrated superior postoperative 12-week PROMIS-PF, 6- and 12-week PROMIS-A, 12-week PROMIS-PI, 6- and 12-week PROMIS-SD, 6- and 12-week PHQ-9, and 6- and 12-week NDI ($p \leq 0.048$, all). MCID achievement rates were higher and lower in the greater anxiety cohort for 6-week PROMIS-A and overall PROMIS-SD, respectively ($p \leq 0.040$, both).

Conclusion: Patients undergoing CDR demonstrated significant postoperative improvement in physical function, anxiety, pain interference, sleep disturbance, pain, and disability outcomes regardless of preoperative anxiety. Patients with lesser baseline anxiety demonstrated superior postoperative outcomes in physical function, anxiety, pain interference, sleep disturbance, mental function, and disability outcomes. The greater anxiety cohort had higher MCID achievement rates for anxiety and lower rates for sleep disturbance. Patients with greater preoperative anxiety undergoing CDR may experience worse clinical outcomes.

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Table 1. Patient Demographics

Characteristic	Total (n=46)	PROMIS-A<55 (n=23)	PROMIS-A≥55 (n=23)	*p-value
Age (mean ± SD, years)	47.4±10.6	49.0±10.1	45.7±11.0	0.307
Gender				0.221
Female	37.0% (17)	26.1% (6)	47.8% (11)	
Male	63.0% (29)	73.9% (17)	52.2% (12)	
Ethnicity				0.609
White	84.1% (37)	78.3% (18)	90.5% (19)	
Black	2.3% (1)	4.4% (1)	0.0% (0)	
Hispanic	6.8% (3)	4.4% (4)	9.5% (2)	
Asian	4.6% (2)	8.7% (2)	0.0% (0)	
Other	2.3% (1)	4.4% (1)	0.0% (0)	
BMI (mean ± SD, kg/m^2)	28.9±5.3	28.5±6.0	29.3±4.7	0.400
Comorbidities				
Smoker	15.2% (7)	17.4% (4)	13.0% (3)	1.000
Hypertension	10.9% (5)	13.0% (3)	8.7% (2)	1.000
Diabetes	2.2% (1)	0.0% (0)	4.4% (1)	1.000
ASA Classification				0.187
<2	13.3% (6)	21.7% (5)	4.6% (1)	
≥2	86.7% (39)	78.3% (18)	95.5% (21)	
CCI Score (Mean ± SD)	1.1±1.0	1.1±0.9	1.1±1.1	0.991
Insurance Type				0.786
Medicare/Medicaid	6.5% (3)	4.4% (1)	8.7% (2)	
Workers' Comp	19.6% (9)	17.4% (4)	21.7% (5)	
Private	73.9% (34)	78.3% (18)	69.6% (16)	

BMI = body mass index; CCI = Charlson Comorbidity Index; ASA = American Society of Anesthesiologists; SD= standard deviation; Workers' Comp = workers' compensation

*p-values calculated using Wilcoxon ranked sum test for continuous variables and Fisher exact test for categorical variables

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Table 2. Perioperative Characteristics

Characteristic	Total (n=46)	PROMIS-A<55 (n=23)	PROMIS-A≥55 (n=23)	*p-value
Spinal Pathology				
Herniated Nucleus Pulposus	100.0% (46)	100.0% (23)	100.0% (23)	-
Degenerative Disc Disease	6.5% (3)	8.7% (2)	4.4% (1)	1.000
Central Stenosis	50.0% (23)	60.9% (14)	39.1% (9)	0.238
Foraminal Stenosis	45.7% (21)	34.8% (8)	56.5% (13)	0.236
Number of levels				0.744
One	70.7% (29)	73.7% (14)	68.2% (15)	
Two	29.3% (12)	26.3% (5)	31.8% (7)	
Operative Time (Mean ± SD; min)	48.7±11.7	49.3±9.9	48.0±13.5	0.474
Estimated Blood Loss (Mean ± SD; mL)	26.1±5.2	26.1±5.2	26.1±5.3	0.975
Length of Stay (Mean ± SD; hours)	8.0±5.7	6.3±0.6	9.8±7.8	0.134
Postoperative Vas pain POD 0	5.0±2.7	4.4±2.8	5.7±2.5	0.112
Postoperative Narcotic Consumption (OME) POD 0	21.5±18.8	20.4±16.2	22.6±21.5	0.569

POD = postoperative day; mL = milliliters; SD = standard deviation; OME = oral morphine equivalents
*p-values calculated using Wilcoxon ranked sum for continuous variables and Fisher exact test for categorical variables

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Table 3. Mean Patient Reported Outcomes

PROM	PROMIS-A<55 Mean ± SD	*p-value	PROMIS-A≥55 Mean ± SD	*p-value	†p-value
PROMIS-PF					
Preoperative	44.6±8.4	-	36.3±7.1	-	**0.002**
6-week	49.8±6.1	0.051	42.6±10.7	0.068	0.052
12-week	55.7±9.2	**0.003**	44.4±9.6	**0.002**	**0.007**
6-month	55.4±12.0	**0.028**	53.0±13.2	**0.043**	0.775
1-year	54.8±7.5	**0.028**	48.5±11.6	0.144	0.262
PROMIS-A					
Preoperative	45.3±7.0	-	63.9±7.4	-	**<0.001**
6-week	40.9±9.4	0.082	54.7±11.3	**0.002**	**0.006**
12-week	40.9±6.6	**0.037**	54.4±12.4	**0.022**	**0.014**
6-month	41.1±8.8	**0.043**	55.9±14.6	0.237	0.071
1-year	44.0±8.1	0.188	56.1±13.2	0.156	0.077
PROMIS-PI					
Preoperative	58.5±10.5	-	63.1±10.5	-	0.134
6-week	54.1±7.9	0.151	58.1±11.9	0.209	0.226
12-week	46.0±6.7	0.110	57.7±12.0	**0.021**	**0.005**
6-month	45.2±8.2	**0.018**	50.7±13.0	**0.028**	0.601
1-year	51.8±9.6	0.068	54.4±11.1	0.109	0.381
PROMIS-SD					
Preoperative	59.4±10.4	-	62.6±8.3	-	0.643
6-week	39.0±9.7	**0.011**	57.1±13.3	**0.036**	**0.002**
12-week	41.0±12.3	**0.012**	57.6±13.9	**0.035**	**0.014**
6-month	45.8±10.9	**0.043**	52.9±13.4	0.109	0.098
1-year	46.0±6.3	0.109	52.3±13.6	0.180	0.281
PHQ-9					
Preoperative	3.4±4.3	-	9.5±6.8	-	**0.001**
6-week	1.6±2.5	0.962	6.6±6.3	0.254	**0.017**
12-week	0.5±0.8	0.250	5.5±6.8	0.057	**0.011**
6-month	1.3±1.5	0.723	5.2±5.2	0.174	0.233
1-year	0.3±0.5	0.092	4.8±5.5	0.465	0.072
VAS neck					
Preoperative	6.1±2.6	-	6.8±2.3	-	0.254
6-week	2.3±1.4	0.068	4.1±3.3	**0.008**	0.142
12-week	1.5±2.4	**0.008**	2.6±2.9	**0.003**	0.144
6-month	1.1±1.4	**0.017**	1.6±2.6	**0.028**	0.758
1-year	1.0±0.8	0.068	3.3±3.2	**0.028**	0.327
VAS arm					
Preoperative	4.9±2.6	-	5.7±2.7	-	0.396
6-week	1.7±2.4	**0.023**	3.1±3.2	**0.009**	0.236
12-week	0.6±1.5	**0.019**	2.0±3.3	**0.009**	0.305
6-month	2.2±2.7	0.276	0.0±0.0	0.317	0.200
1-year	0.3±0.5	0.095	2.5±3.3	0.144	0.321
NDI					
Preoperative	32.6±14.5	-	51.6±17.6	-	**0.002**
6-week	16.5±7.2	**0.041**	37.3±26.6	**0.005**	**0.048**
12-week	6.7±7.6	**0.003**	24.8±22.9	**0.003**	**0.015**
6-month	13.0±9.4	**0.012**	18.6±18.5	**0.035**	0.815
1-year	4.0±4.3	0.068	29.3±25.3	**0.027**	0.069

*p-values calculated using paired sample t-test to determine preoperative to postoperative improvement
†p-values calculated using Student's t-test to compare mean PROMs between both cohorts
Boldface indicates significance

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

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Table 4. Patient-reported outcomes measures

PROM	PROMIS-A<55 %, (n)	PROMIS-A≥55 %, (n)	*p-value
PROMIS-PF			
6-week	65.6% (6)	50.0% (7)	1.000
12-week	72.7% (8)	75.0% (9)	1.000
6-month	71.4% (5)	100.0% (5)	0.470
1-year	100.0% (6)	75.0% (3)	0.400
Overall	82.4% (14)	72.2% (13)	0.691
PROMIS-A			
6-week	36.4% (4)	81.3% (13)	**0.040**
12-week	63.6% (7)	70.0% (7)	1.000
6-month	71.4% (5)	57.1% (4)	1.000
1-year	50.0% (3)	66.7% (4)	1.000
Overall	70.6% (12)	85.0% (17)	0.428
PROMIS-PI			
6-week	50.0% (5)	53.3% (8)	1.000
12-week	63.6% (7)	77.8% (7)	0.642
6-month	71.4% (5)	85.7% (6)	1.000
1-year	75.0% (3)	100.0% (3)	1.000
Overall	66.7% (12)	68.4% (13)	1.000
PROMIS-SD			
6-week	88.9% (8)	53.9% (7)	0.165
12-week	87.5% (7)	83.3% (5)	1.000
6-month	60.0% (3)	66.7% (2)	1.000
1-year	100.0% (3)	100.0% (2)	-
Overall	100.0% (14)	64.7% (11)	**0.021**
PHQ-9			
6-week	18.2% (2)	43.8% (7)	0.231
12-week	27.3% (3)	60.0% (6)	0.198
6-month	37.5% (3)	60.0% (3)	0.592
1-year	25.0% (1)	75.0% (3)	0.486
Overall	31.3% (5)	63.2% (12)	0.092
VAS neck			
6-week	54.6% (6)	56.3% (9)	1.000
12-week	66.7% (8)	83.3% (10)	0.640
6-month	75.0% (6)	83.3% (5)	1.000
1-year	100.0% (4)	66.7% (4)	0.467
Overall	76.5% (13)	73.7% (14)	1.000
VAS arm			
6-week	27.3% (3)	26.7% (4)	1.000
12-week	50.0% (5)	33.3% (3)	0.650
6-month	20.0% (1)	100.0% (1)	0.333
1-year	25.0% (1)	50.0% (2)	1.000
Overall	43.8% (7)	37.5% (6)	1.000
NDI			
6-week	36.4% (4)	68.8% (11)	0.130
12-week	81.8% (9)	91.7% (11)	0.590
6-month	50.0% (4)	83.3% (5)	0.301
1-year	100.0% (4)	83.3% (5)	1.000
Overall	81.3% (13)	89.5% (17)	0.642

*p-values calculated using Fisher exact test
Boldface indicates significance.

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.

POSTER 27

Comparison of Complication Frequency After Anterior Cervical Spine Surgery - CSM vs OPLL

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Introduction: The anterior cervical spine surgery causes local complications as well as systemic complications such as upper airway complications, dysphagia, and pneumonia. Surgeries for ossification of the posterior longitudinal ligament of the cervical spine (OPLL) is generally challenging compared to cervical spondylotic myelopathy (CSM). However, there have been few reports comparing the two diseases, especially in the anterior procedure. Therefore, we conducted this large-scale cohort study comparing perioperative complications in anterior cervical surgery for OPLL and CSM performed at three spine centers in the past 10 years.

Materials and Methods: Of the 1434 patients who underwent anterior cervical spine surgery at 3 spine centers in the same spine research group from January 2011 to March 2021, 333 patients with OPLL (mean age: 60.5 years, 254 males (76.3%) / 79 females (23.7%), BMI: 26.3) and 488 patients with CSM (mean age: 63.7 years, 321 males (65.8%) / 167 females (34.2%), BMI: 23.8) were retrospectively complications examined for patient background, surgical procedure, JOA score (cases followed for more than 1 year), complications during hospitalization and complications after discharge. The outcomes were statistically compared between OPLL and CSM.

Results: The rate of diabetic comorbidity was significantly higher in the OPLL group ($p<0.001$). In the OPLL group, there were 36 anterior cervical decompression and fusion (ACDF) (10.8%), 244 anterior cervical corpectomy retrospectively and fusion (ACCF) (73.3%), and 53 hybrid with ACDF and ACCF surgeries(15.9%), while in the CSM group, there were 387 ACDF (79.3%), 71 ACCF(14.5%corpectomies, and 19 hybrid ACDF/ACCF surgeries (3.9%), 10 total disc replacement (TDR) (2.0%). There were significantly more ACCF in the OPLL group and more ACDF in the CSM group ($p<0.001$). Intraoperative dural tear was significantly more common in the OPLL group: 74 (22.2%) in the OPLL group and 7 (1.4%) in the CSM group ($p<0.001$). Regarding the perioperative complications during hospitalization, reoperation ($p<0.001$), cerebrospinal fluid (CSF) leak ($p<0.001$), C5(6,7,8) palsy ($p<0.001$), graft dislocation ($p=0.020$), hoarseness ($p<0.001$), and upper airway compromise ($p<0.001$) were more common in the OPLL group. Dislocation of graft bone and cage ($p=0.031$) and hoarseness were more common in the OPLL group among complications after discharge. The JOA score recovery rate at 1 year postoperatively was similar in the OPLL and CSM groups.

Conclusion: The present study demonstrated that the OPLL group had significantly more perioperative complications such as reoperation during hospitalization, CSF leak, C5(6,7,8) palsy, hoarseness, and Dislocation of graft bone and cage than the CSM group in the anterior approach. Complications after discharge were also more common in the OPLL group, including hoarseness and dislocation of graft bone and cage. Extensive care should be taken when performing anterior surgery for OPLL because of the high frequency of complications.

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Table 1. Comparison of OPLL and CSM *:p<0.05

	OPLL n=333	CSM n=488	*P* value
Patient's background factors			
Age, mean(SD),years	60.5 (±10.7)	63.7 (±11.8)	< .001*
Sex (Male / Female, Male%)	254 / 79 (76.3%)	321/167(65.8%)	.001*
BMI, mean(SD),kg/m²	26.3 (±4.8)	23.8 (±3.7)	< .001*
Smoking, n(%)	169(50.8%)	236(48.4%)	.501
Preoperative comorbidities			
Diabetes mellitus, n(%)	105(31.5%)	90 (18.4%)	< .001*
Cardiovascular disease, n(%)	47(14.1%)	83(17.0%)	.265
Chronic obstructive pulmonary disease, n(%)	25(7.5%)	38(7.8%)	.883
Cerebrovascular disease, n(%)	15(4.5%)	18(3.7%)	.559
Malignancy, n(%)	29(8.7%)	25(5.1%)	.042*
Rheumatoid arthritis, n(%)	2(0.6%)	7(1.4%)	.324
Steroid history, n(%)	2(0.6%)	7(1.4%)	.324
Parkinson disease, n(%)	1(0.3%)	2(0.4%)	1.000
Past history of cervical spine surgery, n(%)	23(6.9%)	38(7.8%)	.637
Surgery			
ACDF, n(%)	36(10.8%)	387(79.3%)	
ACCF, n(%)	244(73.3%)	71(14.5%)	
Hybrid, n(%)	53(15.9%)	19(3.9%)	< .001*
TDR, n(%)	0(0%)	10(2.0%)	
Others, n(%)	0(0%)	1(0.2%)	
Years of Primary surgeon, mean(SD), years	22.1(±9.1)	18.5(±8.1)	< .001*
Number of operative segments, mean(SD), levels	3.2(±1.0)	1.9(±1.1)	< .001*
Upper vertebra of operative segments, mean(SD), level	3.3(±1.0)	4.0(±0.9)	< .001*
ACCF or Hybrid, n(%)	297(89.2%)	90(18.4%)	< .001*
Combined with posterior fixation, n(%)	10(3.0%)	7(1.4%)	.121
Operation time, mean(SD), min	321.6 (±117.9)	166.6 (±65.9)	< .001*
Blood loss, mean(SD), ml	343.3(5±85.7)	63.7 (±120.5)	< .001*
Return to room with intubation, n(%)	19(5.7%)	1(0.2%)	< .001*
Dural injury, n(%)	74(22.2%)	7(1.4%)	< .001*
Complications during hospitalization			
Reoperation, n(%)	34(10.2%)	14(2.9%)	< .001*
Cerebrospinal fluid leakage, n(%)	71(21.3%)	2(0.4%)	< .001*
C5(6,7,8) paralysis, n(%)	46(13.8%)	30(6.1%)	< .001*
Epidural hematoma, n(%)	14(4.2%)	6(1.2%)	.007*
Dislocation of graft bone・cage, n(%)	11(3.3%)	5(1.0%)	.020*
Instrument failure, n(%)	8(2.4%)	5(1.0%)	.120
Infection, n(%)	5(1.5%)	5(1.0%)	.537
Hoarseness, n(%)	14(4.2%)	3(0.6%)	< .001*
Dysphagia, n(%)	52(15.6%)	55(11.3%)	.069
Mortality, n(%)	1(0.3%)	1(0.2%)	1.000
Upper airway complication, n(%)	36(10.8%)	22(4.5%)	< .001*
Reintubation, n(%)	8(2.4%)	4(0.8%)	0.06
Deep vein thrombosis, n(%)	2(0.6%)	0(0%)	.164
Pulmonary embolism, n(%)	0 (0%)	0 (0%)	-
Pnuemonia, n(%)	12(3.6%)	9(1.8%)	.117
Urinary tract infection	11(3.3%)	8(1.6%)	.119
Cerebral infarction, n(%)	1(0.3%)	0(0%)	.406
Myocaridal infarction, n(%)	0 (0%)	0 (0%)	-
Postoperative steroid use, n(%)	40(51.3%)	739(54.5%)	.579
JOA score			
Pre JOA, mean(SD), score	10.6 (±2.8)	11.0 (±2.9)	.123
Post JOA, mean(SD), score	13.5 (±2.8)	13.6 (±2.6)	.740
Recovery rate, mean(SD), %	45.9 (±34.9)	44.2 (±33.0)	.491
Complications after discharge			
Reoperation, n(%)	7(2.1%)	21(4.3%)	.088
Dislocation of graft bone・cage, n(%)	28(8.4%)	23(4.7%)	.031*
Instrument failure, n(%)	15(4.5%)	22(4.5%)	.998
Hoarseness, n(%)	5(1.5%)	1(0.2%)	.043*
Dysphagia, n(%)	20(6.0%)	24(4.9%)	.497

POSTER 28

Imaging Features and Treatment of Ossification of the Posterior Longitudinal Ligament in the Upper Cervical Spine

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Introduction: Ossification of the posterior longitudinal ligament of the cervical spine (OPLL) occurs most often in the middle cervical spine, but cases of OPLL extending to the upper cervical spine are not uncommon. However, there are few studies focusing on the radiological characteristics and clinical results of OPLL in the upper cervical spine. In this study, we describe radiological findings, surgical methods, and clinical outcomes of upper cervical OPLL cases who were surgically treated in our hospital.

Materials and Methods: We investigated the patient background, ossification classification, occupancy rate, cervical OP-index (number of ossifications between each vertebral body vertebra), surgical technique, and JOA score recovery rate (cases observed for more than 1 year) in 100 cases (mean age 64.3 years, 68 males and 32 females) operated for cervical OPLL between May 2016 and May 2022 in our hospital. The patients with C2 or proximal OPLL (C2+ group) and those without C2 or proximal OPLL (C2- group) were compared.

Results: The mean canal narrowing ratio was 50.6%, the mean cervical OP-index was 6.8, and 43 patients were in the C2+ group. Mean age, gender, BMI, and smoking history were not significantly different between the C2+ and C2- groups. Diabetes comorbidity tended to be higher in the C2+ group ($p=0.09$), and ossification classification was more mixed pattern in the C2+ group ($p=0.004$). Mean canal narrowing ratio was 57.3% in the C2+ group, 45.6% in the C2- group, and mean cervical OP-index was 9.7 in the C2+ group and 4.6 in the C2- group, which was significantly greater in the C2+ group ($p<0.01$). The C2+ group tended to be more proximal than the C2- group in terms of maximum thickness of ossification. The C2+ group (26% anterior, 63% posterior (19% decompression, 44% decompression and fixation), 11% anterior and posterior) performed more posterior approach than the C2- group (51% anterior, 47% posterior (17% decompression, 30% decompression and fixation), 2% anterior-posterior). Even in the anterior cases, anterior-posterior surgery was more common in the C2+ group. The JOA score recovery rate at 1 year postoperatively was similar in the C2+ group (48.5%) and the C2- group (49.3%).

Conclusion: Upper cervical OPLL cases were generally severe ossification cases: often mixed-type, with a wide range of ossification (high cervical OP-index) and a high canal narrowing ratio. It has been reported that patients with a high cervical OP-index also have a high total OP-index in the whole spine, so attention should also be paid to the thoracic and lumbar spine when OPLL is present in the upper cervical spine. Due to the anatomical characteristics of the upper cervical spine, posterior surgery, especially posterior decompression and fusion, was often performed, but some patients underwent A-P combined surgery: posterior surgery up to the upper cervical spine followed by a two-stage selective anterior decompression and fusion. By devising a surgical technique, the results were as good as those for treatment of OPLL in the middle and lower cervical spine.

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Table1. Comparison of C2+ and C2- *:p<0.05

	C2+	C2-	All	P value
Number of patients	43	57	100	
Age, average(yr)	64	64.5	64.3	0.818
Sex				
Male	26	42	68	0.16
Female	17	15	32	
BMI	27.4	25.6	26.4	0.094
Number of smokers	19(44%)	28(49%)	47(47%)	0.62
Comorbidity				
HT	26(60%)	29(51%)	55(55%)	0.29
DM	24(55%)	22(39%)	46(46%)	0.087
Hyperuricemia	7(16%)	6(11%)	13(13%)	0.26
Occupancy rate(%)	57.3	45.6	50.6	<0.01*
Cervical Op-index, average	9.7	4.6	6.8	<0.01*
Ossification classification(%)				
Continuous	10(23)	14(25)	24(24)	0.004*
Segmental	0(0)	11(19)	11(11)	
Mixed	33(77)	29(51)	62(62)	
Localized	0(0)	3(5)	3(3)	
Surgical technique				
ACDF	0	2(4%)	2(2%)	-
ACCF	7(16%)	16(28%)	23(23%)	-
Hybrid	4(9%)	11(19%)	15(15%)	-
Posterior decompression	8(19%)	10(18%)	18(18%)	-
Posterior decompression and fusion	19(44%)	17(30%)	36(36%)	-
A-P combined, one stage （P→A）	1(2%)	0	1(1%)	-
A-P combined, two stage （A→P）	1(2%)	0	1(1%)	-
A-P combined, two stage （P→A）	3(7%)	1(2%)	4(4%)	-

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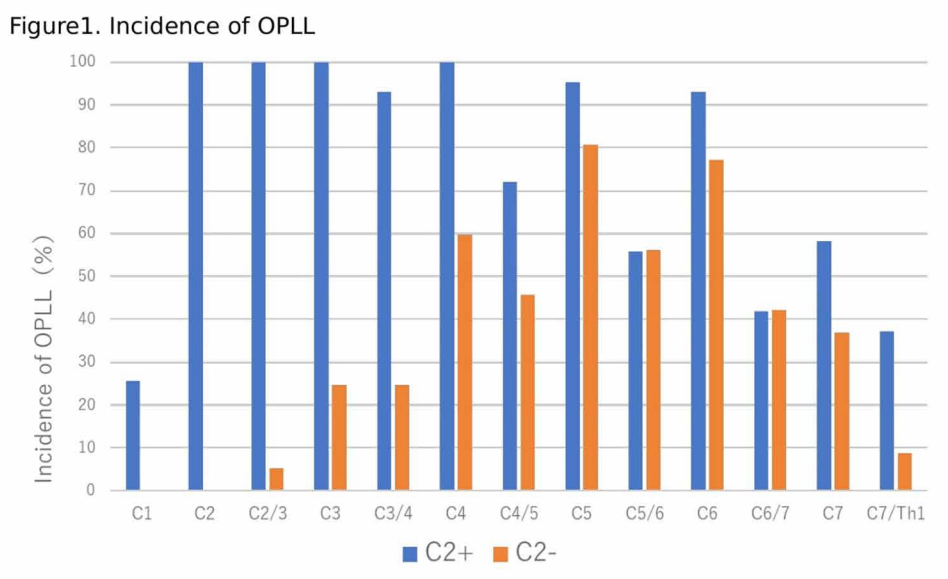

POSTER 29

Comparing Risk Factors for Extended Hospital Stay After Elective Anterior Cervical Discectomy and Fusion Between NSQIP and a Single Institutional Database Using a Propensity Score-matched Analysis

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Introduction: Extended length of stay (LOS) following anterior cervical discectomy and fusion (ACDF) contributes to high medical costs and predicts suboptimal clinical outcomes. The National Surgical Quality Improvement Program (NSQIP) provides detailed, patient-level data regarding surgical risks. However, the generalizability of national database studies at the institutional level is unclear. Thus, we aim to compare significant risk factors associated with prolonged hospitalization between matched NSQIP and institutional cohorts after elective ACDF. The results may help inform the accuracy of NSQIP in guiding quality improvement at the institutional level.

Materials and Methods: This was a retrospective cohort comparison study performed with the 2011-2018 NSQIP database and a 2008-2019 database obtained from an urban, academic tertiary medical center. All patients undergoing ACDF aged <18 years were identified from NSQIP and institutional databases using the CPT codes 22551, 22552, and 22554. Patients were matched on the basis of age, sex, BMI, race, and comorbidities and then matched 1:1 using a logistic regression model. Baseline demographics, comorbidities, and perioperative variables were identified. Normal and prolonged LOS groups from the matched NSQIP and institutional cohorts were compared using univariate and multivariate logistic regression models, where a prolonged LOS was defined as >2 days and normal LOS was <=2 days.

Results: 1353 NSQIP patients were matched to 1353 institutional patients, then stratified into normal and prolonged LOS groups. In the NSQIP cohort, normal and prolonged LOS patients had an average LOS of 1.05 and 5.17 days respectively. In the institutional cohort, normal and prolonged stay patients had an average LOS of 1.19 and 3.91 respectively. Based on the univariate analysis, prolonged stay patients were older (Institution: p<0.001; NSQIP: p<0.001) with higher ASA scores (Institution: p<0.001; NSQIP: p<0.001) (Tables 1 & 2). Multivariate logistic regression revealed significant but different risk factors for prolonged LOS between the two databases. For the NSQIP cohort, anemia (OR=11.86; 95% CI 1.76-80.1; p=0.01), age (OR=1.03; 95% CI 1.01-1.05; p=0.01), length of surgery (OR=1.01; 95% CI 1.01-1.01; p<0.001), and female sex (OR=1.61, 95% CI 1.09-2.36; p=0.02) were significantly associated with extended stay. White race was significantly associated with reduced odds of extended stay (OR=0.48; 95% CI 0.33-0.70; p<0.001) (Table 3). For the single institutional cohort, significant predictors of extended stay included age (OR=1.03; 95% CI 1.01-1.06; p=0.001), ASA score over 2 (OR=2.13, 95% CI 1.34-3.40; p=0.001), length of surgery (OR=1.01; 95% CI 1.00-1.01, p<0.001), diabetes (OR=1.88, 95% CI 1.10-3.20; p=0.02), and female sex (OR=1.89; 95% CI 1.25-2.88; p=0.002) (Table 3).

Conclusion: After matching, significant risk factors for prolonged LOS following ACDF differed between NSQIP and institutional cohorts. While NSQIP is a powerful database that can illustrate national trends, it may lack the granularity needed to guide decision-making at the institutional level. Findings from national data should be interpreted in light of institutional data when

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making changes to care delivery.

Table 1. Baseline comparison and univariate analysis of normal and prolonged length of stay (LOS) patients for a single institution cohort. The single institutional cohort included 1353 patients undergoing elective ACDF. Length of stay was measured in days and length of surgery was measured in minutes. Abbreviations: Length of Stay (LOS); Anterior Cervical Discectomy and Fusion (ACDF); Congestive Heart Failure (CHF).

	Normal LOS	Prolonged LOS	p-value
Single Institution			
Mean Age (SD)	51.81 (0.32)	57.44 (1.12)	**<0.001**
BMI (SD)	28.42 (0.17)	29.73 (0.65)	**0.027**
Female (%)	5851 (46.7)	64 (58.7)	**0.02**
ASA Status > 2 (%)	303 (24.4)	56 (51.4)	**<0.001**
Race/Ethnicity (n, %)			**0.001**
White	827 (66.5)	67 (61.5)	
Black	111 (8.9)	22 (20.2)	
Asian	53 (4.3)	1 (0.9)	
Other	253 (20.3)	19 (17.4)	
Length of Stay (SD)	1.19 (0.012)	3.91 (0.16)	**<0.001**
Length of Surgery (SD)	148.29 (1.65)	184.21 (6.60)	**<0.001**
Anemia	6 (0.5)	1 (0.9)	0.93
Pulmonary Disease	96 (7.7)	16 (14.7)	**0.02**
Coagulopathy	7 (0.6)	4 (3.7)	**<0.001**
Diabetes	150 (12.1)	30 (27.5)	**<0.001**
Hypertension	415 (33.4)	54 (49.5)	**<0.001**
CHF	5 (0.4)	1 (0.9)	0.98
30 Day Readmission	18 (1.4)	3 (2.8)	**<0.001**
Nonhome Discharge	9 (0.7)	24 (22.0)	**<0.001**
Complication	8 (0.6)	5 (4.6)	**<0.001**
Pneumonia	7 (0.6)	4 (3.7)	**<0.001**

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Table 2. Baseline comparison and univariate analysis of normal and prolonged length of stay (LOS) patients for the NSQIP cohort. The NSQIP cohort included 1353 patients undergoing elective ACDF. Length of stay was measured in days and length of surgery was measured in minutes. Abbreviations: Length of Stay (LOS); Anterior Cervical Discectomy and Fusion (ACDF); Congestive Heart Failure (CHF).

	Normal LOS	Prolonged LOS	p-value
NSQIP			
Mean Age (SD)	52.13 (0.32)	56.27 (1.06)	**<0.001**
BMI (SD)	28.69 (0.15)	28.67 (0.56)	0.98
Female (%)	595 (48.9)	79 (58.1)	0.05
ASA Status > 2 (%)	314 (25.8)	56 (41.2)	**<0.001**
Race/Ethnicity (n, %)			**<0.001**
White	816 (67.1)	66 (48.5)	
Black	127 (10.4)	18 (13.2)	
Asian	47 (3.9)	5 (3.7)	
Other	227 (18.7)	47 (34.6)	
Length of Stay (SD)	1.19 (0.012)	5.17 (0.35)	**<0.001**
Length of Surgery (SD)	148.29 (1.65)	162.95 (7.12)	**<0.001**
Anemia	2 (0.2)	3 (2.2)	
Pulmonary Disease	101 (8.3)	19 (14.0)	**0.04**
Coagulopathy	9 (0.7)	0 (0.0)	0.65
Diabetes	169 (13.9)	30 (22.1)	**0.02**
Hypertension	427 (35.1)	58 (42.6)	0.1
CHF	2 (0.2)	0 (0.0)	0.48
30 Day Readmission	28 (2.3)	8 (5.9)	**<0.001**
Nonhome Discharge	15 (1.2)	23 (16.9)	**<0.001**
Complication	0 (0.0)	5 (3.7)	**<0.001**
Pneumonia	0 (0.0)	3 (2.2)	**<0.001**

POSTER 29 continued

Table 3. Multivariate logistic regression and odds ratios for perioperative variables associated with prolonged length of stay for the NSQIP and single institutional cohorts. The single institution and NSQIP cohorts each contained 1353 patients, matched by demographic factors.

	2.5% CI	97.5% CI	Odds Ratio	p-value
Single Institution				
Age	1.01	1.06	1.03	**0.0012**
BMI	0.97	1.04	1.00	0.78
Female	1.25	2.88	1.89	**0.0028**
ASA Status > 2	1.34	3.40	2.13	**0.0015**
White	0.67	1.59	1.03	0.90
Length of Surgery	1.00	1.01	1.01	**<0.001**
Anemia	0.079	9.17	0.85	0.89
Pulmonary Disease	0.67	2.34	1.26	0.47
Diabetes	1.10	3.20	1.88	**0.02**
Hypertension	0.56	1.43	0.89	0.64
NSQIP				
Age	1.01	1.05	1.03	**0.01**
BMI	0.94	1.01	0.98	0.2
Female	1.09	2.36	1.61	**0.02**
ASA Status > 2	0.92	2.23	1.43	0.11
White	0.33	0.7	0.48	**<0.001**
Length of Surgery	1.01	1.01	1.01	**<0.001**
Anemia	1.76	80.1	11.86	**0.01**
Pulmonary Disease	0.89	3.01	1.64	0.11
Diabetes	0.81	2.24	1.34	0.26
Hypertension	0.57	1.38	0.89	0.6

POSTER 30

Range of Horizontal Gaze Following Multilevel Posterior Cervical Fusion Across the Cervicothoracic Junction

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Introduction: Debate exists as to whether multilevel posterior cervical fusion (PCF) should cross the cervical thoracic junction (CTJ). Multiple studies have demonstrated typical spinal radiographic parameters are not significantly changed when patients are fused above vs. across the CTJ. Yet, there is a paucity of evidence examining how horizontal gaze is affected following cervical fusion.

Materials and Methods: Retrospective analysis was performed on patients 18-100 years old who underwent primary PCF involving ≥3 segments with caudal endpoints of C7-T3. McGregor slope (McGS) and C0-C2 cobb angle were measured on lateral cervical x-rays in flexion, extension, and neutral pre- and post-cervical fusion. Statistical analysis was performed to assess for significant change in these measures both pre- and post-fusion as well as between Group 1 and Group 2.

Results: A total of 44 patients were deemed eligible. In all patients, full range of horizontal gaze as measured by McGS in flexion – extension decreased by an average of 15.6° ($p < 0.0001$) while C0-C2 cobb angle extension – flexion increased by an average of 3.9° ($p = 0.014$) pre- vs. post-fusion. Fusion across the CTJ made no difference in range of horizontal gaze in either McGS or C0-C2 cobb angle when patients were separated into Group 1 vs. Group 2.

Conclusion: Our findings demonstrate that multilevel PCF significantly decreases full range of horizontal gaze. This loss is in-part compensated for by an increase in motion above the construct at C0-C2. We did not detect a significant difference in full range of horizontal gaze when constructs terminated at or above C7 vs. across the CTJ to T1-T3. Based on our findings, spine surgeons can expect multilevel PCF to significantly decrease their patients' range of horizontal gaze regardless of fusion across the CTJ.

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Total Population Pre- vs. Post-operative				
Characteristic	Follow-up	Mean	SD	P-value
McGS neutral	Preop.	-3.6°	8.69°	0.84
	Postop.	-3.3°	9.6°	
	Postop-preop.	0.3°	9.9°	
McGS flexion – extension	Preop.	73.8°	24.1°	<0.0001
	Postop.	58.3°	18.0°	
	Postop-preop.	-15.6°	22.5°	
C0-C2 neutral	Preop.	23.6°	10.1°	0.37
	Postop.	24.9°	10.9°	
	Postop-preop.	1.3°	9.4°	
C0-C2 extension – flexion	Preop.	25.4°	11.4°	0.014
	Postop.	29.3°	8.2°	
	Postop-preop.	3.9°	10.1°	

Fusion Termination at C7 vs. T1,2,3 Cohorts						
Characteristic	Follow-up	Subgroup	Results			
			N	Mean	SD	P- value
McGS flexion – extension	Preop.	C7	26	78.6°	24.3°	0.13
		T1,2,3	18	66.9°	22.7°	
	Postop.	C7	26	61.9°	17.6°	0.07
		T1,2,3	18	53.1°	17.8°	
	Postop.-preop.	C7	26	-16.8°	25.8°	0.67
		T1,2,3	18	-13.8°	17.2°	
C0-C2 extension – flexion	Preop.	C7	26	25.8°	11.9°	0.68
		T1,2,3	18	24.7°	10.8°	
	Postop.	C7	26	28.9°	8.2°	0.88
		T1,2,3	18	29.9°	8.3°	
	Postop.-preop.	C7	26	3.0°	11.4°	0.30
		T1,2,3	18	5.2°	8.0°	

POSTER 31
WITHDRAWN

POSTER 32

Impact of Social Deprivation on the Outcomes of Cervical Spinal Cord Injury

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Introduction: Cervical spinal cord injury (SCI) results in devastating paralysis resulting lifelong disability (i.e., tetraplegia). The recovery following cervical SCI is substantially heterogenous with an interplay of multiple factors. Current evidence suggests that low socioeconomic status increases the likelihood of worst injuries and living in a disadvantaged neighborhood has been associated with poor clinical outcomes. However, to date, the impact of social deprivation on neurological and functional outcomes of cervical SCI remains unknown. To address this important gap, the objective of this study was to evaluate the association social deprivation with outcomes following cervical SCI.

Materials and Methods: A secondary analyses of prospective SCI registry (SCI model systems) was performed. We included adult SCI patients >15 years of age with traumatic SCI, neurological-level C1-C8, ASIA impairment-scale (AIS) of A-D, presented within 30-days of SCI at one of the clinical sites. Social deprivation was quantified by the area deprivation index (ADI), which is multidimensional evaluation of a region's socioeconomic conditions, was calculated based on patient's 9-digit residence zip code at the time of SCI and converted into four quartiles from least to most deprived. The association of ADI was evaluated with AIS recovery and functional independence measures using univariable and multivariable analyses.

Results: From 2011-2016, 1823 patients with cervical SCI presented, among which 875 had had complete 1-year follow-up data. At the time of SCI, 25% of patients were living in most deprived and 26% in least deprived ADI quartile. At baseline, the patients in most-deprived quartiles were more likely to have complete SCI (AIS grade A-B), had higher rates of assault, fall, and work-related injuries, however, less severe traumatic brain injury. The patients in most deprived ADI quartile also had higher rates of African-American population, lack of higher education, and greater lack of medical insurance. Although most deprived ADI quartile had worst presentation, after one year follow-up, there was no difference in the recovery of AIS grade and functional independence measures.

Conclusion: Cervical SCI patients belonging to the disadvantaged neighborhoods have worst clinical presentation, however, have a similar recovery potential. Optimization of clinical pathway is needed to provide equitable health care for patients in disadvantaged backgrounds.

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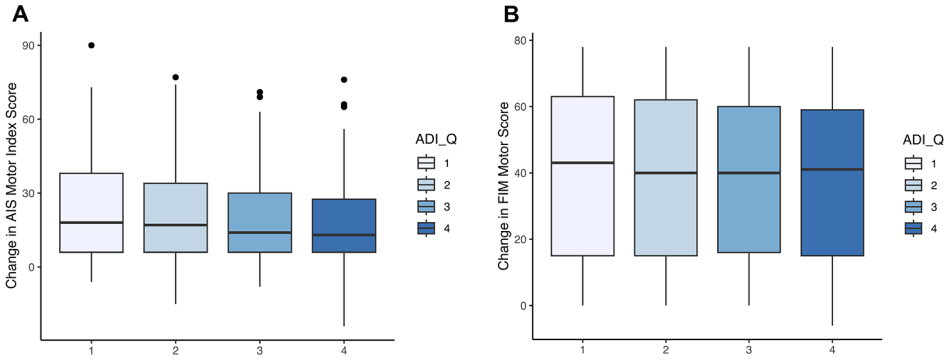

Figure 1. Change in AIS motor index score **(A)** and FIM motor score **(B)** from least (ADI_Q= 1) to most (ADI_Q=4) worst quartiles.

POSTER 33

Short-term Disc Herniation Change After Laminoplasty in Multilevel Cervical Spondylotic Myelopathy Patients

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Introduction: Laminoplasty is a safe and effective treatment for multilevel cervical spondylotic myelopathy(MCSM)[1]. Howerver, the optimal surgical approach for MCSM combined with large anterior soft disc herniation is stil controversial[2,3]. Some previous study showed the change of disc herniation's size after surgery or conservative treatment[4,5]. So we observed the change of disc herniation 3 months postoperatively in MCSM patients to provide imaging evidence for clinical practice.

Materials and Methods: Clinical data of patients with multilevel CSM who underwent laminoplasty in our hospital from January 2017 to September 2019 were collected excluding patients with posterior longitudinal ligament ossification. A total of 67 patients were included, including 44 males and 23 females aged 31-78 years (56.5±9.89 years). The size of cervical disc herniation at each level was measured on sagittal MRI T2-weighted images before surgery and 3 months after surgery. Disc herniation ≧ 2.0mm before surgery was defined as a large disc herniation. The herniation change ≦ 0.5mm was defined as no significant change. The incidences of regression, no significant change and progression were calculated. Paired sample t test and nonparametric test were used to compare the size of disc herniation before and after surgery.

Results: A total of 335 intervertebral discs were measured, among which 314 were herniated before surgery, 57 were C2/3, 64 were C3/4, 66 were C4/5, 65 were C5/6, and 62 were C6/7. The average size was 2.20mm [2.09 (1.43, 2.69)] and 2.12mm [1.97(1.35, 2.76)] after surgery. 83(24.8%) herniations regressed, 184(54.9%) had no significant change, and 68(20.3%) progressed. 163 herniations were larger than 2.0mm before surgery . Among 163 herniations ≧ 2.0mm, 54(33.1%) herniations regressed, 86(52.8%) herniations had no significant change, and 23(14.1%) herniations progressed. For different levels, the average size of C4/5, C5/6 and C6/7 herniations had a significant change of 0.34mm, 0.42mm and 0.34mm, respectively. However the average size of C2/3 and C3/4 herniations had no significant change. The proportion of disc herniation regression at C2/3 and C3/4 was smaller than C4/5,C5/6 and C6/7. Three patients (4.5%) underwent secondary anterior cervical surgery due to large disc herniation or herniation progression after surgery.

Conclusion: The size of large disc herniation could change at 3 months after cervical laminoplasty. About 1/3 of the disc herniation regressed, mostly at C4/5, C5/6, and C6/7 segments, while the incidence of disc herniation progression is low.

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Table 1 Preoperative and postoperative size of large disc herniations (≧2mm)

Levels	Preoperative disc herniation size	Postoperative disc herniation size	P value
C2-3(n=9)	2.63±0.39	2.60±0.83	0.779
C3-4(n=42)	2.97±0.75	3.03±0.87	0.693
C4-5(n=38)	3.23±0.91	2.89±0.87	0.033*
C5-6(n=41)	2.98±1.12	2.56±1.35	0.003*
C6-7(n=33)	2.69±0.74	2.35±1.02	0.029*
Total(n=163)	2.96±0.89	2.72±1.06	0.001*

Table 2. The proportion of large disc herniation regression, no significant change, and progression 3 months after surgery

Levels	Regression	No significant change	Progression
C2-3(n=9)	22.2% (n=2)	55.6% (n=5)	22.2% (n=2)
C3-4(n=42)	11.9% (n=5)	66.7% (n=28)	21.4% (n=9)
C4-5(n=38)	36.8% (n=14)	52.6% (n=20)	10.5% (n=4)
C5-6(n=41)	41.5% (n=17)	43.9% (n=18)	14.6% (n=6)
C6-7(n=33)	42.4% (n=14)	42.4% (n=14)	15.2% (n=5)
C4-7(n=112)	40.2% (n=45)	46.4% (n=52)	13.4% (n=15)
Total(n=163)	33.1% (n=54)	52.8% (n=86)	14.1% (n=23)

POSTER 33 continued

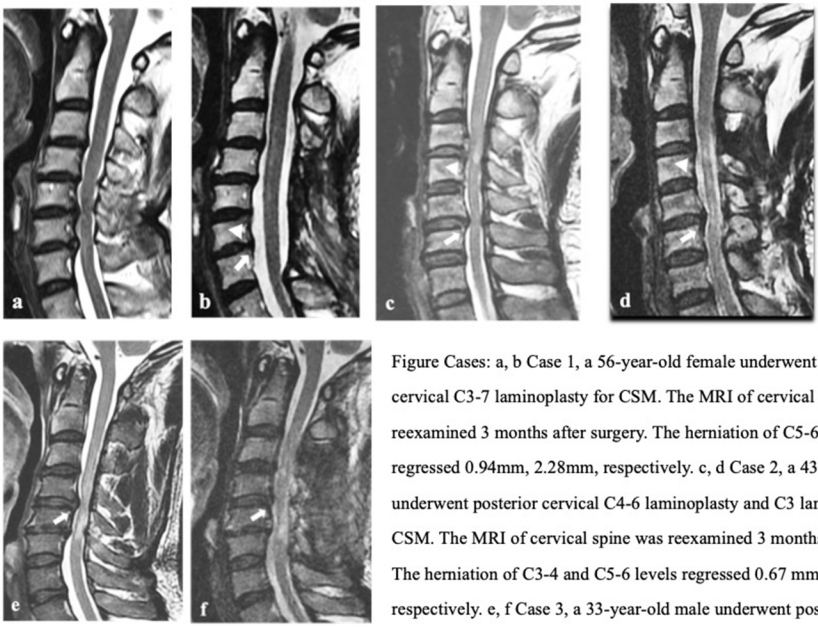

Figure Cases: a, b Case 1, a 56-year-old female underwent posterior cervical C3-7 laminoplasty for CSM. The MRI of cervical spine was reexamined 3 months after surgery. The herniation of C5-6 and C6-7 levels regressed 0.94mm, 2.28mm, respectively. c, d Case 2, a 43-year-old male underwent posterior cervical C4-6 laminoplasty and C3 laminectomy for CSM. The MRI of cervical spine was reexamined 3 months after surgery. The herniation of C3-4 and C5-6 levels regressed 0.67 mm and 2.01mm, respectively. e, f Case 3, a 33-year-old male underwent posterior cervical C4-6 laminoplasty and C3 laminectomy for CSM. The MRI of cervical spine was reexamined 3 months after surgery. The herniation of C4-5 level regressed 0.78 mm.

POSTER 34

Impact of Uniformly Right-Side Opening Laminoplasty on Postoperative C5 Palsy in Patients with Degenerative Cervical Myelopathy

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Introduction: C5 palsy is important complication after unilateral open door laminoplasty (UODL). Many studies had evaluated the risk factors for C5 palsy, but there were few studies about the relationship between lamina opening side and C5 palsy. The aim of this study is to evaluate the impact of uniformly right-side opening laminoplasty on C5 palsy according to preoperative dominant cord compression side and symptom side.

Materials and Methods: Degenerative cervical myeloradiculopathy underwent UODL and followed-up for more than two years were included. UOLD was uniformly performed on the right side and hinge was on the left side in all patients. Patients were sub-grouped based on preoperative dominant 3 characteristics: cord compression side, myelopathy symptom side and radiculopathy symptom side (right, symmetric and left). Occurrence of C5 palsy and C5 palsy side were analyzed for each sub-group.

Results: A total of 368 patients were included. C5 palsy incidence was 4.35% (16/368). Four (25%) occurred from the right side and 12 (75%) from the left side. All patients recovered from palsy. According to dominant preoperative cord compression side, C5 palsy rate was not differ in each sub-group. Right and left ratio was respectively 2:2, 2:6 and 0:4. According to dominant preoperative myelopathy symptom side, C5 palsy rate was not differ in each sub-group. Right and left ratio was respectively 1:3, 3:4 and 0:5. According to dominant preoperative radiculopathy symptom side, C5 palsy rate was not differ in each sub-group. Right and left ratio was respectively 1:3, 2:1 and 1:8.

Conclusion: In this study, the occurrence of C5 palsy after uniformly right-side opening laminoplasty was not affected by preoperative dominant cord compression or symptomatic side. Although there was no statistical significance, the patients with preoperatively dominant left-side radiculopathy tend to reveal postoperative left-side C5 palsy and overall occurrence of C5 palsy was higher in the left-side than in the right-side. Further large-scale research is needed in the future.

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Table 1. Occurrence of C5 palsy in each sub-group

	Right	Symmetric	Left	$p^{\dagger}$
Dominant cord compressive side				
Number of patients	71	209	88	
C5 palsy patients (%)	4 (5.63%)	8 (3.83%)	4 (4.54%)	0.808
Dominant myelopathy side				
Number of patients	75	228	65	
C5 palsy patients (%)	4 (5.33%)	7 (3.07%)	5 (7.69%)	0.244
Dominant radiculopathy side				
Number of patients	115	141	112	
C5 palsy patients (%)	4 (3.48%)	3(2.13%)	9 (8.04%)	0.063

† Chi square test

Table 2. Right and left ratio of C5 palsy in each sub-group

	Right	Left	R / L ratio
Total C5 palsy patients (%)	4 (25%)	12 (75%)	0.333
Dominant cord compressive side			
Right	2	2	1.000
Symmetric	2	6	0.333
Left	0	4	0
Dominant myelopathy side			
Right	1	3	0.333
Symmetric	3	4	0.750
Left	0	5	0
Dominant radiculopathy side			
Right	1	3	0.333
Symmetric	2	1	2.000
Left	1	8	0.125

POSTER 35

Research Productivity Trends Among Residents Applying for Orthopaedic Spine Fellowships in the United States

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Introduction: Among orthopaedic subspecialties, spine surgery is considered one of the most competitive. Although there are no research benchmarks required to match into a spine fellowship, applicants nonetheless routinely engage in research throughout their training. With recent declining match rates in orthopaedic spine surgery, we hypothesize that the number of publications among orthopaedic spine applicants has increased.

Materials and Methods: The North American Spine Society (NASS) Fellowship Directory was used to identify orthopaedic spine fellowship programs in the United States. Programs limited to neurosurgery residents or that failed to include current or former fellows were omitted. Fellowships that listed graduating fellows from 2019 to 2023 were included for analysis. For each fellow, the total number of publications, citation count, authorship, and fellowship program were compiled using Scopus and publicly accessible spine fellowship websites. Only publications and citations in years prior to the start of fellowship were collected. H-index was calculated using these totals to reflect pre-fellowship research output.

Results: Thirty-eight programs qualified with 181 fellows from 2019 to 2023. There were 17 (9.4%) female fellows. Fellows published a total of 1,403 manuscripts resulting in 20,048 citations, with an average of 7.9 ± 10.6 articles and 112.6 ± 226.0 citations per fellow. Most publications involved middle authorship (65.8%) and a minority focused on spine surgery (37.2%). Average number of publications per fellow (11.4 ± 9.1) and h-index (5.0 ± 3.1) were highest for fellows in programs located in the northeast region of the United States. Fellows with an anticipated graduation date of 2023 had the highest average number of publications (10.6 ± 16.4), number of citations (136.5 ± 321.2), and h-index (4.3 ± 4.3).

Conclusion: Over the last several academic years, there has been an increasing trend in the number of pre-fellowship publications, citations, and h-index among orthopaedic spine fellowship applicants. Research productivity was found to be the highest among fellows in spine fellowship programs in the northeast region.

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Table 1. Research productivity among all spine fellows	
	n (%)
Total of All Fellows	
Number of Publications*	1,403
Number of 1st Authorship Articles	442 (31.5%)
Number of Middle Authorship Articles	923 (65.8%)
Number of Articles with Spine Focus	522 (37.2%)
Number of Citations	20,048
Average Per Fellow	
Number of Publications*	7.9 ± 10.6
Number of 1st Authorship Articles	2.5 ± 4.5
Number of Middle Authorship Articles	5.2 ± 6.9
Number of Articles with Spine Focus	2.9 ± 5.6
Number of Citations	112.6 ± 226.0
H-index	3.9 ± 3.7
*Number of publications and citations represents a fellow's research output prior to the start of their fellowship.	

Table 2. Association of research productivity with fellowship program region, fellow sex, and fellowship year

	Number of Publications [n (%)]*	Number of Citations [n (%)]	Number of Fellows	Average Publications per Fellow	Average Citations per Fellow	h-index per Fellow
Fellowship Program Region						
Northeast	297 (21.2%)	3,493 (17.4%)	26	11.4 ± 9.1	134.3 ± 127.2	5.0 ± 3.1
Midwest	344 (24.5%)	4,999 (24.9%)	49	7.0 ± 6.4	102.0 ± 208.7	3.9 ± 3.8
Southeast	265 (18.9%)	4,275 (21.3%)	30	8.8 ± 20.0	142.5 ± 416.1	3.6 ± 5.3
Southwest	26 (1.9%)	673 (3.4%)	6	4.3 ± 2.8	112.2 ± 116.9	2.7 ± 1.2
West	471 (33.6%)	6,608 (33.0%)	70	7.0 ± 7.5	98.6 ± 148.1	3.8 ± 3.0
Fellowship Year						
2022-2023	528 (37.6%)	6,826 (34.0%)	50	10.6 ± 16.4	136.5 ± 321.2	4.3 ± 4.3
2021-2022	239 (17.0%)	2,464 (12.3%)	33	7.2 ± 5.7	74.7 ± 80.7	4.0 ± 2.8
2020-2021	215 (15.3%)	3,108 (15.5%)	30	7.2 ± 7.1	103.6 ± 134.7	3.9 ± 2.9
2019-2020	240 (17.1%)	4,225 (21.1%)	37	6.7 ± 7.1	117.4 ± 186.7	3.8 ± 3.7
2018-2019	181 (12.9%)	3,425 (17.1%)	31	6.2 ± 8.4	118.1 ± 267.1	3.6 ± 4.5
Fellow Sex						
Male	1,314 (93.7%)	18,730 (93.4%)	164	8.2 ± 11.0	116.3 ± 236.4	4.0 ± 3.8
Female	89 (6.3%)	1,318 (6.6%)	17	5.2 ± 4.3	77.5 ± 88.6	3.4 ± 2.6

*Number of publications and citations represents a fellow's research output prior to the start of their fellowship.

POSTER 36

Foraminal Decompression Technique during ACDF for Cervical Radiculopathy that Provides a Better Outcome: Total Uncinatectomy vs. Partial Uncoforaminotomy

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Introduction: Anterior cervical discectomy and fusion (ACDF) provides clinical improvement for cervical radiculopathy, even without direct foraminal decompression, because it stabilizes the mobile segment and provides indirect decompression. Recently, it was determined that foraminal decompression via uncinate process resection could lead to faster and greater improvement of arm pain. Total uncinatectomy (TU) and partial uncoforaminotomy (PU) are commonly used for direct foraminal decompression (Fig 1). However, the advantages and pitfalls of the two techniques remain unknown. We aimed to compare the clinical outcomes and complications of TU and PU to determine the most suitable technique for foraminal decompression during ACDF.

Materials and Methods: Consecutive patients (n=306) who underwent single-level ACDF for degenerative cervical radiculopathy and who were followed up for >2 years were retrospectively reviewed. The patients were divided into two groups depending on the surgical technique: Group TU and Group PU. Subsidence, fusion, operative time, estimated blood loss (EBL), complications, and patient-reported outcome measures including arm pain visual analogue scale (VAS) score, neck pain VAS score, and neck disability index (NDI) were assessed and compared between the two groups.

Results: Groups TU and PU included 152 (49.7%) and 154 (50.3%) patients, respectively. Group TU had a significantly higher degree of subsidence than Group PU. The 1-year (16 [10.5%] vs 6 [3.9%], p=0.025) and 2-year (11 [7.2%] vs 3 [1.9%], p=0.025) postoperative fusion rates were higher in Group PU than those in Group TU (16 [10.5%] vs 6 [3.9%], p=0.027). Postoperative arm pain VAS score, neck pain VAS score, and NDI scores did not demonstrate significant intergroup differences at all time points. Group TU had a significantly longer operative time (94.21±15.74 vs 81.04±16.92, p<.001), greater EBL (121.34±109.9 vs 71.83±85.71, p<.001), higher dysphasia rate (94 (61.8%) vs 75 (48.7%), p=0.021), and more severe retropharyngeal soft tissue swelling (18.20±5.02 vs 15.98±3.73, p=0.016) than Group PU did. There was one case (0.7%) of cerebral infarction due to vertebral artery injury in Group TU (Table 1).

Conclusion: PU resulted in lesser complications, shorter operative time, and lesser intraoperative bleeding than did TU. While TU guarantees complete foraminal decompression during ACDF, it requires a longer time. Furthermore, excessive lateral exposure and retraction is needed to palpate the lateral margin of the uncinate for TU. This might cause greater postoperative neck swelling and dysphagia. Moreover, the uncinate process was partially preserved in PU as a potential stabilizer, causing lesser subsidence and higher fusion rates. However, the clinical efficacy of PU was comparable to that of TU. Thus, resection of only the posterior part of the uncinate process provides sufficient direct foraminal decompression. Therefore, PU could be an effective and safer alternative to TU for foraminal decompression during ACDF.

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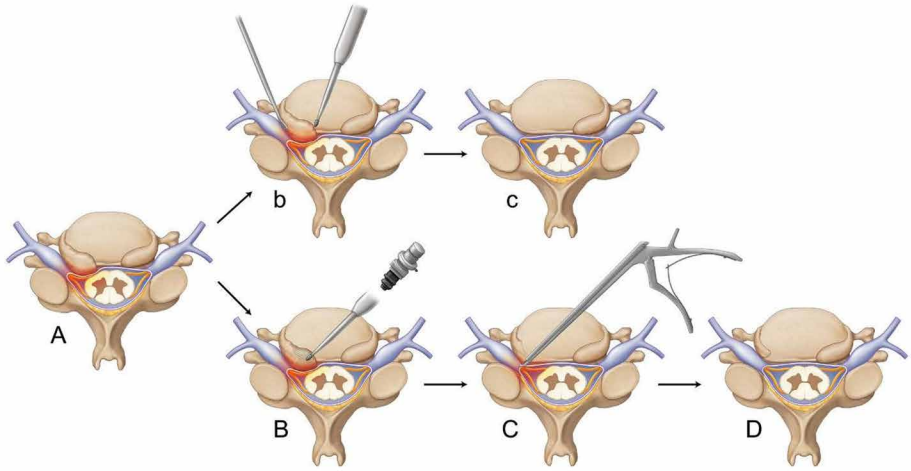

Figure 1. Schematic illustration of the two foraminotomy methods during anterior cervical discectomy and fusion.

A) Right neural foraminal stenosis due to uncinate process (UP) hypertrophy.

Total Uncinectomy (A->b->c): Penfield dissector is inserted lateral to the UP to protect the vertebral artery and nerve root. (b) The UP is removed using a high-speed burr, Kerrison punch, and curette. (c) Completely removed UP and decompressed right neural foramen.

Partial Uncoforaminotomy (A->B->C->D): (B) Using an oblique trajectory with the microscope tilted, a high-speed burr is used to remove the hatched area, leaving a thin outer cortex. (C) The outer cortex and the part adjacent to the nerve are removed by undercutting using a Kerrison punch or a backward micro-curette. (D) Only posterior part of the UP removed and right neural foramen decompressed.

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Table 1. Comparison of the clinical outcomes between Groups TU and PU.

Characteristic	Group TU (n=152)	Group PU (n=154)	*p-value*
Dysphasia score†	13.13±3.51	11.6±2.34	<.001*
Dysphasia††	94 (61.8%)	75 (48.7%)	0.021*
OP time (min)	94.21±15.74	81.04±16.92	<.001*
EBL (ml)	121.34±109.92	71.83±85.71	<.001*
Cage height (mm)	7.63±1.01	6.31±0.61	<.001*
Retro-swelling (mm)			
C2 level	8.10±3.03	6.98±3.51	0.003*
C7 level	18.20±5.02	15.98±3.73	0.016*
(C2+C7)/2	13.65±3.63	11.48±3.06	0.003*
Subsidence (mm)			
POD 1m	0.69±0.71	0.69±0.55	0.95
POD 3m	1.43±0.95	0.95±0.49	<.001*
POD 6m	1.83±0.97	1.32±0.67	<.001*
POD 1y	2.05±1.00	1.45±0.81	<.001*
POD 2y	2.18±1.07	1.52±0.73	<.001*
Nonunion POD 1y	16 (10.5%)	6 (3.9%)	0.025*
Nonunion POD 2y	11 (7.2%)	3 (1.9%)	0.027*
VA injury	1	0	
VAS_{neck}			
POD 1m	4.02±1.81	3.77±3.54	0.45
POD 3m	2.57±1.71	2.35±1.85	0.27
POD 6m	2.44±1.85	2.33±2.23	0.64
POD 1y	2.27±1.55	2.06±1.67	0.26
POD 2y	2.21±1.75	2.10±1.62	0.56
VAS_{arm}			
POD 1m	2.46±1.56	2.59±1.95	0.508
POD 3m	1.97±1.42	2.06±1.73	0.626
POD 6m	1.79±2.42	1.84±2.11	0.859
POD 1y	1.60±1.50	1.59±2.01	0.969
POD 2y	1.13±2.11	1.26±1.72	0.554
NDI			
POD 1m	17.26±10.26	19.59±13.63	0.092
POD 6m	16.74±9.63	16.36±12.56	0.771
POD 1y	16.47±11.50	14.86±12.28	0.236
POD 2y	11.53±11.55	11.96±5.33	0.672

TU, total uncinectomy; PUF, partial uncoforaminotomy; OP, operative; EBL, estimated blood loss; retro-swelling, retropharyngeal soft tissue swelling; VA, vertebral artery; POD, postoperative day; VAS_{neck}, visual analog scale score of neck pain; VAS_{arm}, visual analog scale score of arm pain; NDI, neck instability index.

* P <0.05 calculated using independent samples t-test or chi-square test

† Modified Bazaz dysphagia scoring system.

†† Patient was assessed on the day of operation and on the first, third and fifth post-operative days; the scores were added together. Dysphagia was defined as a cumulative score of ≥ 12.

POSTER 37

Rates of Adjacent Segment Degeneration After Anterior Cervical Discectomy and Fusion vs Cervical Disc Arthroplasty and the Effect of Unconscious Bias: A Systematic Review and Meta-Analysis

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Introduction: For decades, anterior cervical discectomy and fusion (ACDF) has been considered the standard treatment for degenerative cervical disease. One potential long-term sequela is adjacent segment degeneration (ASDeg), which is thought to be due to a compensatory increase in motion and strain at adjacent levels. Cervical disc arthroplasty (CDA) was developed to address these concerns by providing the same neural decompression as ACDF while sparing motion. While there have been several studies comparing the two procedures, it remains unclear whether CDA reduces ASDeg. Of note, many of these studies have been done in trials through the investigational device exemption (IDE) pathway for Food and Drug Administration (FDA) approval and the impact of this bias must also be considered.

Materials and Methods: This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement. PubMed/MEDLINE, Embase, and Cochrane databases were queried. Studies were included if (1) there were two prospective, randomized groups comparing ACDF and CDA, (2) single-level surgery was included, (3) the study population was >18 years old, (4) there was a minimum of 30 patients per group, (5) there was a minimum of two years of follow up, (6) ASDeg on imaging was assessed in all patients and compared between the two groups. For studies using the same patient population, the study with the longest follow up was used for the meta-analysis.

Meta-analyses were performed on studies that reported the proportion of patients with ASDeg after single-level ACDF or CDA. Sub-analysis was conducted based on funding status. Forest plots were generated to a weighted average of individual summary statistics using odds ratio (OR) with 95% confidence interval (CI). All statistical analyses were done using R Studio (Version 4.1.2, Vienna, Austria).

Results: 1294 studies were identified from database searches and 16 met inclusion criteria. Of these, eight were earlier studies of the same population, leaving eight for final analysis (fig 1). Four studies found that patients had less ASDeg after CDA than ACDF, while four found no difference (table a). Interestingly, the four that found differences were all IDE studies. For the quantitative meta-analysis, two of the studies used metrics that could not be compared to the other studies. When comparing the other six studies, CDA was found to have less superior-level ASDeg (42.12% vs 52.08%, p=0.001). However, no difference in ASDeg was found in the Non-IDE group (39.47% vs 42.24%, p=0.632), indicating that the IDE group was the driving factor (39.05% vs 61.05%, p<0.001) (table b). In total, there were 1.97 times increased odds of developing ASDeg at the superior-level (OR 1.97; CI [1.46;2.66]; p<0.05) and 1.60 times increase at the inferior-level (OR 1.60; CI [1.23;2.09]; p<0.05) in the ACDF cohort compared to the CDA cohort (fig 2 and 3).

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Conclusion: While we found that there may be a difference in adjacent segment degeneration between ACDF and CDA, this was mainly driven by IDE studies, which are subject to unconscious bias. This highlights the need for non-industry funded studies and greater transparency in funding.

Figure 1: PRISMA diagram.

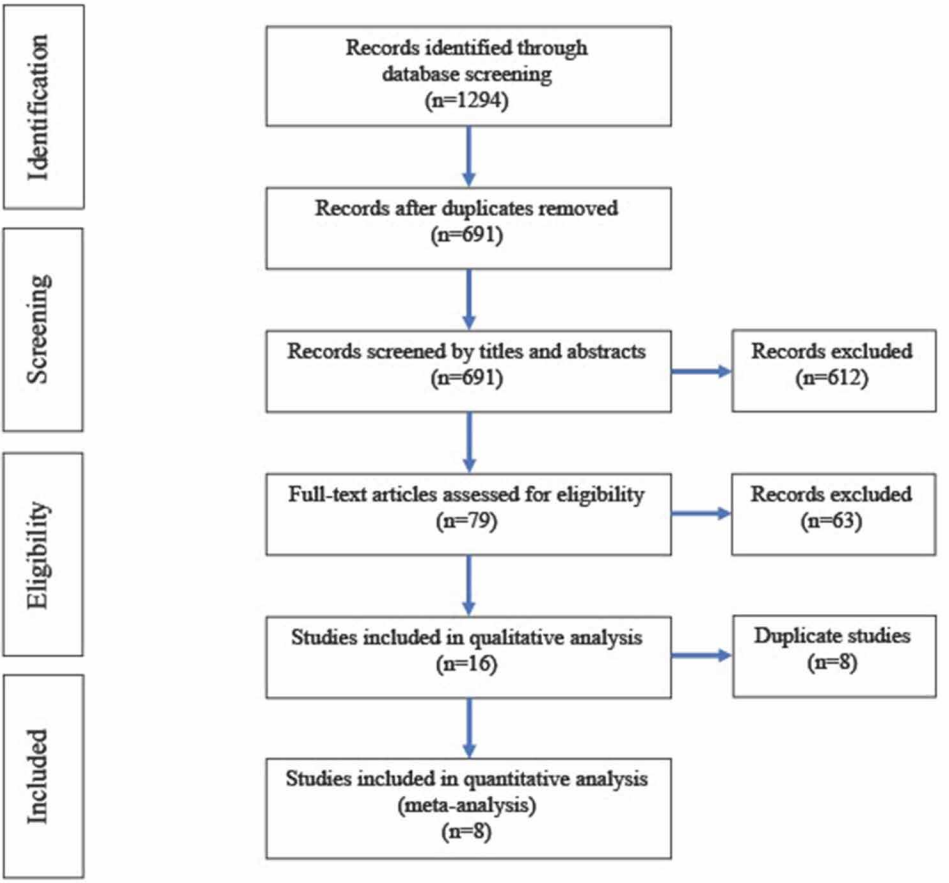

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Table A: Study Characteristics and Adjacent Segment Degeneration of Included Studies

Author	Country/ Region	Funding	Levels	Follow-up (months)	Superior level ASDeg		Inferior level ASDeg		Less ASDeg?
					CDA	ACDF	CDA	ACDF	
Coric	USA	IDE	1	60	47.1%	69.5%	54.7%	71.0%	CDA
Phillips	USA	IDE	1	60	33.1%	50.9%	49.2%	51.7%	CDA
Radcliff	USA	IDE	1	84	40.4%	65.1%	42.7%	63.0%	CDA
Spivak	USA	IDE	1	84	36%	59%	34%	42%	CDA
Kontakis	Sweden	Grant	1/2	120	-	-	-	-	No difference
Kumar[a]	Asia	Sponsored	1	24	40%	43.9%	40%	43.9%	No difference
Miller	USA	Post-hoc[b]	1	84	-	-	-	-	No difference
Vleggeert-Lankamp	Netherlands	Grant	1	24	38.3%	40.0%	28.8%	40.0%	No difference

[a] Separate superior and inferior level ASDeg were not given in this study so the total reported was used for analysis of both levels.
[b] This was an unfunded post-hoc analysis of data gathered from a previous IDE trial.

Table B: Comparison of ASDeg rates and funding subanalysis

	ACDF	CDA	p-value
IDE funding			
Superior ASDeg	61.05% (53.46%-68.14%)	39.05% (33.68%-44.71%)	<0.001*
Inferior ASDeg	56.72% (44.56%-68.12%)	45.26% (37.69%-53.06%)	0.120
Non-IDE funding			
Superior ASDeg	42.24% (33.60%-51.39%)	39.47% (32.78%-46.59%)	0.632
Inferior ASDeg	42.45% (33.42%-52.02%)	36.81% (30.12%-44.05%)	0.344
All studies			
Superior ASDeg	55.34% (46.63%-63.73%)	39.18% (35.21%-43.30%)	0.001*
Inferior ASDeg	52.08% (42.22%-61.78%)	42.12% (35.51%-49.03%)	0.105

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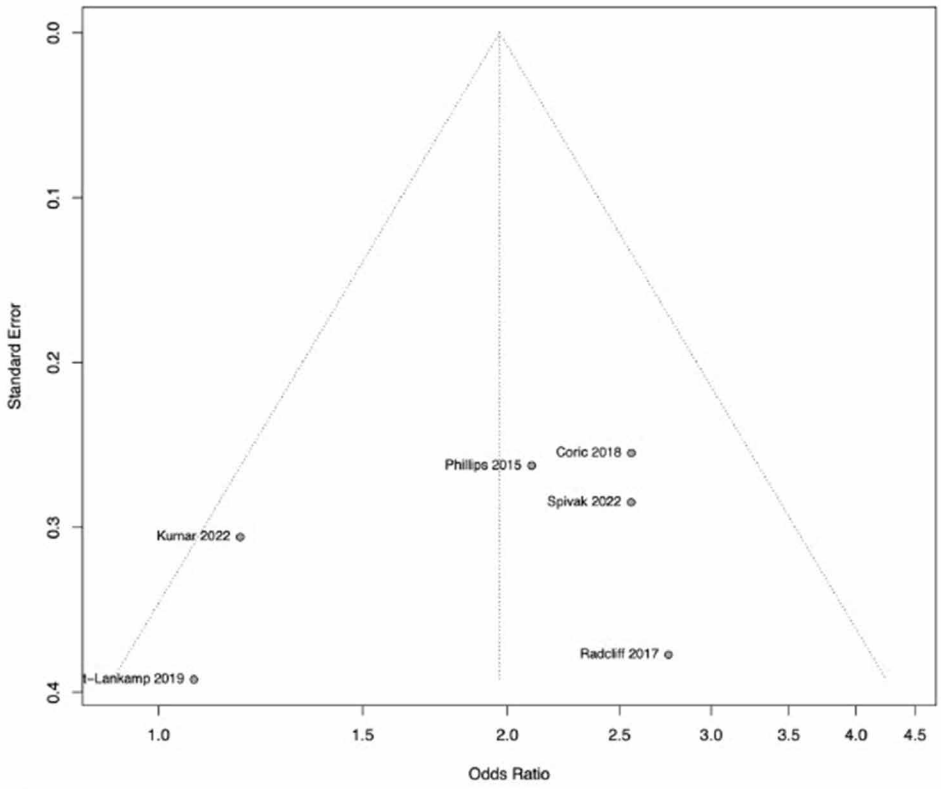
Figure 2: Analysis of Superior-Level Adjacent Segment Degeneration after Single-Level ACDF vs CDA. (A) Funnel plot. (B) Forest Plot.

(A)



(B)

Study	ACDF Events	ACDF Total	CDA Events	CDA Total	Weight	Odds Ratio MH, Random, 95% CI
Phillips 2015	54	106	48	145	20.1%	2.10 [1.25; 3.51]
Radcliff 2017	28	43	42	104	12.4%	2.76 [1.32; 5.77]
Coric 2018	92	133	64	136	20.8%	2.56 [1.55; 4.22]
Spivak 2022	61	103	38	106	18.3%	2.56 [1.46; 4.47]
Vleggeert–Lankamp 2019	20	50	23	60	11.7%	1.07 [0.50; 2.31]
Kumar 2022	29	66	52	130	16.7%	1.18 [0.65; 2.14]
Total (95% CI)		**501**		**681**	**100.0%**	**1.97 [1.46; 2.66]**

Heterogeneity: $Tau^2 = 0.0490$; $Chi^2 = 7.98$, df = 5 (P = 0.16); $I^2 = 37\%$

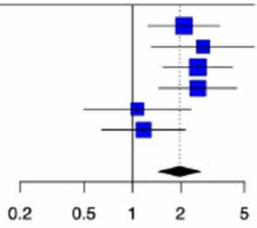


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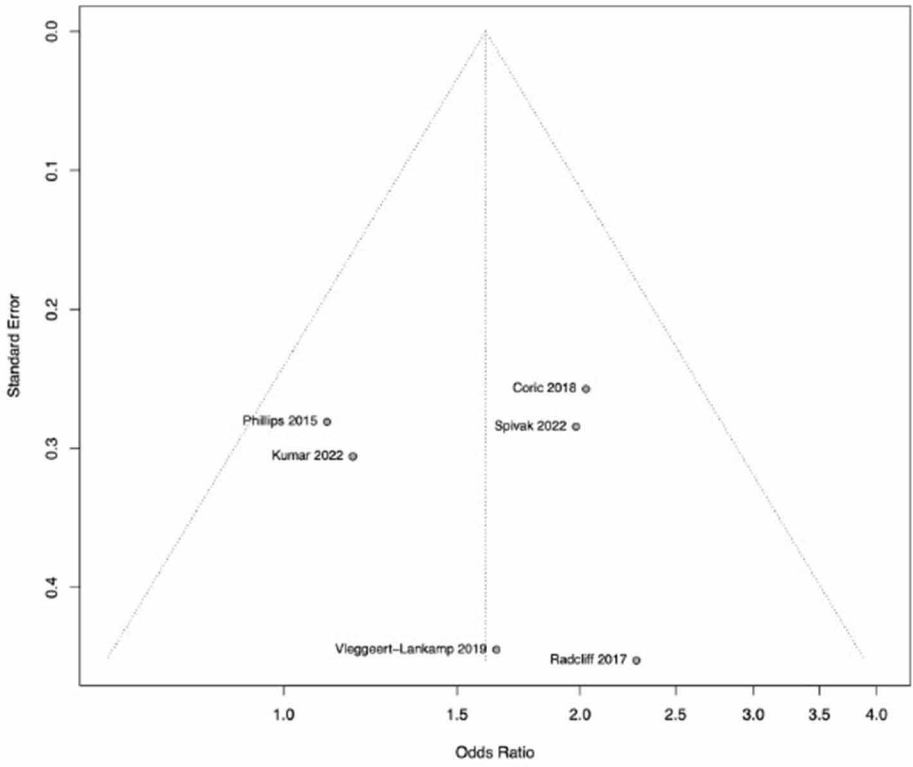
Figure 3: Analysis of Inferior-Level Adjacent Segment Degeneration after Single-Level ACDF vs CDA. (A) Funnel plot. (B) Forest Plot.

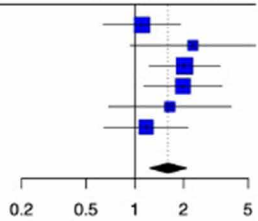
(A)



(B)

Study	ACDF Events	ACDF Total	CDA Events	CDA Total	Weight	Odds Ratio MH, Random, 95% CI
Phillips 2015	46	89	58	118	20.7%	1.11 [0.64; 1.92]
Radcliff 2017	17	27	38	89	8.5%	2.28 [0.94; 5.54]
Coric 2018	94	133	74	136	24.1%	2.03 [1.22; 3.36]
Spivak 2022	52	103	36	106	20.2%	1.98 [1.13; 3.46]
Vleggeert–Lankamp 2019	16	40	15	52	8.8%	1.64 [0.69; 3.93]
Kumar 2022	29	66	52	130	17.7%	1.18 [0.65; 2.14]
Total (95% CI)		**458**		**631**	**100.0%**	**1.60 [1.23; 2.09]**

Heterogeneity: $Tau^2 = 0.0094$; $Chi^2 = 4.77$, df = 5 (P = 0.45); $I^2 = 0\%$



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.

POSTER 38

Spatial Transcriptomics Reveal Oxidative Stress Responsive Niche at Needle Puncture Site of Intervertebral Disc

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Introduction: Although the needle puncture model is widely used to study the mechanism of intervertebral disc (IVD) degeneration, the regional transcriptomic changes and spatial distribution of the biological processes early after injury are still unclear. In this study, we used spatial transcriptomics to identify functional zones at the needle puncture site and shed light on early changes in the intervertebral disc.

Materials and Methods: We employed a needle puncture rat tail IVD degeneration model as described in previous literature. Healthy and punctured rat IVDs at 1, 3, and 28 days post-puncture were collected and horizontal cryostat sections were obtained at the level of the puncture site. Spatial transcriptomics sequencing was performed according to the 10X Visium spatial protocol. Differential gene expression analysis was conducted by screening genes based on their fold change and significance test results. Gene Ontology (GO) and Kyoto Encyclopedia of Genes and Genomes (KEGG) enrichment analysis was performed to identify biological functions and cellular pathways associated with differentially expressed genes under different conditions. Furthermore, spatial pathway enrichment analysis of different IVD regions was performed using the Gene Set Variation Analysis (GSVA).

Results: The control IVD samples exhibited uniform gene expression, allowing for the identification of distinct regions of nucleus pulposus (NP) and annulus fibrosus (AF). An Oxidative Stress Responsive Niche was observed at the puncture site in Day 1 IVD samples, which expanded to a larger region by Day 3. This environment was categorized into three functional areas: the Stress Zone, expressing oxidative stress genes such as Lcn2, Sod2, and Mt2A; the NP Buffer Zone, highly expressing acute anti-stress genes like Hspb1 and Lmcd1; and the AF Buffer Zone, highly expressing wound healing-related genes such as Dst and Sptbn1. GO analysis revealed that the biological processes in the NP/AF Buffer Zones overlapped with those in the Stress Zone and normal NP/AF regions, respectively, indicating their protective roles against oxidative stress. However, by Day 28, the NP and AF buffer zones disappeared, and the Stress Zone extended to involve the entire IVD, leading to degeneration of both the NP and AF regions. The spatial-GSVA analysis further showed that several pathological processes predominantly occurred within the OSRN, including apoptosis, cytokine-mediated inflammation, and extracellular matrix disassembly, emphasizing the critical roles of cell death and inflammation accompanying oxidative stress in IVD degeneration.

Conclusion: Our study discovered an Oxidative Stress Responsive Niche at the puncture site, which connects the injury to other pathological processes during the early stages of degeneration. These findings enhance our understanding of injury-induced IVD degeneration and provide important insights for the development of novel therapeutic approaches.

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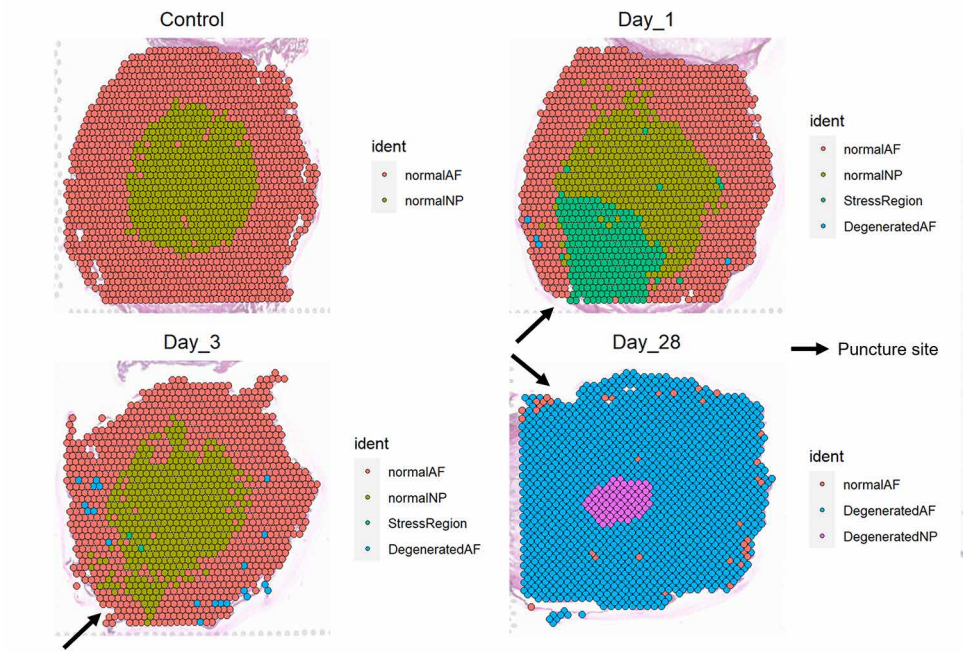

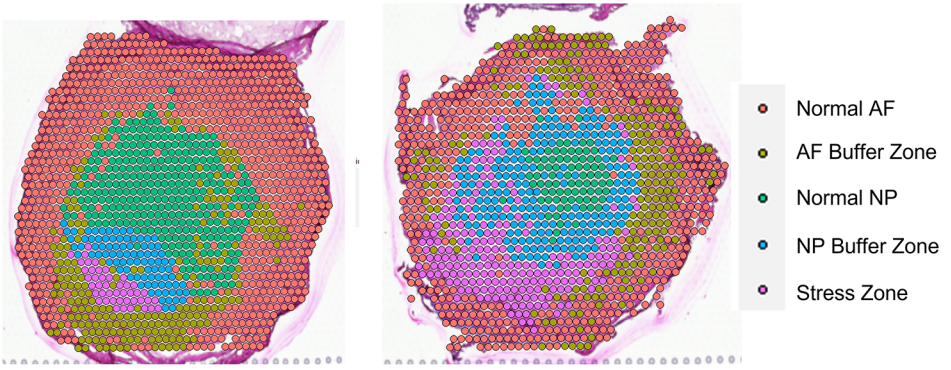

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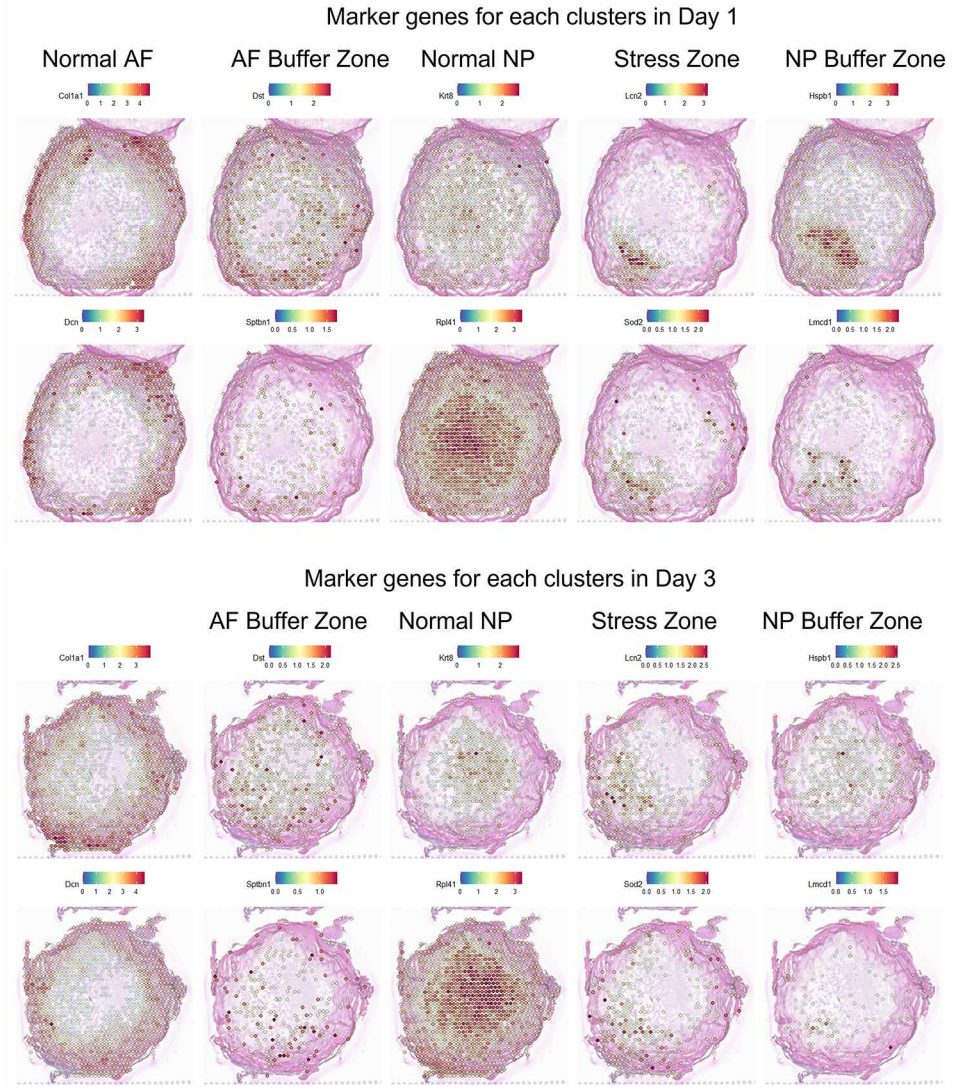

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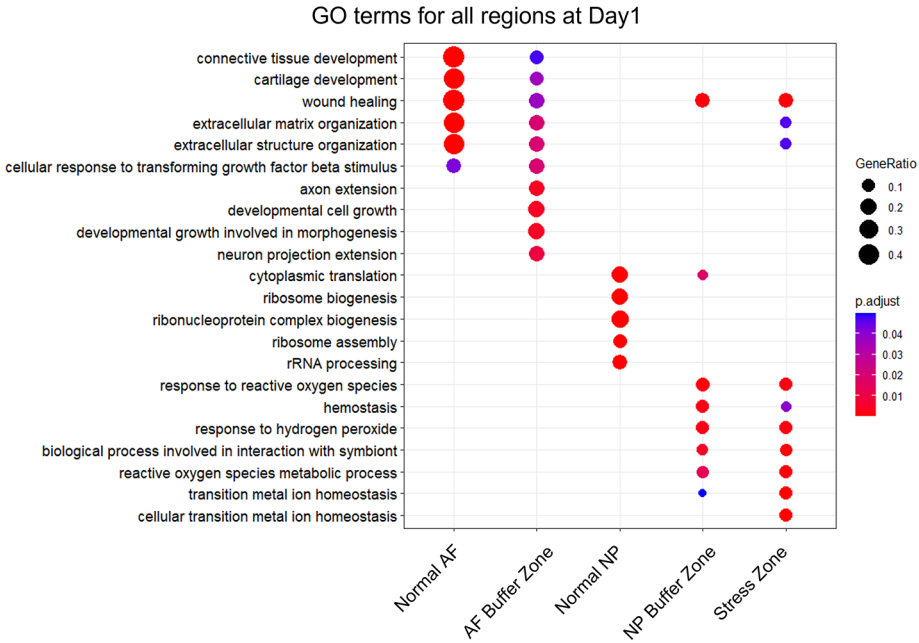

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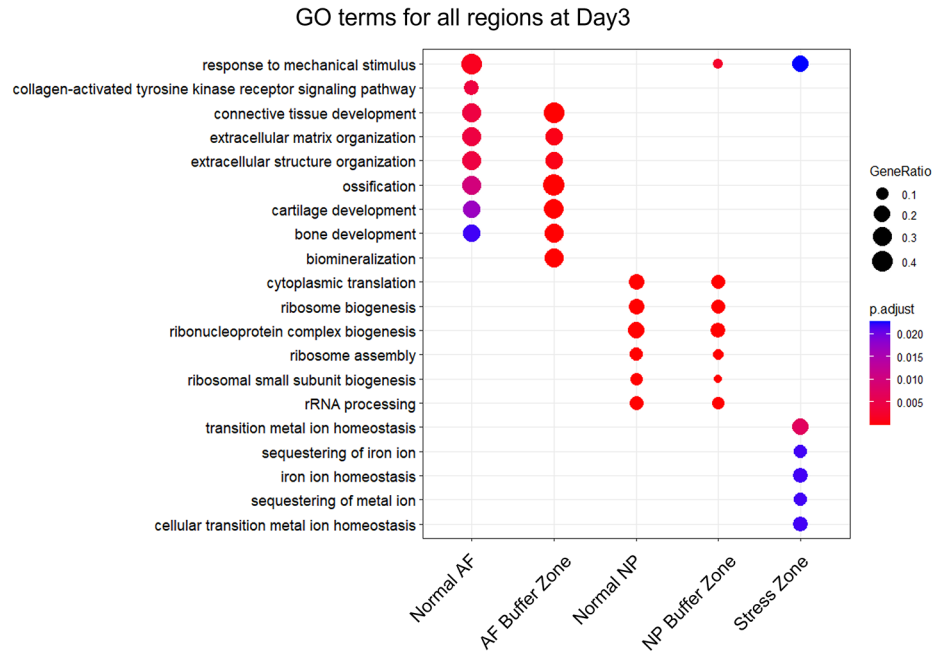

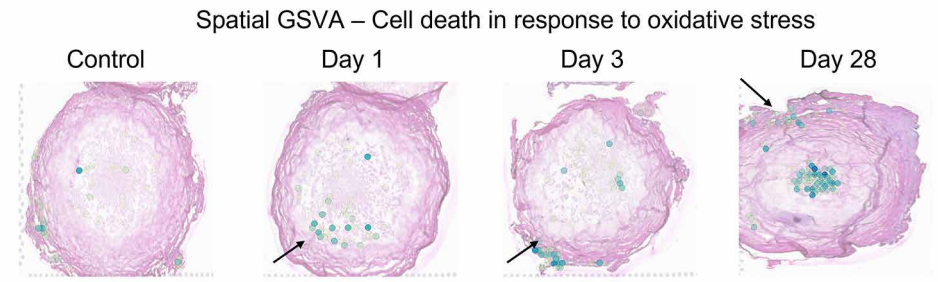

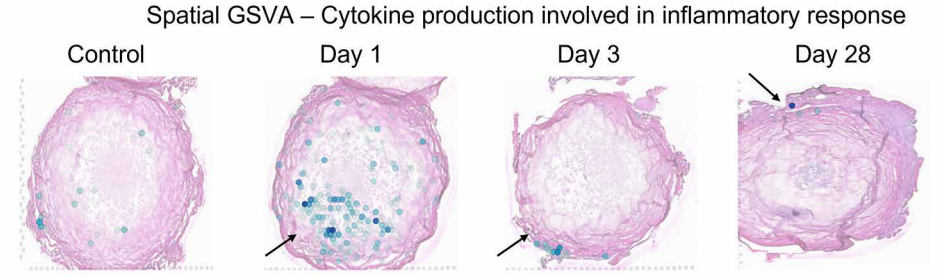

Individual Disclosures can be found in the Disclosure Index pages 18-30.
Papers are numbered based on their presentation date and time, which may be found on pages 10-16. Virtual Posters are listed after podium presentations

POSTER 39

Dynamic Cervical Spinal Canal Stenosis: Identifying Imaging Risk Factors in Extended Positions

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Introduction: A crucial aspect of cervical disorders involves dynamic factors impacting spinal cord compression during neck movement, especially neck extension. Spinal canal stenosis due to the pincer mechanism in extended positions can cause increased compression, leading to neurological dysfunction. Assessing cervical spine extension can help identify stenosis sites, improving decompression effectiveness. Dynamic cervical MRI is a useful diagnostic tool, but MRI is often obtained only in a neutral position, limiting its accuracy for detecting cervical stenosis. This study aims to identify imaging risk factors for stenosis in extended positions, undetectable in preoperative neutral MRI, to optimize surgical planning and decompression strategies.

Materials and Methods:

This study involved 143 patients who underwent decompression surgery for cervical spine disorders at a single academic institution between January 2012 and December 2014. Inclusion criteria were symptomatic cervical disorders, MRI evidence of spinal cord or nerve compression, and no previous cervical spine surgery.

Demographic data, including age, sex, body height, body weight, disease type, JOA score, and follow-up period were collected. Five spinal surgeons independently conducted radiological evaluations. Stenosis levels were determined using myelogram-CT or MRI in neutral and extended positions. This study considers the non-stenotic disc levels on the cephalocaudal side of the stenosis in the neutral position as the adjacent intervertebral disc level.

Measurements of the dural tube and spinal cord diameters at the adjacent disc levels were taken from T2-weighted sagittal MRI sections in the neutral position. Residual space available for the spinal cord (SAC) was calculated as the difference between these diameters. Cervical alignment and range of motion (ROM) were analyzed using standing lateral view plain radiographs taken preoperatively in neutral, flexion, and extension positions. Various angles and distances were measured for further analysis, such as the C2-C7 angle, C2-C5 angle, C5-C7 angle, C2-C7 sagittal vertical axis (SVA), and T1 slope.

Results: New stenosis in extension frequently appeared caudal to the site of stenosis in a neutral position, with C5/C6 and C6/C7 being the most common sites.

No significant differences in new stenosis incidence rates were observed when compared with the total number of stenosis levels or by the location of adjacent disc levels in neutral positions.

Low SAC was a significant risk factor for new stenosis development in both upper and lower adjacent disc levels. A 1mm decrease in SAC resulted in an 8.9-fold increased risk of new

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stenosis development in the upper adjacent intervertebral disc levels, and a 5.6-fold increased risk of new stenosis development in the lower adjacent intervertebral disc levels.

SAC cutoff values were established, with 1.0mm being a practical threshold for new stenosis development in both upper and lower adjacent intervertebral disc levels (AUC 0.85, sensitivity>0.95, specificity>0.94).

Conclusion: Notably, the narrowing of residual space for the spinal cord (SAC) emerged as the primary risk factor for new stenosis, with a clinically relevant cutoff value of 1 mm. The study emphasizes the importance of local factors in stenosis development. Further research is needed to understand these factors better and improve patient outcomes in cervical spine disorders.

POSTER 40

Influence of Cervical Level Fused on Subsidence of Cage and Allograft in Anterior Cervical Discectomy and Fusion

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Introduction: Anterior or posterior segmental subsidence following ACDF can contribute to cervical malalignment and worse clinical outcomes. Lower vertebral levels may see more subsidence than those further up in the cervical spine. Some studies have suggested that this may be due to the increasing weight supported by the lower cervical spine. This study aims to evaluate the differences in anterior and posterior subsidence experienced by different intervertebral surgical levels following ACDF.

Materials and Methods: This is a retrospective study of patients who underwent ACDF between 2016 and 2021 at a single institution. Lateral cervical radiographs from both the immediate postoperative period (<4 weeks) as well as from the final follow-ups (>6 months) post procedure were used to measure the anterior and posterior vertebral disc heights. Anterior and posterior cage subsidence were quantified by subtracting disc height measurements of final follow-up postoperative radiographs from disc height measurements of immediate postoperative radiographs. ANOVA statistical testing was used to examine association between cervical levels fused and subsidence. Multivariable linear regression analysis was used to control for other factors including age, sex, smoking status, osteopenia, number of levels fused, and cage-to-body ratio associated with anterior subsidence and adjusted for multiple measurements from the same patient.

Results: This study includes 131 patients who underwent a total of 244 fusions. Of the 244 segments fused, 19 (7.8%) were C3-C4 fusions, 59 (24.2%) were C4-C5 fusions, 105 (43.0%) were C5-C6 fusions and 61 (25.0%) were C6-C7 fusions. There were a variety of cage types with 68 (51.9%) allographs, 27 (%) PEEK, 22 (20.6%) titanium, 11 (8.4%) ceramic and 3 (2.3%) zero profile cages. No significant difference was found when comparing cage types between different cervical levels fused (p=0.809). There was a significant difference in the degree of anterior subsidence observed based on location of intervertebral level fused (p = 0.015) with a mean subsidence of 0.94 mm (SD 1.55) for C3-C4, 1.12 mm (SD 1.35) for C4-C5, 1.69 mm (SD 1.47) for C5-C6 and 1.80 mm (SD 1.61) for C6-C7 fusions (Figure 1). Relative to C3-C4 segmental fusions, C5-C6 fusions (beta = 0.686; 95% CI: [0.18, 1.20]; p = 0.030) and C6-C7 fusions (beta = 0.799; 95% CI: [0.24, 1.36]; p = 0.020) were associated with increased anterior subsidence in the multivariable analysis.

Conclusion: Our results suggest a correlation between fusion of lower cervical levels and increased anterior subsidence. Lower cervical vertebrae have an increased weight bearing load compared to upper cervical vertebrae, which may account for the greater degree of subsidence observed in the lower vertebrae.

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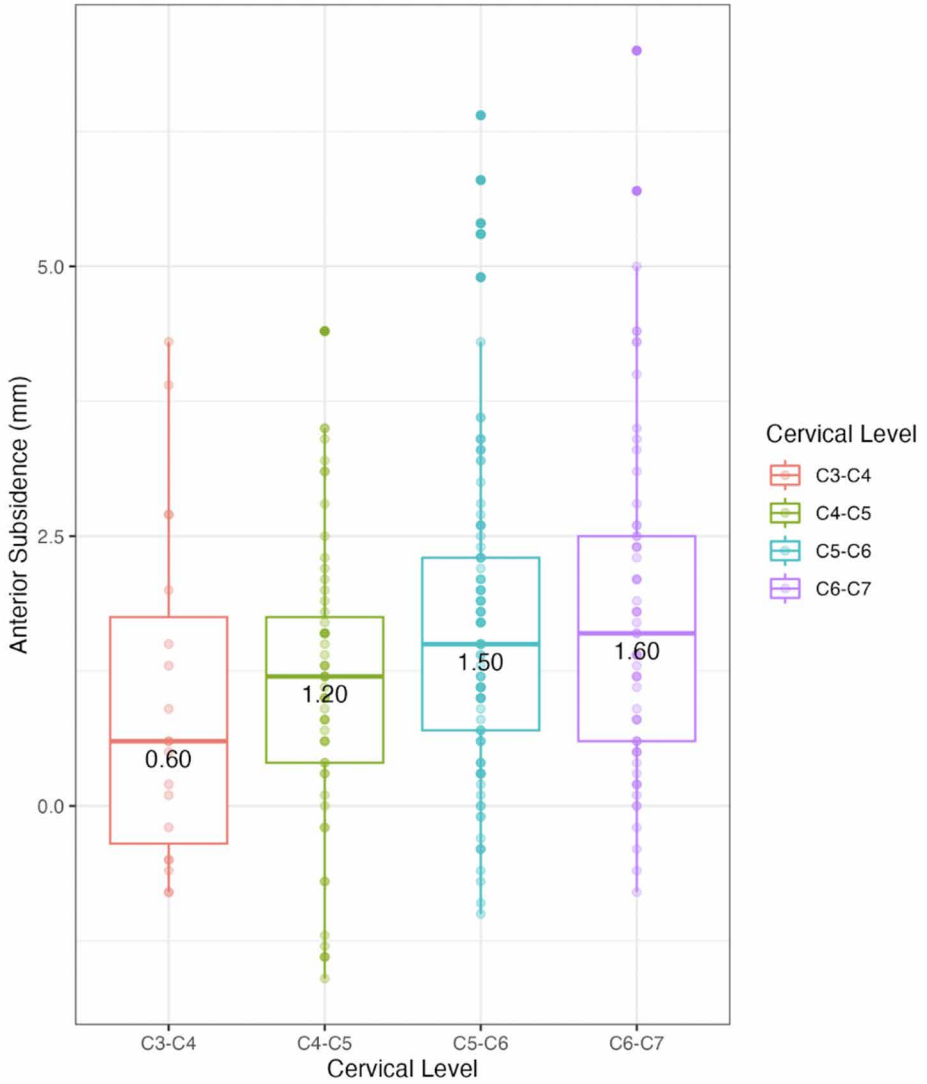
Figure 1: Boxplot comparing anterior subsidence (in mm) between different cervical levels. Horizontal bolded lines represent medians. The box represents the interquartile range (IQR). The whiskers represent 1.5 times the IQR.



POSTER 41

Anterior Cervical Discectomy and Fusion After Presentation to the Acute Care Setting: A Comparison of Post-operative Outcomes

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Introduction: For patients presenting with cervical radiculopathy or cervical myelopathy, surgical treatment is typically pursued after discussion in the outpatient setting. Yet, there exists a group of patients presenting to the acute care setting with intractable pain or progressive neurologic deficits who are indicated for operative treatment outside of outpatient evaluation. Given the differences in initial management and pre-operative optimization, it is unclear if surgical and post-operative outcomes differ between these populations.

Materials and Methods: This was a retrospective cohort study from an academic medical center. Surgical case logs from the institution's electronic medical record were used to identify patients who underwent anterior cervical discectomy and fusion (ACDF) with 4 fellowship trained orthopaedic spine surgeons from 1/1/2017 to 12/30/2021. Analysis was grouped by admission status to the hospital; those presenting for scheduled outpatient surgery ("Outpatient" group) versus those who underwent surgery after presentation to the emergency department due to acute symptoms ("ED" group). The medical record was reviewed for patient demographic information, subsequent returns to the ED without readmission, post-procedure length of stay (LOS), readmissions, and reoperations. Follow-up for late revision extended through 12/30/2022. Statistical comparisons were performed with Chi-squared and Student's t-tests.

Results: A total of 755 patients were identified for both indications (443 with radiculopathy and 312 with myelopathy); 671 patients (88.9 %) presented for scheduled outpatient surgery and 84 (11.1 %) presented through the ED. Outcomes were dichotomized by presenting complaints (Table 1). Post-operative length of stay (LOS) was shorter for those presenting with radiculopathy versus myelopathy in both the outpatient and EC groups. For those presenting with cervical myelopathy, a significantly higher rate of 90-day re-admissions was observed in patients in the ED group (29.9 % vs 5.9 %; $p < .001$). Additionally, those indicated for surgery for radiculopathy after presentation to the ED demonstrated a higher rate of return to the ED within 90 days post-operatively (17.9% vs 5.0 %; $p = .004$).

Conclusion: For patients indicated for ACDF after presenting to the acute care setting with cervical radiculopathy, there were relatively higher rates of return to the ED compared to those undergoing planned elective surgery. In this group, post-operative counseling should be focused on identifying issues appropriate for outpatient follow-up, rather than repeat presentation to the acute care setting. For those indicated for ACDF after presentation to the ED with myelopathy, a higher rate of re-admission was observed compared to the outpatient group. Further investigation is required to identify pre-operative and post-operative interventions to prevent readmission in this population.

POSTER 42

Effects of Diabetes on Pain and Patient-Reported Outcome Measures are Different between Cervical Laminoplasty and Lumbar Decompression Surgery

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Introduction: Patients with diabetes tended to have peripheral neuropathy, which can be disadvantageous for pain relief and quality of life (QOL) after treatment. However, the effects of diabetes on peripheral pain and PROMs in patients with degenerative cervical myelopathy (DCM) or degenerative lumbar disease undergoing cervical laminoplasty or lumbar decompression surgery have not been suitably characterized. Previous reports have lacked an examination of which parts of the body cause differences in pain. The aim of this study is to elucidate the effects of diabetes on peripheral pain and patient-reported outcome measures (PROMs) after cervical laminoplasty and lumbar decompression surgery.

Materials and Methods: After permission by Institutional Review Board, we performed a prospective observation study. The subjective of this study was patients who underwent laminoplasty between C3 and C7 or lumbar decompression surgery with or without fusion within three levels in 11 hospitals from April 2017 to October 2019. They were divided into diabetic and nondiabetic groups based on the diagnostic criteria for diabetes. They were asked to complete a booklet questionnaire including the Numerical Rating Scale (NRS) for pain, Euro-QOL-5 dimensions (EQ-5D), Neck Disability Index (NDI) or Oswestry Disability Index (ODI) at baseline and 12 months after surgery. NRS for pain included head, neck, upper back, arm, hand, lower back, buttock, leg, and foot. Subsequently, the intergroup baseline clinical characteristics and PROMs were compared. To adjust patients' factors, we utilized the adjusted p values by inverse probability weighting method after calculating propensity scores based on seven variables (age, sex, body mass index, smoking status, ASA class, operative time, and estimated blood loss).

Results: Of total, 1332 patients were registered. The average HbA1c was 7.0% in the diabetic group. We analyzed 339 patients as a cervical cohort (82 diabetic and 257 non-diabetic) and 993 patients as a lumbar cohort (152 diabetic and 841 non-diabetic). Preoperative NRS pain scores and EQ-5D and NDI or ODI scores were comparable between the two groups. In the diabetic group of the cervical cohort, postoperative arm and hand NRS scores, EQ-5D and NDI were similar to those of the non-diabetic group. The diabetic group tended to be satisfied with the surgical outcomes. The diabetic group of the lumbar cohort showed worse greater NRS scores for leg pain and EQ-5D/ODI one year after surgery than the non-diabetic group. The trend was preserved after an adjustment.

Conclusion: Diabetes did not adversely affect pain or PROMs 1 year after laminoplasty for DCM. However, diabetes was found to have a negative impact on postoperative outcomes after lumbar decompression surgery. The effect of postoperative diabetes may differ between central spinal cord disease and lumbar nerve root disease. It should be noted in this study that the preoperative HbA1c in the diabetic group was relatively well controlled at 7.0%.

POSTER 43

The 5-Factor Modified Frailty Index (mFI-5) Predicts Adverse Outcomes After Elective Anterior Cervical Discectomy and Fusion (ACDF)

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a reliable procedure commonly performed in older patients with degenerative diseases of the cervical spine. Frailty is an age-associated decline in functioning of multiple organ systems and has been shown to predict adverse outcomes following various spine procedures. The 11-factor modified frailty index (mFI-11) has been shown to be an effective tool for predicting complications in patients undergoing ACDF. More recent literature suggests that the 5-factor modified frailty index (mFI-5) may be a more concise and equally effective predictor of adverse events. However, there is a paucity of literature assessing the utility of the mFI-5 as a risk stratification tool for patients undergoing elective ACDF. Therefore, the purpose of this study was to analyze the predictive capability of the mFI-5 score for 30-day postoperative adverse events following elective ACDF.

Materials and Methods: A retrospective review was performed using the National Surgical Quality Improvement Program (NSQIP) database from 2010-2019. Adult (≥18 years old) patients who underwent elective ACDF were identified using Current Procedural Terminology (CPT) codes 22554, 22551, 22552, and 63075. Exclusion criteria removed patients under the age of 50, as well as those with sepsis, disseminated cancer, a prior operation in the last 30 days, ascites, wound infection, or an emergency surgery. The mFI-5 score was calculated using variables for hypertension, congestive heart failure, diabetes, chronic obstructive pulmonary disease, and partially or fully dependent functional status which were each assigned 1 point. Univariate analysis, using chi-squared and one-way analysis of variance (ANOVA) tests, was conducted to compare demographics, comorbidities, and postoperative complications across the varying cohorts based on mFI-5 scores. Multivariate logistic regression, including patient demographics and preoperative comorbidities as covariates, was performed to evaluate the impact of mFI-5 scores on the odds of 30-day postoperative adverse events.

Results: 45,991 patients were included (mFI-5=0: 16,646; mFI-5=1: 19,560; mFI-5=2: 8,865; mFI-5=3+: 920). Results from the multivariate regressions are illustrated in Table 1. Our analysis revealed that mFI-5 scores of 1 to 3+ increased the odds of overall complications (1: OR=1.2, p<0.001; 2: OR= 1.3, p=0.014; 3+: OR= 2.6, p<0.001), cardiac arrest requiring CPR (1: OR= 2.6, p=0.01; 2: OR= 2.8, p=0.013; 3+: OR= 12.6, p<0.001), pneumonia (1: OR= 1.5, p=0.012; 2: OR= 1.8, p<0.001; 3+: OR= 3.6, p<0.001) and mortality (1: OR= 2.3, p=0.016; 2: OR= 3.1, p=0.002; 3+: OR= 4.6, p<0.001). MFI-5 scores of 2 and 3 were independent predictors of readmission (2: OR=1.5, p<0.001; 3+: OR= 2.0, p<0.001) and myocardial infarction (2: OR=3.6, p<0.001; 3+: OR= 7.2, p<0.001). A score of 3+ increased the odds of acute renal failure (OR= 9.6, p=0.022), septic shock (OR= 3.7, p=0.034) and reoperations (OR= 1.8, p= 0.003).

Conclusion: In summary, the mFI-5 was an independent predictor for 30-day postoperative morbidity, reoperations, readmissions, and various complications following elective ACDF surgery in adults over the age of 50. The mFI-5 is a quick and concise risk assessment tool that

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may be used by spine surgeons to identify high risk patients for surgery in order to prevent adverse events.

Table 1. Multivariate logistic regression utilized to determine impact of mFI-5 score on adverse post-operative outcomes

Effect	Odds Ratio	95% Confidence Interval	p-value
Total Complications			
mFI-5: 1 vs. 0	1.2	1.0 – 1.3	**<0.001**
mFI-5: 2 vs. 0	1.3	1.1 – 1.5	**0.014**
mFI-5: 3 vs. 0	2.6	2.0 – 3.3	**<0.001**
Pneumonia			
mFI-5: 1 vs. 0	1.5	1.1 – 2.0	**0.012**
mFI-5: 2 vs. 0	1.8	1.3 – 2.5	**<0.001**
mFI-5: 3 vs. 0	3.6	2.3 – 5.8	**<0.001**
Acute Renal Failure			
mFI-5: 1 vs. 0	2.0	0.4 – 9.9	0.413
mFI-5: 2 vs. 0	4.8	1.0 – 24.5	0.056
mFI-5: 3 vs. 0	9.6	1.4 – 67.1	**0.022**
Myocardial Infarction			
mFI-5: 1 vs. 0	1.3	0.6 – 2.6	0.541
mFI-5: 2 vs. 0	3.6	1.7 – 7.5	**<0.001**
mFI-5: 3 vs. 0	7.2	2.7 – 19.5	**<0.001**
Bleeding Transfusions			
mFI-5: 1 vs. 0	1.2	0.8 – 1.6	0.380
mFI-5: 2 vs. 0	1.0	0.6 – 1.6	0.825
mFI-5: 3 vs. 0	2.3	1.2 – 4.2	**0.009**
Cardiac Arrest/CPR			
mFI-5: 1 vs. 0	2.6	1.3 – 5.2	**0.010**
mFI-5: 2 vs. 0	2.8	1.2 – 6.2	**0.013**
mFI-5: 3 vs. 0	12.6	5.0 – 31.6	**<0.001**
Septic Shock			
mFI-5: 1 vs. 0	1.5	0.7 – 3.3	0.303
mFI-5: 2 vs. 0	0.84	0.3 – 2.3	0.737
mFI-5: 3 vs. 0	3.7	1.1 – 12.2	**0.034**
Reoperation			
mFI-5: 1 vs. 0	1.1	0.9 – 1.3	0.267
mFI-5: 2 vs. 0	1.2	1.0 – 1.5	0.062
mFI-5: 3 vs. 0	1.8	1.2 – 2.6	**0.003**
Readmission			
mFI-5: 1 vs. 0	1.1	1.0 – 1.3	0.063
mFI-5: 2 vs. 0	1.5	1.3 – 1.8	**<0.001**
mFI-5: 3 vs. 0	2.0	1.6 – 2.7	**<0.001**
Death			
mFI-5: 1 vs. 0	2.3	1.2 – 4.5	**0.016**
mFI-5: 2 vs. 0	3.1	1.5 – 6.4	**0.002**
mFI-5: 3 vs. 0	10.6	4.6 – 24.4	**<0.001**

mFI-5= 5-factor modified frailty index; Note: p-values < 0.05 were bolded

POSTER 44

Comparing Outcomes Between Anterior Cervical Disc Replacement (ACDR) and Minimally Invasive Posterior Cervical Foraminotomy (MI-PCF) in the Treatment of Cervical Radiculopathy

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Introduction: Cervical radiculopathy is a common pathology that can be managed with various surgical options. Historically, anterior cervical discectomy and fusion (ACDF) has been utilized to address radiculopathy in patients. However, anterior cervical disc replacement (ACDR) and minimally invasive posterior cervical foraminotomy (MI-PCF) are two effective alternatives that have become increasingly popular. Both techniques provide advantages of segmental motion preservation and lower rates of adjacent segment degeneration (ASD) compared to ACDF. However, there is a paucity of literature directly comparing these two techniques using an adequate sample of patients. Therefore, the aim of this study was to compare the clinical and functional outcomes of patients undergoing 1- and 2-level ACDR or MI-PCF for the treatment of unilateral cervical radiculopathy.

Materials and Methods: A retrospective cohort review at a single institution was performed to identify all patients between 2012-2020 who underwent ACDR or MI-PCF. Patients were included in this study if they met the following criteria: adult (> 18 years of age), 1- or 2-level procedure from C3 to C7 level, minimum follow-up of 24 months, and availability of complete medical records. Patient demographics, months of follow-up, and numbers of levels operated on were assessed between the two groups. Perioperative outcomes, revision rates, and postoperative complications including dysphagia, dysphonia, infections, revisions, and ASD, were analyzed. Patient reported outcome measures based on Visual analogue scale (VAS) and Neck Disability Index (NDI) scores were recorded at follow-up visits.

Results: 158 patients were included in the study (86 ACDR and 66 MI-PCF). Patient demographics and levels operated on are shown in Table 1. There were no significant differences between the groups regarding the number of levels operated on, months of follow-up, or BMI. However, the MIPCF group was significantly older (55.7 years vs 47.2 years, $p<0.001$), and had a lower percentage of smokers (15.2% vs 36.0%, $p=0.004$) when compared to the ACDR group. The ACDR group had a significantly greater mean operative time (99.8 minutes vs 79.2 minutes, $p<0.001$) and estimated blood loss (22.4 mL vs 12.6 mL, $p<0.001$) (Table 2). Revision rates and postoperative complications are illustrated in Table 3. The overall complication rate was significantly greater in the ACDR group than the MI-PCF group (24.2% vs 6.2%; $p=0.003$), but was largely driven by the rate of approach-related dysphagia present in 20.9% of ACDR patients which resolved within 12 weeks. The MI-PCF group did demonstrate significantly greater revision rates (13.6% vs 0%; $p<0.001$) due to persistent symptoms postoperatively with an average time to revision of 20.7 months. Both groups demonstrated significant improvement in VAS and NDI scores compared to preoperative values ($p<0.001$). However, the ACDR cohort had significantly greater improvements in both VAS (3.0 vs 1.9, $p<0.001$) and NDI (21.7 vs 13.8, $p<0.001$) scores at final follow-up.

Conclusion: At final follow-up ACDR demonstrated a significantly greater complication rate

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due to transient approach-related postoperative dysphagia, whereas MIPCF had a greater rate of revision to ACDF. Therefore, ACDR may offer more clinically relevant advantages over MI-PCF in terms of long-term revision rates and patient reported outcome measures.

Table 1. Patient demographics and levels operated on

Demographic	ACDR	MI-PCF	p-value
# of patients	86	66	
1- level (%)	63 (73.2%)	46 (69.7%)	0.629
2- level (%)	23 (26.8%)	20 (30.3%)	0.629
Age (years)	47.2	55.7	**<0.001***
Males (%)	37 (43.0%)	39 (59.1%)	**0.050***
BMI (kg/m^2)	29.6	28.0	0.731
Smoking	36.0%	15.2%	**0.004***
Diabetes (%)	13 (15.1%)	9 (13.6%)	0.676
Months of Follow-Up	31.8	33.1	**<0.001***

ACDR= Anterior Cervical Disc Replacement; MI-PCF= Minimally Invasive Posterior Cervical Foraminotomy; BMI= Body Mass Index

Table 2. Perioperative data

Perioperative Data	ACDR	MI-PCF	p-value
EBL (ml)	22.4	12.6	**<0.001***
Operative Time (min)	99.8	79.2	**<0.001***

ACDR= Anterior Cervical Disc Replacement; MI-PCF= Minimally Invasive Posterior Cervical Foraminotomy; EBL= Estimated Blood Loss

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Table 3. Reoperation rates and postoperative complications

	ACDR	MI-PCF	p-value
Revisions	0 (0.0%)	9 (13.6%)	**<0.001***
Time to Revision	-	20.7 months	**<0.001***
Any Complications	21 (24.4%)	4 (6.2%)	**0.003***
ASD	4 (4.7%)	0 (0.0%)	0.076
Dysphagia	18 (20.9%)	0 (0.0%)	**<0.001***
Dysphonia	1 (1.2%)	0 (0.0%)	0.379
Infection	1 (1.2%)	1 (1.5%)	0.850

ACDR= Anterior Cervical Disc Replacement; MI-PCF= Minimally Invasive Posterior Cervical Foraminotomy; ASD= Adjacent Segment Disease

POSTER 45

Is it Safe to Perform Foraminotomies in Patients Undergoing Laminoplasty for Degenerative Cervical Myeloradiculopathy?

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Introduction: Many spine surgeons remain hesitant to perform laminoplasty in patients with myeloradiculopathy due to concerns regarding the feasibility of foraminotomies, especially in patients with bilateral or multilevel radicular symptoms. The primary purpose of the present study was to investigate whether foraminotomies can be safely performed at the time of laminoplasty. Secondarily, we sought to identify whether patients with myeloradiculopathy undergoing foraminotomy and laminoplasty achieve improved outcomes in comparison to patients undergoing isolated laminoplasty.

Materials and Methods: We retrospectively reviewed a cohort of consecutive patients undergoing laminoplasty between the years 2010-2021 at a single academic institution. Patients were included if they underwent laminoplasty for cervical spondylotic myelopathy with or without radiculopathy. Patient demographics and surgical variables were collected. Patients were then subdivided based upon whether a concomitant foraminotomy was performed within the laminoplasty levels. These two subgroups were then compared based upon patient demographics, presenting clinical symptoms, manual motor testing (MMT), patient reported outcome measures (PROMs), and complications. Student's t-tests were performed to compare means within and between groups.

Results: We identified 147 patients for inclusion in this study. The mean age in the entire cohort was 60.2 years, and there were 52 males (35.4%). Within this cohort, 73 patients underwent an isolated laminoplasty, and 74 patients underwent at least one foraminotomy in addition to their laminoplasty, including 13 patients in whom foraminotomies were performed ipsilateral to the hinge. There were no differences in baseline demographic variables or presenting clinical symptoms between subgroups (Table 1). Mean upper extremity MMT scores were similar between the two subgroups at all time points, and both the isolated laminoplasty and the laminoplasty-foraminotomy subgroups experienced a significant improvement in their mean MMT from preoperative to postoperative. There was no difference in neck disability index (NDI), visual analog scale (VAS) neck, or VAS arm scores between subgroups at any time point, and both subgroups experienced significant improvement in all of these parameters at 1 year postoperatively (Table 2). There was no difference in complication rates between subgroups. The hinge fracture rate did not differ between the isolated laminoplasty (12.3%) and laminoplasty-foraminotomy (5.4%) groups (P=0.14) (Table 3).

Conclusion: Foraminotomies can be safely performed at the same time as laminoplasty in patients with myeloradiculopathy without an increased risk of hinge fracture. Further studies are needed to identify which patients are most likely to benefit from foraminotomy at the time of laminoplasty.

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Table 1: Demographics			
	No Foraminotomy (N=73)	Yes Foraminotomy (N=74)	P Value
Demographics			
Age	62.2 (13.7)	58.2 (12.5)	0.07
Gender (Male)	44 (60.3%)	51 (68.9%)	0.27
BMI	28.9 (5.4)	28.7 (5.2)	0.8
Active smoker	8 (11.0%)	9 (12.2%)	0.82
CKD	6 (8.2%)	5 (6.8%)	0.74
Chronic Steroid Use	1 (1.4%)	1 (1.4%)	0.99
Inflammatory Arthritis	6 (8.2%)	6 (8.1%)	0.98
mFI	11.1 (15.7)	10.2 (14.0)	0.72
CCI	3.0 (2.9)	2.4 (2.8)	0.2

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Table 2: Patient Reported Outcome Measures			
	No Foraminotomy (N=73)	Yes Foraminotomy (N=74)	P Value
Neck Disability Index			
Preoperative	14.0 (8.7)	13.8 (8.7)	0.9
6 Months Postoperative	11.3 (8.8)	12.1 (8.5)	0.67
Δ Preop to 6 Months Postop	3.8 (6.8)	0.7 (7.5)	0.08
P Value	<0.01	0.54	
1 Year Postoperative	8.2 (7.6)	8.0 (6.4)	0.9
Δ Preop to 1 Year Postop	6.5 (6.9)	4.3 (7.4)	0.22
P Value	<0.01	<0.01	
VAS Neck			
Preoperative	3.5 (2.6)	3.8 (3.0)	0.7
6 Months Postoperative	1.7 (1.7)	2.0 (2.2)	0.56
Δ Preop to 6 Months Postop	2.2 (2.3)	1.4 (3.4)	0.31
P Value	<0.01	0.02	
1 Year Postoperative	1.5 (1.8)	1.3 (1.8)	0.6
Δ Preop to 1 Year Postop	2.2 (2.6)	1.9 (3.0)	0.72
P Value	<0.01	<0.01	
VAS Arm			
Preoperative	2.9 (2.8)	2.5 (3.4)	0.59
6 Months Postoperative	1.6 (2.0)	1.3 (2.3)	0.63
Δ Preop to 6 Months Postop	1.5 (3.0)	1.2 (2.9)	0.77
P Value	0.02	0.05	
1 Year Postoperative	1.0 (1.7)	1.1 (1.5)	0.78
Δ Preop to 1 Year Postop	2.0 (2.8)	1.6 (3.0)	0.72
P Value	<0.01	0.02	

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Table 3: Complications			
	No Foraminotomy (N=73)	Yes Foraminotomy (N=74)	P Value
Superficial Infection	3 (4.1%)	1 (1.4%)	0.3
Deep Infection	-	-	-
Delayed Wound Healing	1 (1.4%)	2 (2.7%)	0.57
New or Progressive Neurologic Deficit	7 (9.6%)	4 (5.4%)	0.34
Hematoma Requiring Intervention	-	-	-
Dysphagia	-	-	-
Hinge Fracture	9 (12.3%)	4 (5.4%)	0.14
Reoperation	3 (4.1%)	4 (5.4%)	0.71

POSTER 46

Cervical Spine Deformity Patients Have High Rates of Poor Sleep Quality Which Do Not Improve Following Deformity Correction

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Introduction: Poor sleep quality is associated with higher levels of pain, poor mental health and disability in patients with degenerative spinal conditions. We examined the relationship between pre-operative sleep quality and radiographic parameters of adult cervical spine deformity and impact of deformity surgery on sleep.

Materials and Methods: A retrospective analysis of a prospective multicenter CSD database stratified patients as poor sleep quality (PSQ) and normal sleep quality (NSQ) using the Neck Disability Index (NDI) sleep domain (PSQ=NDI Sleep ≥2 and NSQ=NDI Sleep≤1). Preoperative demographics, radiographic measurements, and HRQL were compared between both groups. Primary outcomes included neck pain and sleep quality at 1-year follow-up. Multivariable analysis was performed to assess neck pain and sleep quality at 1-year post-op.

Results: Of 168 patients included, 117 (69%) had PSQ pre-op. PSQ patients were younger (59.9 vs 65.0, p<0.01), had higher BMI (30.5 vs 26.8, p<0.01), worse anxiety (EQ5D 1.9 vs 1.5, p<0.01) and worse neck pain (7.4 vs 5.2, p<0.01). Radiographic measurements showed difference in C7-S1 SVA (1.3 vs -1.5, p=0.01), C7 Vertical Tilt (-0.1 vs -3.5, p=0.01), and T1 Spinopelvic Inclination (-5.0 vs -7.8, p<0.01). Univariable analysis showed that PSQ patients have worse Neck pain scores (5.0 vs 2.3, p<0.01). At one-year post-op, poor sleep persisted in 66% of patients who underwent corrective surgery. 34% of patients with normal sleep preoperatively reported poor sleep at 1 year follow up. Patients who underwent posterior approach were more likely to develop new PSQ at 1 year compared to anterior or combined (27% vs 4% vs 0,p<0.01). After controlling for possible confounders, preoperative PSQ was associated with worse Neck Pain (Difference= 0.30, [0.08 – 0.52]; p=0.007) and poor sleep (OR=6.2, [1.9 – 20]; p<0.01) at 1-year follow-up (67% Follow up).

Conclusion: Preoperative poor sleep quality in adult cervical spinal deformity patients is common and is significantly associated with preoperative malalignment. Sleep quality did not improve substantially with deformity correction, while 34% of CSD patients with normal sleep developed de novo sleep disturbance post op.

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	Poor Sleep	Normal Sleep	p-value
Age (SD)	59.9 (10.7)	65.0 (9.1)	**0.003**
Gender			0.153
Male	41 (35.3%)	24 (47.1%)	
Female	75 (64.7%)	27 (52.9%)	
Smoking	10 (8.6%)	3 (6.0%)	0.564
BMI	30.5 (8.0)	26.8 (5.4)	**0.005**
Previous Cervical Surgery	58 (50.0%)	16 (32.0%)	**0.032**
Baseline HRQL			
Depression	40 (34.4%)	13 (25.5%)	0.250
EQ5D Anxiety	1.9 (0.6)	1.5 (0.6)	**0.001**
NSR Neck Pain	7.4 (2.1)	5.2 (2.8)	**<0.001**
mJOA	13.3 (2.7)	14.1 (2.9)	0.086
SWAL-Mental	82.7 (27.2)	90.7 (20.5)	0.066
Radiographic Measurement			
C2-C7	-6.01 (20.7)	-9.3 (25.7)	0.422
SVA C2-C7	4.6 (2.5)	4.9 (2.5)	0.518
SVA C7-S1	1.3 (7.5)	-1.5 (5.4)	**0.019**
C7 Plumb Line	2.2 (2.9)	2.3 (2.0)	0.810
C7 Vertical Tilt	-0.1 (8.2)	-3.5 (6.2)	**0.01**
T1 Spinopelvic Inclination	-5.0 (6.3)	-7.8 (5.5)	**<0.01**
Outcomes at 1 year			
NSR Neck Pain	5.0 (2.8)	2.3 (2.4)	**<0.01**
Poor Sleep Quality	54 (66%)	28 (34%)	**<0.01**
mJOA Score	13.9 (3)	14.4(3)	0.37

POSTER 47

Prediction of Hospitalization Length and Discharge Disposition After Instrumented Cervical Fusion

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Introduction: With an increase in value-based payment models, there is increasing interest in identifying areas of cost reduction. The length of hospitalization is a major contributor to healthcare costs; a single day of hospitalization can increase costs by over $5,000 in the United States [1]. A large proportion of the total length of hospitalization is attributable to delay in placement to a skilled nursing or rehabilitation facility [2]. Additionally, delays in discharge may contribute to development of perioperative complications such as delirium and hospital-acquired infection. Prediction of non-home discharge timing after instrumented cervical fusion may improve discharge planning, potentially decreasing costs and improving outcomes. We aim to develop a classification model predicting non-home discharge after instrumented cervical fusion as well as perform a survival analysis to predict length of hospitalization.

Materials and Methods: Consecutive adult patients who underwent instrumented cervical fusion at our institution between 2013-2020 were included. The primary outcome was time to non-home discharge, defined as discharge to a skilled nursing facility or acute rehabilitation hospital. Surgical approach, pre-operative neurologic symptoms, and medical/psychiatric comorbidities were included as explanatory features. We built an ensemble machine learning model as well as standard machine learning and logistic regression models. Discrimination was assessed using the area under the receiver operating characteristic curve (AUROC) and area under the precision-recall curve (AUPRC). Calibration was assessed using the calibration slope, calibration intercept, and Brier score. For survival analysis, we employed the following models: accelerated failure time, Cox proportional hazard, random survival forest, extreme survival forest, and temporal quilting. Time-dependent concordance index (c-index) and Brier score are reported.

Results: A total of 1,024 patients met inclusion criteria. Two hundred and sixty-four (25.8%) patients had a non-home discharge. The ensemble model had excellent discrimination with an AUROC of 0.891 $\pm$ 0.018 and AUPRC of 0.749 $\pm$ 0.040. The model was well-calibrated with a calibration slope of 1.10, calibration intercept of -0.023, and Brier score of 0.114. The following features were the most important for performance of the model: pre-operative motor deficit, spinal trauma, posterior instrumentation, anterior-posterior approach, pre-operative bladder dysfunction, pre-operative radicular symptoms, interbody fusion, bipolar disorder, prior epidural steroid injection, and spinal metastasis (Table 1). The extreme survival forest model predicts discharge within three days with a time-dependent c-index of 0.864 $\pm$ 0.028. The temporal quilting model predicts discharge within five and seven days with a time-dependent c-index of 0.838 $\pm$ 0.011 and 0.817 $\pm$ 0.011, respectively.

Conclusion: We report a well-calibrated ensemble algorithm for prediction of non-home discharge after instrumented cervical fusion. With an AUROC of 0.891, this model has excellent discrimination. Additionally, we provide models that accurately predict the likelihood of discharge at three different time points: three, five, and seven days. To our knowledge, these

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represent the first ML algorithms predicting discharge destination and time to discharge after instrumented cervical fusion. Physicians underestimate the risk of non-home discharge in their patients and systems overestimate the time to discharge [3]. Implementation of these models may thus facilitate improved discharge planning, reducing costs and complications associated with prolonged hospitalization.

Table 1. Relative feature importance for ensemble model performance for prediction of non-home discharge after instrumented cervical fusion

Feature	Rank
Binary features	
Pre-operative motor weakness	1
Spinal trauma	2
Posterior instrumentation	3
Anterior-posterior approach	4
Bladder dysfunction	5
Radicular symptoms	6
Interbody fusion	7
Bipolar disorder	8
Prior epidural steroid injection	9
Metastatic disease	10
Continuous features	
Pre-operative hemoglobin	1
Age	2
Number of fused levels	3
Pre-operative white blood cell count	4
Charlson comorbidity index	5
Body mass index	6

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Clinical Outcomes of Posterior Cervical Surgery in Patients with Ossification of the Posterior Longitudinal Ligament

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Introduction: Laminoplasty and laminectomy with fusion are recognized as two reliable and effective methods in treating multilevel ossification of the posterior longitudinal ligament(OPLL) of the cervical spine. However, there is a continuous debate on which surgery is better. Therefore, this study aimed to compare the clinical outcomes of cervical laminoplasty and cervical laminectomy with fusion for treatment of OPLL.

Materials and Methods: This study included patients who underwent posterior cervical spine surgery for OPLL from March 2014 to December 2021. 135 patients underwent laminoplasty and 82 patients underwent laminectomy with fusion. The clinical outcomes were evaluated with neck pain visual analogue scale (VAS), arm pain VAS, Japanese Orthopedic Association (JOA) score, neck disability index (NDI) and the patient-reported subjective improvement rate (IR). These parameters were evaluated preoperatively, postoperative 6 months, 1 year, and 2 years. Clinical outcomes were analyzed using an independent two sample t-test and linear mixed model.

Results: The cohorts were well matched by age (p=0.471), gender (p=0.261) and follow-up duration (p=0.157) between the two groups. In both groups, all clinical outcomes improved after surgery compared to preoperative status. There were no significant differences in neck pain, arm pain, JOA score, and self-improvement rate pre- and postoperatively (6 months, 1 year and 2 years). The NDI was not significantly different between the laminoplasty (17.14) and the laminectomy with fusion (19.95) before surgery. (p=0.163) However, at postoperative 6 months, there was a difference, with the laminoplasty (10.05) showing lower NDI compared to the laminectomy with fusion (14.67). (p=0.001) At 1-year post-surgery, the NDI was 9.48 in the laminoplasty and 14.31 in the laminectomy with fusion, with statistically significant difference. (p=0.001) Additionally, at postoperative 2 years, the NDI was 9.50 in the laminoplasty and 12.84 in the laminectomy with fusion, also showing a significant difference. (p=0.029) Additionally, by separately analyzing the specific items consisting the NDI, laminectomy with fusion group showed higher NDI scores compared to laminoplasty group in the areas of personal care, lifting, work, driving, and recreation (p=0.001).

Conclusion: Both laminoplasty and laminectomy with fusion demonstrated excellent clinical outcomes in patients with OPLL after surgery. But the laminectomy with fusion showed higher neck disability scores after surgery compared to the laminoplasty, particularly in the NDI subcategories with higher activity levels.

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What Perioperative Factors are Associated with High-Risk Daily Morphine Milligram Equivalents in Cervical Spinal Fusions?

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Introduction: Morphine Milligram Equivalent (MME) dosing recommendations were introduced in 2016 by the Centers for Disease Control and Prevention (CDC) as a guideline for primary care providers to aid in understanding the cumulative effect of opioids and the risk associated with long term use in chronic pain patients. The formula is defined as: Strength per Unit X (Number of Units/Days Supply) X MME = MME/Day. Daily dosages of ≥ 100 MME/day are associated with an almost nine-fold increased risk of overdose. Current general recommendations endorse the lowest effective dose and ≤ 50 MME/day. We sought to understand how many patients undergoing cervical spinal fusions received opioids at higher risk doses and which patient demographic and historical factors could predict this higher risk.

Materials and Methods: Retrospective analysis was conducted on 237 patients that underwent one to six level cervical fusion within a multi-center network over 2 years. All surgeries were conducted in a hospital system that encourages surgeons to deploy multi-modal post-operative pain pathways. Average MME/day was calculated as the sum of qualifying inpatient MMEs administered divided by the sum of inpatient length of stay (LOS). 14 independent variables were collected from demographic, clinical and surgical domains and were subject to comparative analysis. Data was then grouped and coded for logistic regression analysis.

Results: Overall mean MME per day was 67.32 ± 42.34, with a range of 0-188.54 MME/day. "High MME" was defined as greater than the overall upper quartile value, 95.02 MME/day. A total of 60 patients were determined to have "High MME" during their inpatient stay. Patients with high MMEs were significantly younger than those with MMEs within normal limits (WNL), 52.87 ± 11.33 vs 59.49 ± 11.94 respectively. (p= 0.0002). Patients age ≤60 accounted for 70% (n=42) of the High MME group. 23.3% were categorized "young" (25-44 years) and 46.7% were "middle" aged (45-60 years). There were also significant differences between the two groups in terms of preoperative prescriptions for opioids. 32.3% (n=32) of patients with High MMEs had an active preoperative opioid prescription vs 20.3% (n=28) of those with MMEs WNL. There we no significant demographic or intraoperative differences between the groups, nor any significant difference in length of stay. When subject to logistic regression the final optimized model returned a test recall value of 0.61, identifying age as the only significantly variable affecting the odds ratio. For each unit decrease in age, risk increased by 0.48 or 51.9%.

Conclusion: Patients with high MME/day who underwent one to six level cervical fusions were significantly younger and more likely to have been prescribed preoperative opioids than cervical fusion patients with MME WNL. Younger age at the time of surgery significantly impacted the risk of high MME. As a result, pre-operative opioid risk education and mitigation strategies should be considered for those at risk, especially in the younger spine population.

POSTER 52

When to Initiate Post-Operative Physical Therapy in Multilevel Posterior Cervical-Thoracic Fusions?

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Introduction: The role of Physical Therapy (PT) in patients undergoing surgery for cervical spondylotic myelopathy is understudied and not well understood. Current literature reports varied effects on outcomes, and thus post-operative standards of care neither address nor include PT in post-op posterior cervico-thoracic fusions. The aim of this study was to analyze when neck strengthening exercise should be initiated after multilevel posterior cervical-thoracic fusions.

Materials and Methods: Retrospective chart reviews were conducted between 2016-2020 on patients who underwent a ≥3 level posterior cervico-thoracic fusion with caudal levels as C7 and T1/T2. Prescription and completion of PT were study inclusion criteria. Demographic, clinical, and radiographic data was collected at structured intervals from preoperative to two years postoperative. % Improvement for cervical lordosis, T1 slope and C2-C7 sagittal plumbline was compared at 2 weeks and 2 years post-op. Visual Analog Scale (VAS) for pain and Oswestry Disability Index (ODI) scores were similarly analyzed.

Results: 105 patients were included in the study and were divided into two cohorts: those that initiated PT ≤ 6 weeks post-op and those who initiated PT > 6 weeks post-op. 58 patients were included in the Early PT cohort, and 47 were included in the Late PT cohort. Demographically, the Early PT and Late PT cohorts were similar in age (62.8 vs 61.1 years, respectively) and predominantly female (64.5% vs. 67.6%, respectively). No significant difference was reported between the groups in body mass index, with a mean of 30.7 for Early PT and 31.2 for Late PT. While both cohorts showed improvement in radiographic parameters and patient reported outcomes at 2 years post-op, there were significant differences in level of improvement between the two groups. The Early PT group had a comparatively better % improvement in cervical lordosis (25.2% vs 14.2%); mean T1 slope (-5.6% vs. -2.6%); and mean C2-C7 sagittal plumbline (-15.2% vs -11.7%). Patients who started PT ≤ 6 weeks post-op also reported greater VAS % improvement 61.9% vs 41% and Oswestry Disability Index % improvement 46.3% vs. 29.6% at 2 years post-op.

Conclusion: Patients who underwent a three or more-level posterior cervico-thoracic fusion and started PT at or before 6 weeks post-op exhibited greater radiographic and patient reported outcomes benefits than those starting PT more than 6 weeks post-op. The results of this study support the early initiation of neck strengthening PT in most uncomplicated post-cervical fusion adult patients.

POSTER 53

Clinical Outcomes of Cervical Disc Arthroplasty (CDA) in Keel vs Keel-less implants: Early Results

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Introduction: Cervical Disc Arthroplasty (CDA) has proven to be comparable to Anterior Cervical Discectomy and Fusion (ACDF) for treating various cervical pathologies. CDA has also shown a much greater potential in preserving the cervical range of motion. Keel and Keel-less implants have been utilized for CDA but the clinical outcomes for the patients for the respective implants have yet to be explored in detail. We aim to compare the patient-reported outcome measures (PROMs) for the CDA for keel vs keel-less groups.

Materials and Methods: 37 patients with keeled implants CDA and 122 with keel-less implant CDA were retrospectively analyzed with a minimum follow-up for 6 months from 2017 to 2021. Patient-reported outcomes (PROMS) - Neck Disability Index (NDI), Short Form 12-Item Physical Health Score (SF12-PHS), Short Form 12-Item Mental Health Score (SF12-MHS), Visual Analog Scale (VAS), PROMIS Physical Function (PROMIS PF), PROMIS Physical Health (PROMIS PH) and PROMIS Mental Health (PROMIS MH) were utilized. Descriptive statistics were utilized to compare early and late PROMs. Changes in PROMs from preoperative values to early (<6 months) and late (>=6 months) time points and percentage of people achieving minimally clinically important difference (MCID) were compared between different groups.

Results: A total of 159 patients (37 keeled and 122 keel-less implants) were included in the study. A more significant proportion of patients undergoing primary CDA had keel-less implants (94.3%, p=0.042). The keeled implant group demonstrated lesser preoperative VAS arm and neck scores as compared to the keel-less implant group ($p<0.05$). Both keeled and keel-less implant cohorts showed significant improvement in early and late NDI, VAS arm and neck, PROMIS-PF, and PROMIS PH scores. Patients with keel-less implants showed more significant improvement in VAS-neck as compared to the keeled implant group ($p<0.05$). 56.5% of patients with keel-less implants achieved MCID as compared to 32% of patients with keeled implants for PROMIS-PH outcome at early time point($p<0.05$). No statistically significant difference was found in the MCID achievement rates for NDI, VAS- arm and neck, SF-12PHS, SF-12MHS, and PROMIS PF in both the cohorts.

Conclusion: Keeled and keel-less implants show comparable clinical outcomes at early and late time points in patients undergoing CDA. While the early results are comparable between both groups, long-term outcomes are awaited.

POSTER 54

Association Between Cervical Paraspinal Muscle Health and Patient-Reported Outcomes After Anterior Cervical Discectomy and Fusion

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Introduction: MRI-based measurements of lumbar paraspinal muscle health have been associated with patient-reported outcome measures (PROMs) following lumbar spine surgery. However, there is a paucity of literature evaluating the importance of cervical paraspinal muscle health on clinical outcomes following cervical spine surgery. The purpose of this study is to evaluate for an association between cervical paraspinal muscle health and PROMs following anterior cervical discectomy and fusion (ACDF).

Materials and Methods: Axial T2-weighted MRI were assessed at C2-3 and C5-6 levels for muscle health measurements. The degree of fatty infiltration of the paraspinal muscles were assessed utilizing the Goutallier Classification. Bilateral cross-sectional areas were measured for the following muscle groups: Deep Extensors (DE), Superficial Extensors (SE), Deep Flexors (DF), Superficial Flexors (SF), Sternocleidomastoid (SCM), Trapezius. Bilateral cross-sectional areas were normalized by the square of the patient's height to compute the cervical paraspinal muscle index (CPMI). Mean preoperative PROMs and mean improvement in PROMs were compared based on Goutallier grade using independent t-test. Bivariate analyses were performed to assess for correlations between CPMI and PROMs. The muscle health measurements were compared between patients who achieved patient acceptable symptom state (PASS) for NDI vs. those who did not.

Results: A total of 74 patients were included (30 one-level, 26 two-level, 15 three-level, and 3 four-level ACDF). Higher Goutallier grade was significantly associated with higher preoperative NDI (37.9 vs. 30.2, p=0.029), greater change in NDI (22.8 vs. 15.5, p=0.035), greater change in VAS arm (4.0 vs. 2.6, p=0.047), and lower preoperative PROMIS-PF (39.7 vs. 44.4, p=0.036) (Table 2). DE CPMI significantly correlated with NDI change, preoperative VAS neck, VAS neck change, preoperative VAS arm, preoperative SF-12 PCS, and SF-12 PCS change. Complete CPMI correlations with PROMs are detailed in Table 3. Lastly, patients who achieved PASS for NDI had significantly greater DE CPMI compared to those who did not meet PASS (Table 4).

Conclusion: Our analysis reveals that both qualitative and quantitative measurements of cervical paraspinal muscle health are associated with patient-reported outcomes following ACDF. Greater fatty infiltration was associated with higher preoperative disability and greater postoperative improvement in pain/disability from baseline. Cross-sectional areas of the deep extensor muscles were most often found to be associated with PROMs. Greater cross-sectional areas generally correlated with lower preoperative pain/disability, greater improvement in PROMs, and higher rate of PASS achievement for NDI. Given these associations between cervical paraspinal muscle health and PROMs, assessment of baseline muscle health may serve as a valuable component of preoperative evaluation among patients undergoing ACDF.

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Table 1. Patient and Procedural Characteristics

	N	%
Total	74	
Age (years), mean ± SD	58.1 ± 9.9	
Female sex	25	33.8%
Non-white race	10	13.5%
Hispanic ethnicity	2	2.7%
BMI (kg/m^2), mean ± SD	27.7 ± 5.5	
CCI ≥1	57	77.0%
Smoking	21	28.4%
Depression	12	16.2%
Anxiety	15	20.3%
ACDF number of levels		
1-level	30	40.5%
2-level	26	35.1%
3-level	15	20.3%
4-level	3	4.1%
ACDF levels		
C3-C4	10	13.5%
C4-C5	36	48.6%
C5-C6	55	74.3%
C6-C7	33	44.6%
C7-T1	5	6.8%

SD, standard deviation. BMI, body mass index. CCI, Charlson Comorbidity Index. ACDF, anterior cervical discectomy and fusion.

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Table 2. Association between Goutallier Grade and Patient-Reported Outcomes

	Total	Goutallier ≤2	Goutallier >2	*p* -value
NDI				
N of patients	74	45	29	
Mean preoperative score	33.2 ± 17.1	30.2 ± 17.8	37.9 ± 15.0	**0.029**
Mean Δ score at LTFU	18.4 ± 16.9	15.5 ± 18.5	22.8 ± 13.1	**0.035**
VAS Neck				
N of patients	73	44	29	
Mean preoperative score	4.6 ± 3.0	4.5 ± 3.1	4.8 ± 3.0	0.336
Mean Δ score at LTFU	2.6 ± 2.9	2.7 ± 2.9	2.6 ± 2.9	0.457
VAS Arm				
N of patients	73	44	29	
Mean preoperative score	4.7 ± 3.3	4.5 ± 3.5	4.9 ± 3.1	0.480
Mean Δ score at LTFU	3.2 ± 3.5	2.6 ± 3.6	4.0 ± 3.3	**0.047**
SF-12 Physical Component				
N of patients	63	36	27	
Mean preoperative score	37.8 ± 10.8	38.6 ± 11.3	36.6 ± 10.1	0.234
Mean Δ score at LTFU	6.1 ± 11.3	6.3 ± 10.3	5.9 ± 12.7	0.449
SF-12 Mental Component				
N of patients	63	36	27	
Mean preoperative score	49.5 ± 10.9	49.4 ± 11.5	49.5 ± 10.2	0.488
Mean Δ score at LTFU	5.4 ± 9.3	5.1 ± 10.3	5.8 ± 8.0	0.387
PROMIS Physical Function				
N of patients	59	36	23	
Mean preoperative score	42.5 ± 10.0	44.4 ± 10.1	39.7 ± 9.4	**0.036**
Mean Δ score at LTFU	7.0 ± 10.8	6.3 ± 10.9	10.1 ± 10.3	0.102

NDI, Neck Disability Index. VAS, visual analogue scale. SF-12, 12-Item Short Form Survey. PROMIS, Patient-Reported Outcomes Measurement Information System. LTFU, long-term follow-up.

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Table 3. Bivariate Analysis of Cervical Paraspinal Muscle Index and Patient-Reported Outcomes

	C2-C3 CPMI				C5-C6 CPMI					
	DF	DE	SE	SCM	DF	DE	SE	SCM	Trapezius	Levator sc.
NDI										
Preoperative	-0.65 p=0.587	-0.23 p=0.053	-0.23 p=0.051	-0.01 p=0.985	0.13 p=0.283	-0.18 p=0.123	**-0.25** **p=0.039**	-0.10 p=0.553	-0.11 p=0.346	-0.09 p=0.483
Δ NDI	-0.11 p=0.341	**-0.25** **p=0.037**	-0.22 p=0.063	-0.13 p=0.466	0.09 p=0.445	0.028 p=0.816	-0.16 p=0.179	-0.13 p=0.474	-0.05 p=0.668	-0.05 p=0.702
VAS Neck										
Preoperative	-0.07 p=0.561	-0.21 p=0.071	**-0.24** **p=0.047**	-0.06 p=0.732	0.06 p=0.615	**-0.23** **p=0.049**	**-0.24** **p=0.048**	-0.15 p=0.389	**-0.25** **0.039**	-0.21 p=0.079
Δ VAS Neck	-0.03 p=0.797	**-0.29** **p=0.014**	**-0.22** **p=0.072**	-0.17 p=0.329	0.05 p=0.672	-0.14 p=0.259	-0.16 p=0.187	-0.18 p=0.306	-0.17 p=0.154	-0.15 p=0.215
VAS Arm										
Preoperative	0.01 p=0.989	**-0.27** **p=0.024**	-0.20 p=0.092	0.18 p=0.314	0.20 p=0.096	-0.01 p=0.996	-0.15 p=0.202	0.10 p=0.554	-0.02 p=0.879	-0.09 p=0.442
Δ VAS Arm	-0.01 p=0.941	-0.22 p=0.066	-0.08 p=0.532	0.17 p=0.329	**0.26** **p=0.027**	0.11 p=0.345	-0.13 p=0.292	0.10 p=0.568	-0.02 p=0.892	0.01 p=0.949
SF-12 PCS										
Preoperative	0.03 p=0.844	**0.28** **p=0.028**	0.19 p=0.144	-0.29 p=0.100	**0.26** **p=0.039**	0.07 p=0.577	0.13 p=0.313	-0.02 p=0.903	0.04 p=0.732	-0.15 p=0.257
Δ SF-12 PCS	-0.14 p=0.302	**-0.34** **p=0.007**	-0.17 p=0.192	0.02 0.924	0.17 p=0.187	0.10 p=0.460	-0.13 p=0.309	-0.04 p=0.826	-0.05 p=0.731	-0.02 p=0.861
SF-12 MCS										
Preoperative	0.04 p=0.788	-0.03 p=0.812	0.09 p=0.509	-0.03 p=0.854	0.18 p=0.168	0.10 p=0.430	-0.01 0.988	0.10 p=0.577	0.22 p=0.085	0.12 p=0.368
Δ SF-12 MCS	-0.01 p=0.986	-0.13 p=0.325	-0.17 p=0.187	-0.23 0.202	0.03 p=0.813	-0.01 p=0.920	-0.12 p=0.351	-0.21 p=0.227	0.01 p=0.968	0.07 p=0.611
PROMIS-PF										
Preoperative	0.08 p=0.574	0.13 p=0.314	0.06 p=0.667	-0.05 p=0.777	-0.24 p=0.07	0.09 p=0.524	0.12 p=0.380	-0.03 p=0.880	0.01 p=0.921	-0.05 p=0.702
Δ PROMIS-PF	-0.13 p=0.347	-0.16 p=0.244	-0.07 p=0.624	-0.07 p=0.703	0.07 p=0.642	0.19 p=0.167	-0.12 p=0.398	-0.04 p=0.847	0.07 p=0.646	-0.02 p=0.914

Pearson correlation coefficient (r). Bold indicates statistical significance (p <0.05). CPMI, cervical paraspinal muscle index (cross-sectional area normalized by square of height). DF, deep flexors. DE, deep extensors. SE, superficial extensors. SCM, sternocleidomastoid.

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Table 4. Cervical Paraspinal Muscle Health and PASS Achievement for NDI

	Total Cohort	PASS Achieved	PASS Not Achieved	*p* -value
N of subjects	74	51	23	
Goutallier Grade				
≤2	45	33 (64.7%)	12 (52.2%)	0.318
>2	29	18 (35.3%)	11 (47.8%)	
C2-C3 CPMI (mm^2/m^2)				
Deep flexors	95.9 ± 20.7	96.9 ± 20.0	93.9 ± 22.4	0.296
Deep extensors	144.3 ± 70.1	141.2 ± 71.6	150.7 ± 67.9	0.294
Superficial extensors	745.5 ± 233.9	747.8 ± 240.1	740.8 ± 225.4	0.452
Sternocleidomastoid	221 ± 55.6	218.7 ± 58.2	227.3 ± 51.3	0.337
C5-C6 CPMI (mm^2/m^2)				
Deep flexors	59.5 ± 22.9	59.0 ± 23.2	60.6 ± 22.7	0.383
Deep extensors	223.4 ± 65.2	**233.3 ± 60.0**	**202.3 ± 71.9**	**0.040**
Superficial extensors	414.5 ± 121.4	429.3 ± 129.8	383.8 ± 96.9	0.070
Sternocleidomastoid	322.5 ± 83.8	327.1 ± 67.8	312.6 ± 114.8	0.320
Trapezius	540.9 ± 300.3	561.9 ± 313.5	496.9 ± 271.9	0.198
Levator scapulae	283.4 ± 93.8	290.5 ± 96.7	268.6 ± 87.8	0.347

Bold indicates statistical significance ($p < 0.05$). CPMI, cervical paraspinal muscle index (cross-sectional area normalized by square of height). PASS, Patient Acceptable Symptom State.

POSTER 55

High-Volume Cervical Fusion Hospitals are Associated with Lower Hospital Resource Utilization: A Database Study of 28,507 Medicare Claims in 2019

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Introduction: With the advent of bundled payments in spine surgery, there is an increasing emphasis on value-based spine care, involving both quality and cost.[1] Economies of scale have been demonstrated to reduce costs of care in lower extremity arthroplasty.[2] However, there remains a paucity of literature on the impact of hospital volume on costs of spine surgery. The purpose of this study was to assess the impact of hospital volume on cost, length of stay, and discharge destination for elective inpatient cervical spine surgery procedures in a Medicare population.

Materials and Methods: The 2019 Medicare Provider Analysis and Review (MEDPAR) Limited Data Set (LDS) and Centers for Medicare and Medicaid Services (CMS) 2019 Impact File were utilized for this project. Diagnosis Related Group (DRG) codes for cervical fusion (473, 472, 471) were identified (n=53,165), of which elective cases were included (n=43,081, 81%). Medicare advantage patients were excluded due to non-Inpatient Prospective Payment System hospitalizations (n=14,574), leaving 28,507 cases for analysis (66%). Hospital volumes were calculated by stratifying number of claims by National Provider ID and binned into cohorts of low volume (1-25 cases), medium volume (26-50 cases), or high volume (51+ cases). Total cost of index hospital admission was calculated using cost-to-charge ratios, a validated costing methodology. Multivariate models were created for length of stay, total cost, and discharge destination, controlling for DRG comorbidity or complication codes, demographics, comorbidities, indication, surgical details, and hospital characteristics.

Results: There were 1,804 different hospitals included, of which 1,462 were low volume (81%), 241 were medium volume (13%), and 101 high volume (6%) centers. There were 12,770 cases performed in low volume (45%), 8,350 cases performed in medium volume (29%), and 7,387 cases performed in high volume (26%) hospitals. On univariate analysis of all spine surgery cohorts, medium volume hospital costs ($21,467±11,003) were less than low ($23,399±13,006) and high ($22,109±12,619) volume hospitals ($p<0.001$). Incidence of non-home discharge was lowest for high-volume hospitals (14%), compared to 17% for low and 16% for medium volume hospitals ($p<0.001$).

Multivariate regression showed that increased hospital volume was associated with decreased cost (-$1,152 for medium volume, -$2,304 for high volume, $p<0.001$), decreased length of stay (-0.148 days for medium volume, -0.296 days for high volume, $p<0.001$), and decreasing risk of non-home discharge (adjusted odds ratio: 0.777 for medium volume and 0.597 for high volume, $p<0.001$) (Table 1).

Conclusion: Higher-volume hospitals were associated with lower cost, shorter length of stay, and decreased risk of non-home discharge for elective inpatient cervical fusions in a Medicare population. High-volume centers may benefit from economies of scale, such as bulk purchasing, and lean methodology practices that should be studied to improve value

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on a national level. Additionally, small and medium hospitals may be disproportionately impacted by declining Medicare reimbursements, which may create financial disincentives that discourage treatment of Medicare patients. This could limit access to care for rural and underserved communities that are often treated by small-volume hospitals. Further study is necessary to provide fair reimbursement adjustments as bundled payments for spine surgery are introduced.

Table 1. Multivariate Analysis of Outcomes by Hospital Volume

	Low	Medium	High	95% Confidence Interval	P-value
Cost ($)	Reference	-1152	-2304	-1328- -978	<0.001
Length of Stay (Days)	Reference	-0.148	-0.296	-0.183- -0.114	<0.001
Non-home discharge	Reference	0.777	0.597	0.715-0.844, 0.544-0.655	<0.001

POSTER 56

Preoperative Disability Influences Effectiveness of MCID and PASS in Predicting Patient Improvement Following Cervical Spine Surgery

Pratyush Shahi, MBBS[1], Omri Maayan, BS[1], Tejas Subramanian, BE[1], Nishtha Singh, MBBS[1], Sumedha Singh, MD[1], Kasra Araghi, BS[1], Olivia Tuma, BS[1], Maximilian Korsun, BS[1], Tomoyuki Asada, MD[1], Evan Sheha, MD[1], James Dowdell, MD[1], Sheeraz Qureshi, MD MBA[1], Sravisht Iyer, MD[1]
Hospital for Special Surgery[1]

Introduction: There are two metrics for the interpretation of Neck Disability Index (NDI) - minimal clinically important difference (MCID) and patient acceptable symptom state (PASS). MCID is the smallest change in NDI following surgery that would be clinically significant for the patient. PASS is an absolute postoperative NDI score, unlike MCID which is a change score, below which patients are expected to achieve an acceptable symptom state. It is unclear if there is a clear better metric between the two or which metric should be utilized when. Answering these questions can help substantiate our understanding regarding the clinical interpretation of NDI as an outcome measure. The objective of this study was, therefore, to compare the characteristics and predictive power of MCID and PASS when interpreting NDI following cervical spine surgery.

Materials and Methods: This retrospective cohort study included patients who underwent primary anterior cervical discectomy and fusion (ACDF), cervical disc replacement (CDR), or laminectomy and had ≥6 months of follow-up data. The global rating change (GRC) and NDI data at 6 months/1 year/2 years were analyzed. The response on GRC was used as the anchor to assess the improvement status - "Compared to preoperative, you feel 1) much better, 2) slightly better, 3) same, 4) slightly worse, or 5) much worse." It was collapsed to a dichotomous outcome variable – a) improved (response of 1 or 2), b) not improved (response of 3,4, or 5). MCID was achieved if the difference between preoperative and 1-year NDI was ≥10.5 [1]. PASS was achieved if the 1-year NDI was ≤21 [2]. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of MCID and PASS in terms of predicting improvement on GRC were calculated for the overall cohort and separately for patients with minimal (NDI <30), moderate (NDI 30 – 49), and severe (NDI ≥50) preoperative disability [3]. Two groups with patients who achieved PASS but not MCID and patients who achieved MCID but not PASS were also analyzed.

Results: 141 patients (206 data points) were included. PASS had significantly greater sensitivity for the overall cohort (85% vs. 73% with MCID, p=0.02) (Table 1) and patients with minimal disability (96% vs. 53% with MCID, p<0.001). Contrastingly, MCID had greater sensitivity for patients with severe disability (78% vs. 57% with PASS, p=0.05). Sensitivity was not significantly different for PASS and MCID in patients with moderate preoperative disability (83% vs. 92%, p=0.1). 17% of patients achieved PASS but not MCID and 9% of patients achieved MCID but not PASS, with the preoperative NDI being significantly greater in the latter. Most of these patients still reported improvement with no significant difference between the two groups (89% vs. 72%, p=0.13).

Conclusion: PASS is a better metric for patients with minimal preoperative disability and MCID is a better metric for patients with severe preoperative disability. Both metrics are equally effective for patients with moderate preoperative disability. Adequate interpretation of NDI

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using the PASS and MCID metrics warrants individualized application as their utility is highly dependent on the degree of preoperative disability.

Overall (n=206)	Improvement on GRC (n=174)	No Improvement on GRC (n=32)	Sensitivity	Specificity	PPV	NPV
PASS			85%	79%	96%	37%
- Yes	145	9				
- No	29	23				
MCID			73%	79%	93%	32%
- Yes	127	10				
- No	47	22				
p - value			**0.02**	1	0.61	0.16

POSTER 57

Pretreatment With Hepatocyte Growth Factor Enhances Human iPSC-NS/PC Transplantation-mediated Functional Recovery After Spinal Cord Injury

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Department of Orthopaedic Surgery, Keio University School of Medicine[1] Department of Physiology, Keio University School of Medicine[2]

Introduction: Neural stem/progenitor cells derived from human induced pluripotent stem cells (hiPSC-NS/PCs) transplantation is a new therapeutic strategy for spinal cord injury (SCI), but the degree of functional recovery reported to date is limited in animal models. This limitation could be due to poor preservation of damaged tissue in addition to inflammatory response and loss of regenerating ability in neurons. Hepatocyte growth factor (HGF) was identified as a potent mitogen for mature hepatocytes and a mediator of inflammatory responses to tissue injury, and it has been reported to suppress secondary damage after SCI through angiogenic and anti-apoptotic effects. Therefore, the aim of this study was to combine HGF and hiPSC-NS/PCs transplantation to improve further the efficacy of hiPSC-NS/PCs transplantation therapy for subacute SCI.

Materials and Methods: Severe contusive SCI was induced in RNU nude rats, and recombinant human HGF protein was administered continuously into the subarachnoid space with osmotic mini-pump immediately after SCI for 2 weeks. Histological and comprehensive RNA-Seq gene expression analyses were conducted 2 or 7 days after SCI. To assess the effectiveness of combined therapy, subsequent to the HGF administration, hiPSC-NS/PCs were transplanted into the injured spinal cord at 9 days post-injury. We compared outcomes among the four groups: Control (HGF(-), Transplantation(-)), HGF alone, Transplantation alone, and Combination groups. Motor function was assessed by the Basso, Beattie, Bresnahan (BBB) score, kinematics, and electrophysiological analysis was performed using motor evoked potentials (MEP). The spinal cords were used for histological analyses at 12 weeks after SCI. The survival of transplanted cells was evaluated by in vivo imaging using fluorescent protein.

Results: HGF-treated tissues in the acute phase showed higher vascularization, anti-inflammatory (decrease in TNF-α and IL-1β), anti-apoptotic, and neuroprotective effects (mainly increase in BDNF activity) by histological and RNA-Seq analyses. In addition, Tissue at 84 days post-injury showed preservation of the lesion site compared to the control group (Fig.1). Combination therapy of HGF and hiPSC-NS/PCs transplantation promoted the survival rate of graft cells, remyelination, synaptic activity, and regeneration of intraspinal nerve fibers. The synaptic formation between host and graft neurons was observed by immunoelectron microscopy (Fig.2). Furthermore, BBB score and kinematic analysis showed significant recovery of motor function in the lower extremity at 84 days post-injury, and MEPs showed high action potentials (Fig.3).

Conclusion: Preservation of the lesion site by HGF treatment in the acute phase further enhanced motor function recovery via hiPSC-NS/PCs transplantation, which was directly related to the interaction between the surviving host and graft cells. The combination therapy of HGF and hiPSC-NS/PCs transplantation is a novel and highly promising therapeutic strategy for the treatment of acute to subacute severe SCI.

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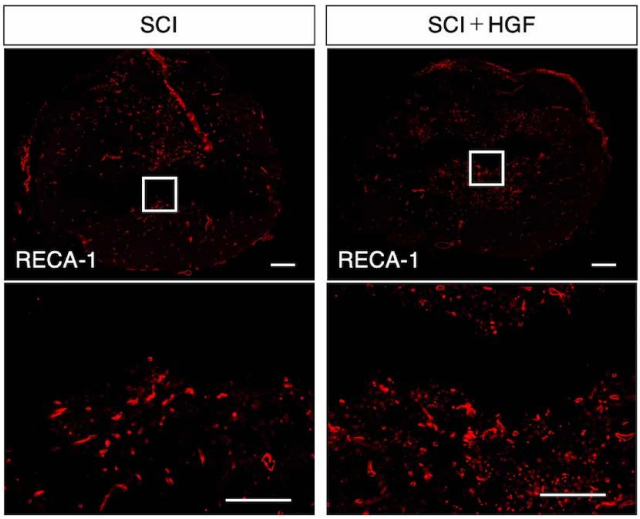

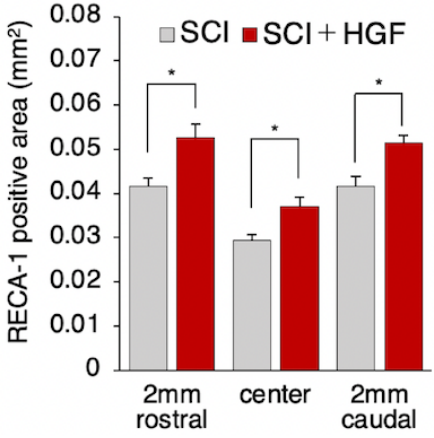

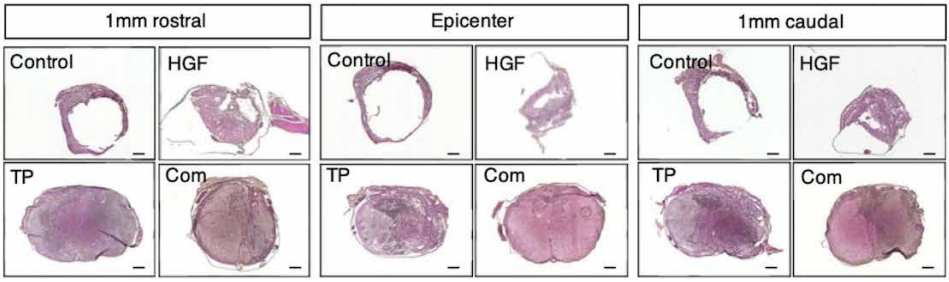

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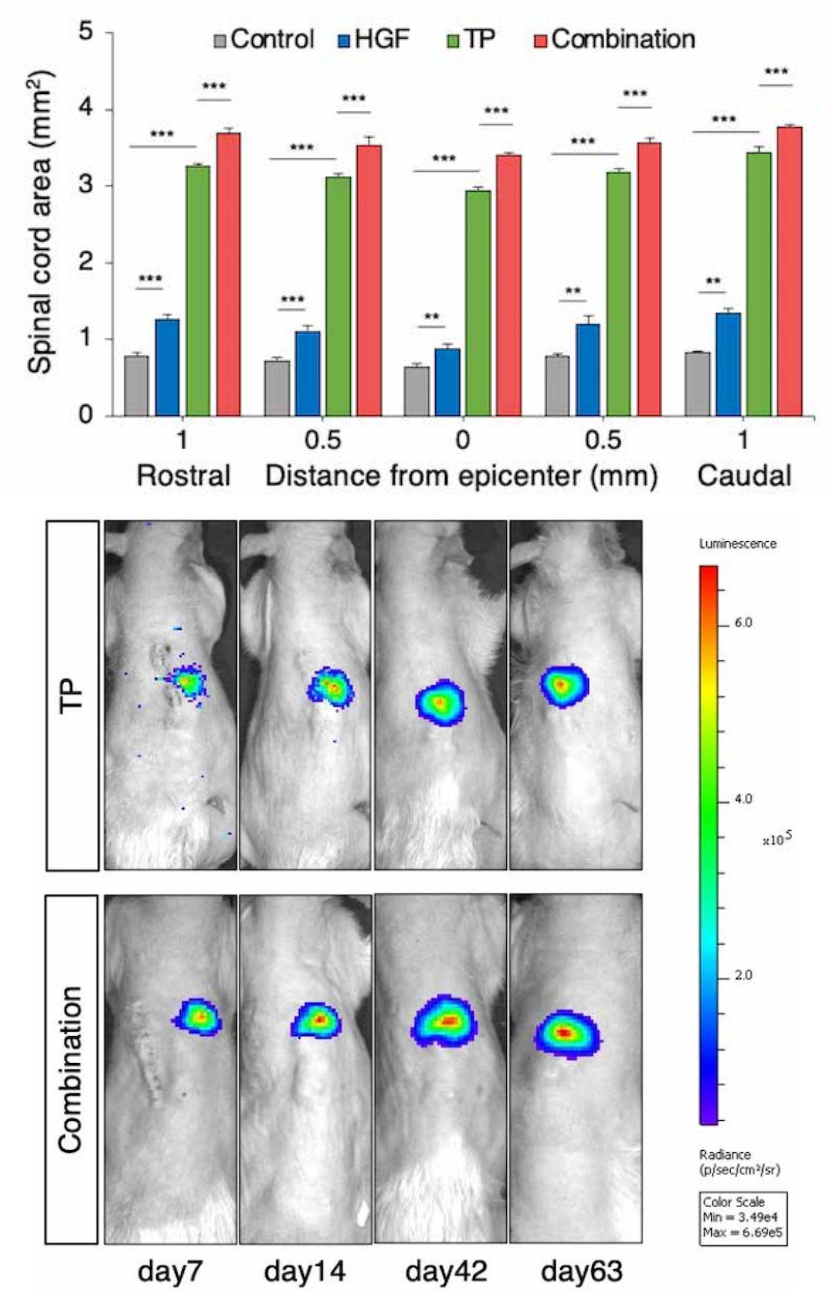

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or meidcal device he or she wishes to use in clinical practice.

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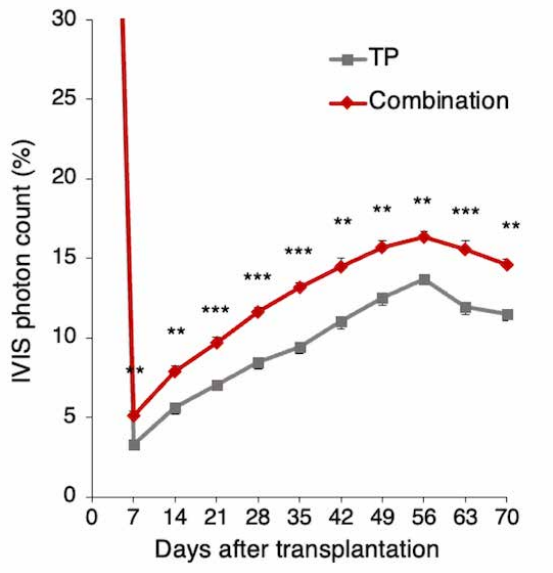

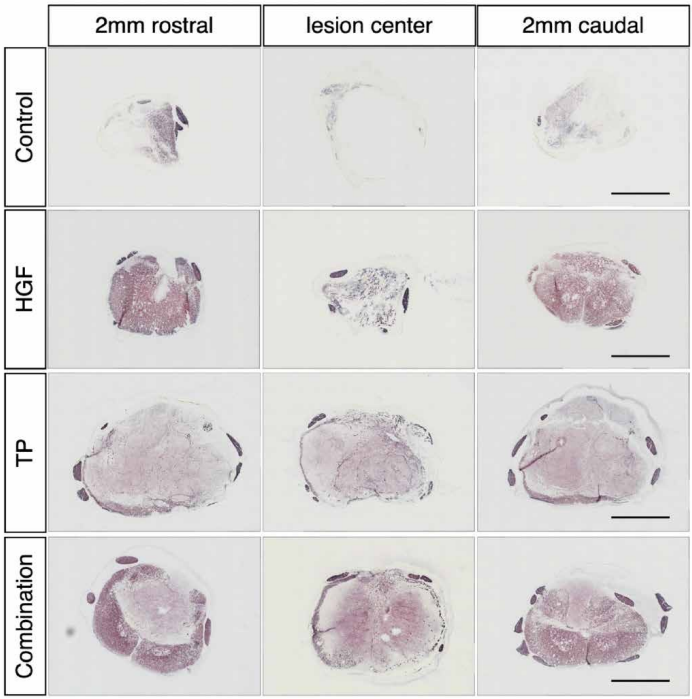

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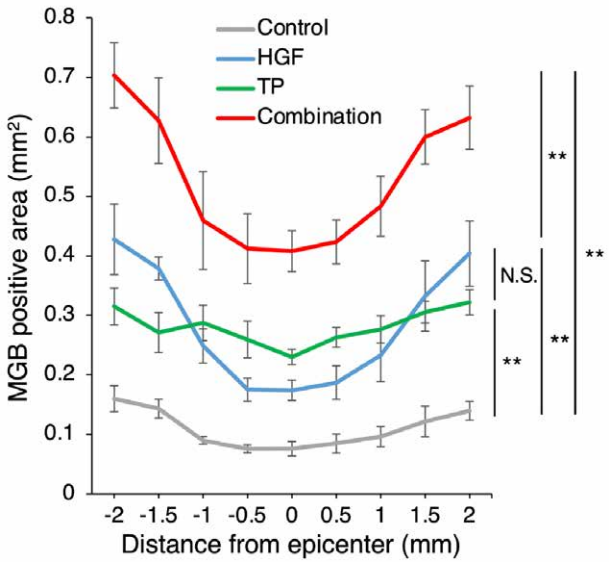

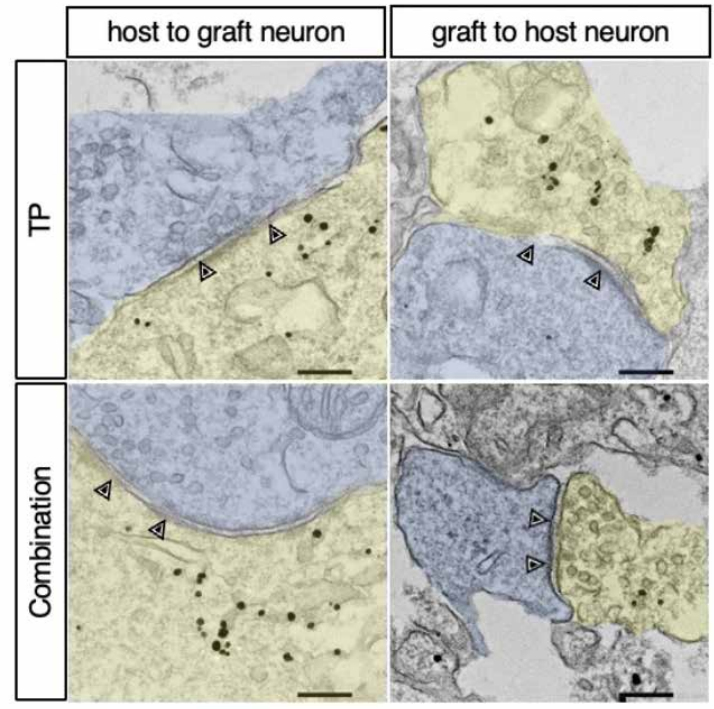

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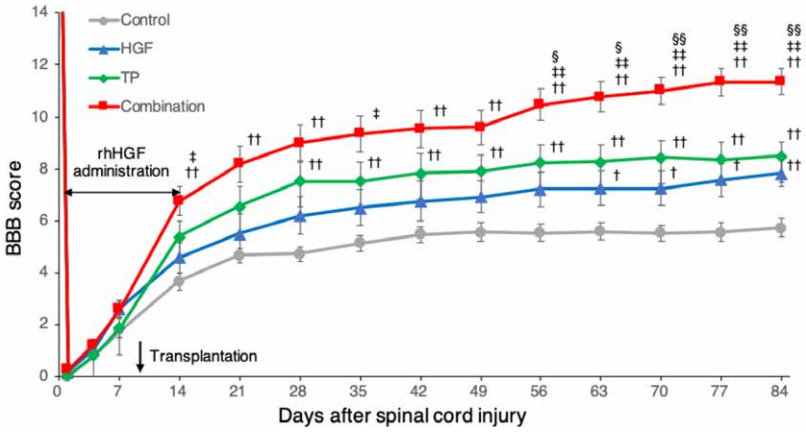

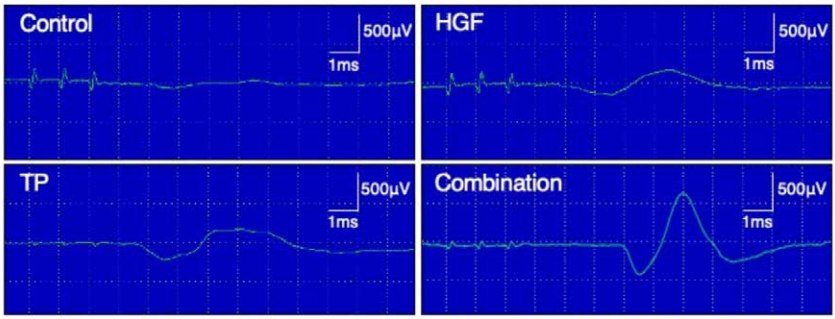

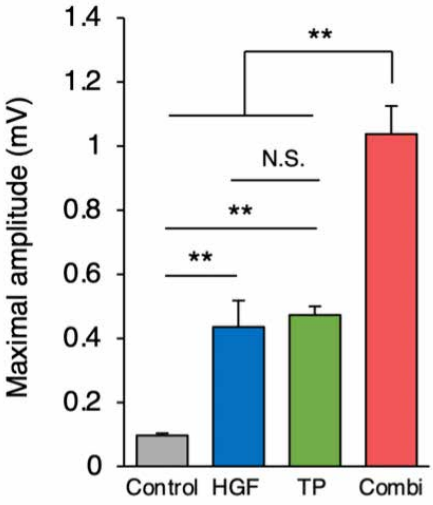

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POSTER 58

A Multidisciplinary Approach to Social Functioning Might Improve the Surgical Outcomes of Patients with Cervical Myelopathy: Comparisons of Two Prospective Cohorts

Koji Tamai, MD, Hidetomi Terai, MD[1], Akinobu Suzuki, MD[1], Kato Minori, MD[1], Hiromitsu Toyoda, MD[1], Shinji Takahashi, MD[1], Akito Yabu, MD[1], Yuta Sawada, MD[1], Masayoshi Iwamae, MD[1], Yuki Okamura, MD[1], Yuto Kobayashi, MD[1], Hiroaki Nakamura, MD[1]
Osaka Metropolitan University[1]

Introduction: Surgical decompression with adequate timing is the standard treatment strategy for the patients with degenerative cervical myelopathy (DCM) (1). However, spine surgeons and attending physicians sometimes experience that despite significant improvement in the disease outcomes of cervical myelopathy, the patients are not satisfied with the surgery and/or the patient's quality-of-life (QOL) does not improve after surgery (2). A previous study revealed that patient's social functioning (SF), rather than myelopathy severity, correlated with QOL improvement after decompression surgery for cervical myelopathy (3). Based on this background, this study aimed to identify the effects of a multidisciplinary approach for improving SF on 1-year surgical outcomes in cervical myelopathy patients.

Materials and Methods: This study compared two prospective cohorts in Japan. Patients who underwent cervical laminoplasty for cervical myelopathy from 2018 to 2020 were enrolled in the control cohort. Patients who underwent the same surgery with the same indications between 2020 and 2021 were enrolled in the SF cohort. Patients in the control cohort were treated with a standard care and those in the SF cohort were treated with a multidisciplinary protocol that focused on SF improvement. The key to the protocol was as follows: 1. clinical psychologists identified the patient's SF before surgery through several interviews; 2. information on SF was shared by physicians, therapists, nurses, and medical secretaries; and 3. spine surgeons, therapists, and clinical psychologists developed patient-oriented rehabilitation programs with information on the patient's SF. Clinical outcomes at 1-year were compared between the groups.

Results: The control and SF cohorts comprised 140 patients (mean age, 73.5 ± 7.0 years; 62 females) and 31 patients (mean age, 72.2 ± 6.9 years; 15 females) respectively. Although there was no significant differences in the background data, the improvement in the Japanese Orthopaedic Association (JOA) score was significantly better in the SF cohort than in the control cohort ($p=0.040$, mixed effect model). In a detailed analysis of each JOA score domain, the improvement of upper limb function was significantly better in the SF cohort than in the control cohort ($p=0.033$, mixed effect model). Similarly, the SF cohort demonstrated significantly higher patient reported outcome for upper extremity function than those in the control cohort ($p<0.001$, Mann-Whitney U test). Although there was no significant difference in the total QOL score, the self-care domain in the QOL score was significantly higher in the SF group than in the control group ($p=0.047$, Mann-Whitney U test).

Conclusion: The evidence for the effectiveness of a multidisciplinary approach in the care of patients with DCM is not well established (4). Current study identified that a multidisciplinary approach to improving/rebuilding a patient's SF was effective in improving cervical myelopathy and self-care domain of QOL. This study is the first to demonstrate the effectiveness of a postoperative multidisciplinary approach in patients with DCM.

POSTER 59

Comparisons of Accuracy Between Real-world Spine Surgeons and Deep Learning Algorithm to Identify Degenerative Canal Stenosis and Cervical OPLL on Plain Radiography

Koji Tamai, MD, *Hidetomi Terai, MD[1], Akinobu Suzuki, MD[1], Minori Kato, MD[1], Hiromitsu Toyoda, MD[1], Shinji Takahashi, MD[1], Akito Yabu, MD[1], Yuta Sawada, MD[1], Masayoshi Iwamae, MD[1], Yuki Okamura, MD[1], Yuto Kobayashi, MD[1], Hiroaki Nakamura, MD[1]*
Osaka Metropolitan University[1]

Introduction: Degenerative cervical myelopathy (DCM) caused by degenerative canal stenosis and/or cervical ossification of posterior longitudinal ligament (OPLL) is recognized as the leading cause of spinal cord impairment worldwide(1). However, it is well-known that the diagnosis of DCM is often delayed, resulting in improper management(2). Accordingly, radiographic screening tools currently have heightened importance in reducing delays in diagnosis and facilitating the implementation of timely therapy in patients with early-phase DCM. In this context, we developed two deep learning algorithms that can detect cervical degenerative canal stenosis and cervical OPLL on cervical radiography (Figure). The aim of this study is to compare the accuracy between real-world spine surgeons and our deep learning algorithms to identify degenerative canal stenosis and cervical OPLL on plain radiography.

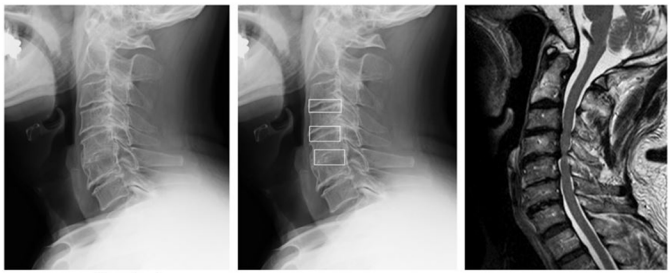
Materials and Methods: The deep learning algorithm, designed to identify the suspected stenosis level on radiography was constructed using a convolutional neural network model called EfficientNetB2, and radiography and magnetic resonance imaging data from training dataset including 100 patients with degenerative stenosis and 100 patients without canal stenosis. Similarly, deep learning algorithm, designed to identify the suspected OPLL was constructed using a same convolutional neural network model, and radiography and computed tomography data from training dataset including 200 patients with OPLL and 200 patients without OPLL. Four spine surgeons (with >25, >20, >10, and >5 years of experience, respectively) and deep learning algorithms evaluated independent test data sets; 50 cervical radiographic jpeg images for the presence or absence of OPLL, and 42 cervical radiographic jpeg images for the presence or absence of degenerative canal stenosis. The accuracy and area under the curve (AUC) of the receiver operating characteristic curve were calculated for the independent test dataset. Additionally, the number of correct diagnoses was compared between the algorithm and 4 physicians using the test dataset.

Results: In the degenerative canal stenosis test dataset, the diagnostic accuracy and AUC of the deep learning algorithm were 0.81 and 0.81, respectively. The rate of correct responses in the test dataset was significantly higher for the algorithm than for the spine surgeons (81.0% vs. 63.1%; p=0.029, Chi-squared test). In the OPLL test dataset, the diagnostic accuracy and AUC of the deep learning algorithm were 0.88 and 0.94, respectively. The rate of correct responses in the test dataset was significantly higher for the algorithm than for the spine surgeons (94.0% vs. 78.0%; p=0.041, Chi-squared test).

Conclusion: The accuracies of our two deep learning algorithms which capable of suggesting the presence or absence of degenerative canal stenosis and cervical OPLL on cervical radiography were significantly higher than those of real-world spine surgeons. We believe that combination of our algorithms can significantly assist physicians as a screening tool for early phases DCM.

POSTER 59 continued

DL algorithm for detect degenerative canal stenosis



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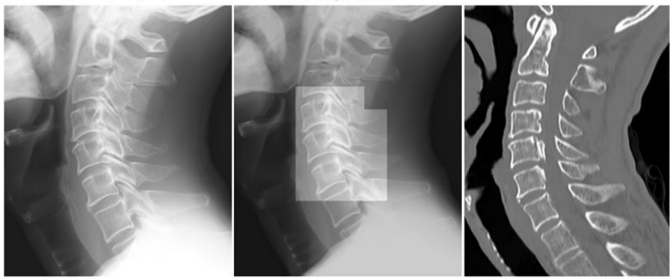
DL algorithm for detect cervical OPLL



POSTER 60

Predicting Conversion to Inpatient in Ambulatory Patients Undergoing ACDF: A Machine Learning Approach

William Zelenty, MD[1], *Soji Tani, MD[1], Lukas Schonnagel, MD[1], Tu-Lan Vu-Han, MD[2], Jiaqi Zhu, MA[1], Gaston Camino-Willhuber, MD[1], Yusuke Dodo, MD[3], Thomas Caffard, MD[1], Erika Chiapparelli, MD[1], Lisa Oezel, MD[4], Jennifer Shue, MS[1], Darren Lebl, MD, MBA[1], Frank Cammisa, MD[1], Federico Girardi, MD[1], Gbolabo Sokunbi, MD[1], Alexander Hughes, MD[1], Andrew Sama, MD[1]*
Hospital for Special Surgery[1] Charité - Universitätsmedizin Berlin[2] Showa University[3] University Hospital Duesseldorf[4]

Introduction: Machine-learning is a powerful tool that has become increasingly important in the orthopedic field. Recently, several studies have reported that predictive models could provide new insights into patient risk factors and outcomes. Anterior cervical discectomy and fusion (ACDF) is a common operation that is typically performed as an outpatient procedure. However, some patients are required to convert to inpatient status and prolonged hospitalization due to their conditions. Appropriate patient selection and identification of risk factors for conversion could provide great benefits to patients and the use of medical resources. This study aimed to develop a machine-learning algorithm, to identify risk factors associated with unplanned conversion to inpatient status.

Materials and Methods: We included patients who underwent one- or two-level ACDF in an ambulatory setting at a single specialized orthopedic hospital between February 2016 to December 2021. Patients were divided into two groups based on length of stay: 1) Ambulatory (Discharge within 24 hours) or Extended stay (fewer than 48 hours), and 2) Inpatient (greater than 48 hours). Factors included in the model were based on literature review and clinical expertise. Patient demographics, comorbidities, and intraoperative factors were included. No postoperative data were included in the analysis. We compared the performance of different machine learning algorithms: a modern form of gradient boosting (XGBoost), a support vector machine (SVM), and a logistic regression model. We split the patient data into a training and validation dataset using a 70/30 split. The different models were trained in the training dataset using cross-validation. The performance was then tested in the unseen validation set. This step is important to detect overfitting of the model. The performance was evaluated using the area under the curve (AUC) of the receiver operating characteristics analysis (ROC) as the main outcome. An AUC of 0.7 was considered fair, 0.8 good and 0.9 excelent, according to established cut-offs.

Results: A total of 662 patients (59% female) were available for analysis. Of those, 168 (25.3%) were converted to inpatient status. The median age was 52 years (IQR 44 – 59), and the median BMI was 28 kg/m^2(IQR 24 – 32). The XGBoost model showed the best performance with an AUC of 0.80. The most important features were the length of the operation, followed by BMI, age, and sex. A list of the ten most important features is given in Figure 1. The logistic regression model and the SVM showed worse results, with an AUC of 0.72 and 0.57, respectively.

Conclusion: This study demonstrated a novel approach to predicting conversion to inpatient status in patients who were eligible for ambulatory surgery. The XGBoost model showed good predictive capabilities, superior to the older machine learning approaches. This model also revealed the importance of surgical duration time, BMI, and age as risk factors for patient

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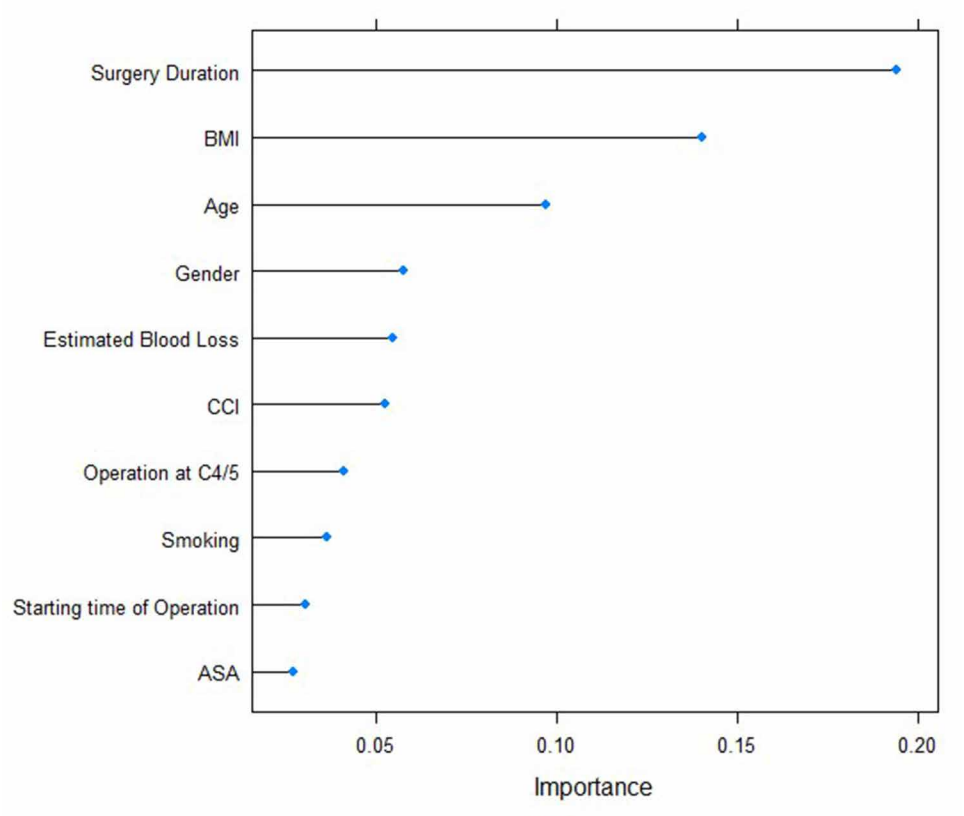
conversion. A developing field of study is the use of machine learning in clinical decision-making. Our findings contribute to this field by demonstrating the feasibility and accuracy of such methods in predicting outcomes and identifying risk factors although external and multi-center validation studys are needed.



POSTER 61

Nationwide Analysis of Hybrid Surgery for Two-Level Cervical Degenerative Disease

Nicole Hang, BS[1], *Andy Ton, BS, Christian Au, BS[1], Anahit Sargsyan, BS[1], Emily Mills, MD[1], Jacob Ball, MD[1], Jeffrey Wang, MD[1], Raymond Hah, MD[1], Ram Alluri, MD[1]*
Keck School of Medicine of USC[1]

Introduction: Hybrid cervical surgery (HS) is a relatively newer technique which combines the conventional gold standard, anterior cervical discectomy and fusion (ACDF), and cervical disc arthroplasty (CDA) to provide advantages offered by each technique. Recent adoption of HS has seen growing evidence to support expanding indications. Given the growing use of HS, this study evaluates utilization and demographic trends associated with two-level HS and compares postoperative outcomes with two-level ACDF.

Materials and Methods: Patients who underwent either index two-level ACDF (n=191,838) or HS (1,798) for degenerative cervical pathology from 2010-2021 were queried from the PearlDiver National database. Indications for trauma, malignancy, and infection were excluded. Relevant diagnoses and procedures were obtained using International Classification of Disease, 9th and 10th Edition (ICD-9, ICD-10) and Current Procedural Terminology (CPT) codes. Annual utilization was recorded and demographic and clinical characters were recorded and compared between two-level ACDF and two-level HS. Weighted average cost was obtained and adjusted for inflation. Both procedure cohorts were propensity-matched 1:1 to account for age, sex, Elixhauser Comorbidity Index (ECI), myelopathy, smoking, and obesity. Following assessment of data normality, student's t-test and chi-squared analyses were conducted for continuous and categorical data respectively, and conditional logistic regression was performed to assess risk for 30-day complications and two-year revision between two-level ACDF and HS.

Results: From 2010 to 2021, a total of 1,798 patients (55.2% female) underwent two-level HS, with utilization rates steadily increasing over the years and peaking in 2020 (14.1%). Patients undergoing two-level HS compared to those undergoing two-level ACDF were significantly younger (mean age=50.3$\pm$10.3 vs 56.9$\pm$10.6, p<0.001). Relative to ACDF, two-level HS had a lower proportion of procedures performed in the South (38.9% vs 48.3%, p<0.001), a higher percentage of patients with cervical myelopathy (14.4% vs 10.5%, p<0.001), and less who were smokers (27.5% vs 29.7%, p<0.001) (Table 1). Propensity-matching yielded 1,798 patients for each cohort, wherein conditional logistic regression revealed decreased odds of revision within two years (OR:0.70, p=0.024) and all 30-day complications (OR 0.72, p=0.008) with two-level HS compared to ACDF. Two-level HS was associated with higher admission costs compared to two-level ACDF ($6,989$\pm$2,638 vs $5,019$\pm$1,825, p<0.001).

Conclusion: Patients undergoing two-level HS tended to be younger; a higher proportion of patients undergoing two-level HS, however, were diagnosed with cervical myelopathy. Utilization of two-level HS has steadily increased from 2010-2020, with regional variations in adoption. Despite higher initial costs, a propensity-matched comparison between similar cohorts revealed significantly lower risk of all 30-day complications and decreased two-year revision risk with two-level HS relative to two-level ACDF. These findings suggest that HS, when appropriately indicated, may be a more cost-efficient alternative to ACDF for two-level degenerative cervical pathologies.

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Table 1. Demographic and procedure characteristics for two-level hybrid surgery (HS) and anterior cervical discectomy and fusion (ACDF). Continuous variables are presented as mean values ± standard deviation. ECI = Elixhauser Comorbidity Index. A $p<0.05$ is considered significant.

Demographic Characteristics	HS (n=1,798)	ACDF (n=191,838)	p-value
Age (years)	50.3 (±10.3)	56.9 (±10.6)	**p<0.001**
ECI	3.0 (±3.0)	3.2 (±3.2)	**p<0.001**
Sex			p=0.90
Female	992 (55.2%)	105,511 (55.0%)	
Male	806 (44.8%)	86,327 (45.0%)	
Location			**p<0.001**
Inpatient	698 (38.8%)	110,394 (57.5%)	
Outpatient	1,092 (60.7%)	80,663 (42.0%)	
Region			**p<0.001**
Midwest	505 (28.1%)	46,242 (24.1%)	
Northeast	290 (16.1%)	27,266 (14.2%)	
South	700 (38.9%)	92,847 (48.4%)	
West	297 (16.5%)	24,506 (12.8%)	
Cervical Myelopathy	259 (14.4%)	20,083 (10.5%)	**p<0.001**
Cervical Radiculopathy	1,539 (85.6%)	171,755 (89.5%)	**p<0.001**
Smoking	495 (27.5%)	57,017 (29.7%)	**p=0.046**
Obesity	593 (33.0%)	64,556 (33.7%)	p=0.57
Cost ($USD)	$6,989 (±2,638)	$5,019 (±1,825)	**p<0.001**

POSTER 62

Patterns in Treatment Practice in the United States for Initially Nondisplaced Type II Odontoid Fractures

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Introduction: Fractures of the odontoid process account for approximately 20% of all cervical spine fractures in the adult population, with those being classified as type II comprising over half of these injuries, and the overwhelming majority of fractures occurring in the geriatric population. Despite their high prevalence, their management remains controversial and varies greatly based on a multitude of factors, including age, degree of symptoms, stability, angulation, and fracture displacement. This variance is further exacerbated when considering treatment for nondisplaced type II odontoid fractures, with the majority of initial treatment consisting of cervical collar orthosis. However, fracture nonunion rates for non-operative treatment are high and vary greatly, and patients presenting on a spectrum from asymptomatic to significant neurologic symptoms. Due to the large degree of inconsistency surrounding the treatment of nondisplaced type II odontoid fractures, there is a strong need for additional studies providing large scale characterization of fracture progression and treatment. The purpose of this study is to investigate overall patterns of surgical treatment for initially nondisplaced type II odontoid fractures as well as delineate any geographic differences in surgical rates.

Materials and Methods: The Military Health System Data Repository, consisting of medical treatment data of all active duty servicemembers, dependents, and retired beneficiaries, was queried for the ICD-10 code for nondisplaced type II odontoid fractures, as well as current procedural terminology (CPT) codes for their surgical treatment (posterior cervical fusion and anterior odontoid screw fixation). The percentage of patients that underwent surgical treatment for this injury was calculated, as well as the rate of displacement and nonunion status as determined by a change in the associated ICD-10 code. Timing between diagnosis and surgery was also recorded and categorized as acute (<4 weeks), subacute (4 weeks to 3 months), and delayed fixation (>3 months). A subanalysis of surgical treatment rates was also performed based on geographic region within the United States.

Results: Within the military healthcare system between 2015 and 2022, a total of 2,157 patients were diagnosed with an initially nondisplaced type II odontoid fracture, of which 368 patients (17.1%) underwent surgery for it. Surgical treatment included posterior cervical fusion in 278 patients (75.5%) and anterior screw fixation in 90 (24.5%) Reasons for treatment included: 208 subsequent fracture displacements (56.6%), 9 neurologic deficits (2.4%), and 58 with delayed union/non-union (15.8%). Timing for surgery included 235 patients treated acutely (63.9%), 48 treated subacutely (13%), and 85 treated in a delayed fashion (23.1%). When analyzed based on geographic region, the highest rate of surgery was in the South (19.5%) and the lowest was in the Northeast (9.4%).

Conclusion: Of patients initially diagnosed with a nondisplaced type II odontoid fracture, 17.1% underwent surgical management, primarily via posterior cervical fusion (75.5%), with most patients treated within 4 weeks of diagnosis. Geographically within the U.S., the South had the highest rate of surgery, with the Northeast having the lowest rate.

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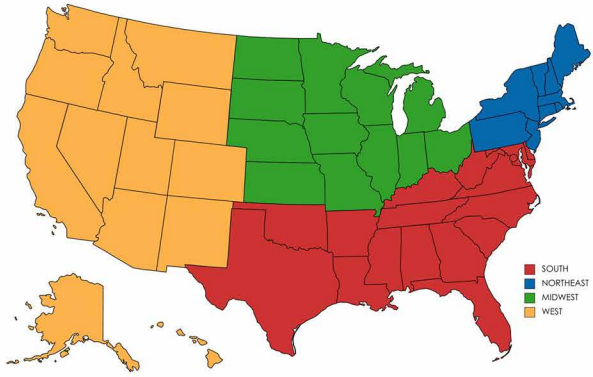
Figure 1. Rate of surgery for nondisplaced type II odontoid fractures based on U.S. geographic region.

U.S. Region	Total Diagnosed	Surgery Count	Rate of Surgery
South	1192	232	19.5%
West	508	89	17.5%
Midwest	297	32	10.8%
Northeast	160	15	9.4%
Grand Total	2157	368	17.1%



POSTER 63

Assessing the Economic Benefit of Enhanced Recovery After Surgery (ERAS) Protocols in Adult Cervical Deformity Patients: Is the Initial Additive Cost of Protocols Offset by Clinical Gains

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Introduction: Enhanced Recovery After Surgery (ERAS) can help accelerate patient recovery and assist hospitals in maximizing the incentives of bundled payment models while maintaining high-quality patient care. However, the economic benefit of ERAS protocols has not been established.

Materials and Methods: Operative CD patients ≥18yrs with complete pre-(BL) and up to 2-year(2Y) postop radiographic/HRQL data were stratified by enrollment in Standard-of-Care ERAS beginning in 2020. Differences in demographics, clinical outcomes, radiographic alignment targets, peri-operative factors and complication rates were assessed via means comparison analysis. Costs were calculated using PearlDiver database estimates from Medicare pay-scales. QALY was calculated using NDI mapped to SF6D using validated methodology with 3% discount rate to account for residual decline to life expectancy.

Results: 270 patients were included (58.11 ± 11.97 years, 48% female, 29.13 ± 6.89 kg/m^2. Of these patients, 54 (20.0%) received ERAS protocol recovery treatment post-operatively. ERAS- patients were significantly more likely to utilize opioids than ERAS+ patients (p=.016) at baseline. In terms of net savings Peri-operatively, ERAS+ patients also reported lower mean LOS overall (4.33 vs 5.84, p=.393), and were more likely to be discharged directly to home ($\chi 2(1) = 4.974$, p=.028). ERAS+ patients also required significantly lower doses of opiates post-operatively than ERAS- patients (p=.020). In terms of peri-operative complications, ERAS+ patients were less likely to develop neurological complications overall (p=.025). and less likely experience venous thromboembolic complications or be diagnosed with venous disease post-operatively (p=.025). By 2Y, ERAS+ were also significantly less likely to develop major complications (p=.040) overall, suffer instrumentation failure (p=.032), or require reoperation (p=.027). Per cost analysis, ERAS+ patients reported a significantly lower mean total 2Y cost of 33,829 USD compared to ERAS- patients at 36,951 (p<.001). Furthermore, ERAS+ patients trended towards greater life-expectancy 2Y QALYs gained versus ERAS- patients (.423 vs .368, p=.051), and demonstrated significantly lower costs at reoperation by 2Y (7050 USD vs 8110, p<.001). Controlling for age, surgical invasiveness, and deformity per BL TS-CL, ERAS+ patients below 70 years old were significantly more likely to achieve a cost-effective outcome by 2Y compared to their ERAS- counterparts (OR: 1.011 [1.001 – 1.999, p=.048].

Conclusion: Patients undergoing Enhanced Recovery After Surgery (ERAS) protocols experience lower operative times, length of stays, as well as lower rates of peri-and and post-operative complications. Subsequently, this study demonstrates that ERAS programs in ACD surgery demonstrate improved cost-effectiveness and reduced total cost by 2Y post-operatively. Due to the potential economic benefit of ERAS for patients, physicians and instutions should consider incorporation of ERAS into practice for eligible patients.

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Table 1. Enhanced Recovery After Surgery (ERAS) Protocols Utilized

Pre-Operative	Nutritional optimization (eg. Diabetes, dietary management)
	Specialist consult: ENT (dysphasia risk), cardiology (cardiac stress test)
	Psychological assessment, goal setting, setting recovery expectations
Peri-Operative	Opioid-sparing multimodal approach
	Early mobilization with physical therapists
	Intensive care unit avoidance or minimization
	Enhanced wound care protocol and expedited catheter/drain removal when possible
	Expedited discharge
Post-Discharge	Care team virtual follow-up (discharge day +1)
	Pain-management consultation
	In-office consolation (2-3 weeks post-discharge)

POSTER 64

Impact of Enhanced Recovery After Surgery (ERAS) Program on Post-Operative Course in Adult Cervical Deformity Patients

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NYU Langone Health[1] Brown University[2] University of Arizona[3] Hoag Hospital[4] University of Munich[5] New York Spine Institute/NYU Medical Center[6]

Introduction: Enhanced Recovery After Surgery (ERAS) can help accelerate patient recovery and assist hospitals in maximizing the incentives of bundled payment models while maintaining high-quality patient care. A key component of an enhanced recovery pathway is the ability to predictably reduce inpatient length of stay, and reduce post-operative opioid use and complications.

Materials and Methods: Operative CD patients ≥18yrs with complete pre-(BL) and up to 2-year(2Y) postop radiographic/HRQL data were stratified by enrollment in Standard-of-Care ERAS beginning in 2020. Differences in demographics, clinical outcomes, radiographic alignment targets, peri-operative factors and complication rates were assessed via means comparison analysis.

Results: 220 patients were included (58.11 ± 11.97 years, 48% female, 29.13 ± 6.89 kg/m^2. Of these patients, 54 (20.0%) received ERAS protocol recovery treatment post-operatively. At baseline, ERAS+ also had significantly higher NDI (p=.005) and EQ5D (p=.023), and significantly lower mJOA scores (p<.001). At BL, ERAS- patients were significantly more likely to utilize opioids than ERAS+ patients (p=.016). Peri-operatively, ERAS+ patients had significantly lower operative times overall, and if staged, ERAS+ patients had a significantly lower mean Stage 1 op time (both p<.021). Furthermore, ERAS+ patients also had significantly lower EBL overall (583.48 vs 246.51, p<.001), and required significantly lower doses of propofol intra-operatively than ERAS- patients (p=.020). ERAS+ patients also reported lower mean LOS overall (4.33 vs 5.84, p=.393), and were more likely to be discharged directly to home ($\chi 2(1) = 4.974$, p=.028). In terms of complications, ERAS+ patients were less likely to require steroids after surgery (p=.045), were less likely to develop neuromuscular complications overall (p=.025), and less likely experience venous complications or be diagnosed with venous disease post-operatively (p=.025).

Conclusion: Enhanced Recovery After Surgery (ERAS) programs in ACD surgery demonstrate significant benefit in terms of peri-operative outcomes for patients. Patients undergoing ERAS-based protocols experience lower operative times, length of stays, as well as lower rates of opioid use, anesthetic dose, and post-operative complications. For ERAS-eligible patients, such programs may improve patient HRQLs and clinical outcomes, and reduce cost burden for both hospitals and patients alike.

POSTER 65

Optic Nerve Sheath Diameter and CSF Outflow Are Directly Related to Operative Time in Prone Cervical Spine Surgery

Douglas Weinberg, MD[1], *Aneesh Rahangdale, BS*[1], *David Fleischman, MD*[1]
University of North Carolina, Chapel Hill[1]

Introduction: Visual loss after spinal surgery is a rare perioperative complication with an incidence ranging from 0.01% - 2%. The most common causative pathology of perioperative vision loss (POVL) is ischemic optic neuropathy (ION), with posterior ischemic optic neuropathy (PION) being more common than anterior ischemic optic neuropathy (AION). Despite the rarity of ischemic optic neuropathy, either AION or PION, it is an important perioperative complication because the vision impairment caused by ION is irreversible and it is often severe and bilateral.

The purpose of this project was to evaluate the effect of intraoperative positioning and lack of eye movement on the amount of cerebrospinal fluid around the optic nerve in prone spinal surgery patients by indirectly measuring the optic nerve sheath diameter (ONSD) via ultrasound.

Materials and Methods: Fifteen patients undergoing posterior cervical spine surgery (30 eyes) were enrolled in study. Patients were positioned prone on the Jackson table in Mayfield head holder. The ONSD was scanned preoperatively, intraoperatively 20 minutes before the end of the surgery, and postoperatively in the PACU at least 10 minutes after completion of the surgery. The probe was adjusted to give a suitable angle for displaying the entry of the optic nerve into the globe, at the depth of 3 mm behind the globe.

Results: The average ONSD preoperatively was 0.53cm, which increased to 0.63cm intraoperatively($p < 0.001$). On average, patients undergoing prone spinal surgery had a 20.7% increase in ONSD intraoperatively. Moreover, the more hours patients were prone intraoperatively, we noted a larger percent change in ONSD ($R^2 = 0.51$, $p < 0.001$)

Conclusion: This experiment showed a significant increase (20.7%, 1mm) in ONSD intraoperatively, suggesting pooling and inadequate clearance of CSF during prone spinal surgery. Prolonged surgical time in the prone position coupled with lower optic nerve perfusion may contribute to visual loss, although future study is needed.

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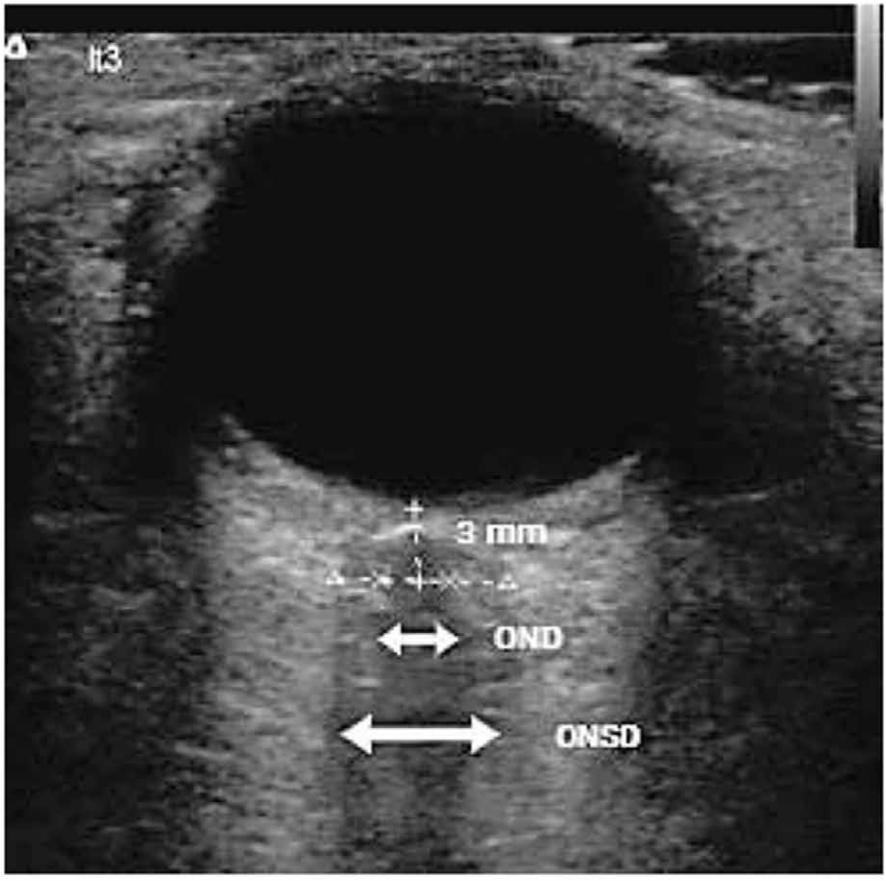

Figure 1. Ultrasound of the eye depicts anatomical landmarks. Optic Nerve Diameter (OND) and Optic Nerve Sheath Diameter (ONSD) were measured 3mm from the back of the globe in this study.[16]

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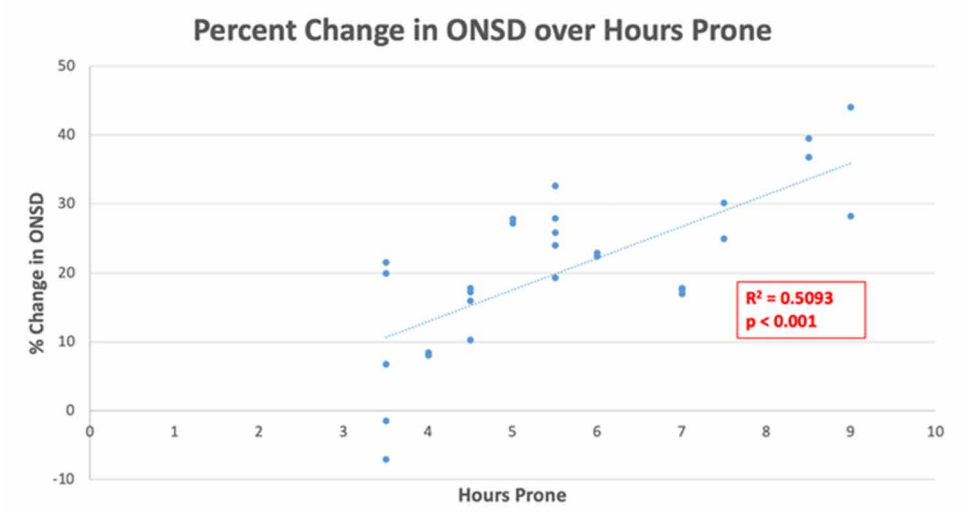

Figure 2. Percent change in ONSD over hours prone depicts a time-dependent relationship with regards to overall length of surgery ($R^2 = 0.51$, $p < 0.001$). On average, patients undergoing prone spinal surgery had a 21% increase in ONSD intraoperatively. Patients were prone for at least 3.5 hours and on average were prone for 5.7 hours. Notably, one patient prone for 9 hours had a 44% increase in ONSD intraoperatively.

POSTER 66

Preoperative Symptom Duration Influences Neurological Recovery and Achievement of the Minimal Clinically Important Difference After Surgical Treatment of Cervical Ossification of the Posterior Longitudinal Ligament

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Tokyo Medical and Dental University[1] Tsukuba University[2]

Introduction: Previous research has reported that various factors such as age, preoperative neurological score, comorbidities, surgical approach, and high signal intensity on MRI are associated with surgical outcomes for cervical ossification of the posterior longitudinal ligament (OPLL(1,2)). However, the effect of symptom duration on postoperative neurological outcomes have not been well studied. It is important to know the threshold of symptom duration for favorable postoperative recovery in order to discuss the optimal timing for surgery. Therefore, we investigated the factors influencing postoperative neurological recovery, specifically focusing on the duration of the symptoms, in this multicenter prospective study of surgical treatment of cervical OPLL.

Materials and Methods: This study included 395 OPLL patients with cervical myelopathy (291 men and 104 women, mean age 63.7± 11.4 years) who had been followed up on for more than two years and had sufficient clinical and radiological data. In the 395 patients, 204 patients were treated with laminoplasty, 90 patients with posterior decompression and fusion, 85 patients with anterior decompression and fusion, 11 patients with anterior-posterior combined surgery, and 5 patients with laminectomy. The Japanese Orthopedic Association (JOA) score was used to assess clinical outcomes both preoperatively and two years later. We also evaluated patient reported outcomes using JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). The factors influencing neurological recovery and achieving the minimal clinically important difference (MCID) were investigated.

Results: When the symptom duration exceeded two years, the recovery rate decreased. The recovery rate was significantly lower in the group with a duration of ≥ 5 years compared to the groups with a duration of <0.5 years, 0.5–1 year, and 1–2 years in multiple comparisons. When the symptom duration exceeded two years, the rate of MCID achievement also decreased. The MCID achievement rate was significantly lower in the group with a symptom duration of ≥ 5 years compared to the groups with a symptom duration of < 6 months and 1–2 years.

Logistic regression analysis revealed that symptom duration (OR: 0.993, 95% CI: 0.988–0.997, $p = 0.001$), age (OR: 0.953, 95% CI: 0.933–0.974, $p < 0.001$), and BMI (OR: 0.912, 95% CI: 0.864–0.963, $p < 0.001$) were significant factors influencing postoperative MCID achievement (Table1). According to the ROC anaysis, the cutoff value for symptom duration for MCID achievement is 23 months (AUC 0.616, sensitivity, 67.4%; specificity, 53.5%). We further evaluated PROMs using JOACMEQ, and found that the improvement rate of the scores tended to decrease as the symptom duration increased. When we compared symptom duration < 2 years and ≥ 2 years, the improvement of JOACMEQ scores were significantly worse in patients with symptom duration ≥ 2 years in the upper extremity function score ($p<0.001$), lower function score ($p=0.039$), and bladder function score ($p=0.034$).

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Conclusion: In the prospective study of 395 surgically treated patients with cervical OPLL, the duration of symptoms had a significant impact on neurological recovery patient reported outcomes and MCID achievement. The threshold of symptom duration from onset to surgical intervention for MCID success was 23 months.

Table 1. Factors influencing MCID achievement and results of JOACMEQ (patient reported outcomes)

	OR	95% CI	*P*-value
Age	0.950	0.929-0.972	< 0.001*
Gender	1.430	0.879-2.330	0.149
BMI	0.910	0.861-0.961	< 0.001*
Medical comorbidities	0.709	0.415-1.180	0.181
Duration of symptoms (months)	0.993	0.989-0.997	0.001*
Preoperative JOA score	0.964	0.894-1.040	0.345
JOACMEQ	Symptom duration < 2 years	Symptom duration ≥ 2 years	*P*-value
Cervical spine function	35.8%	28.4%	0.206
Upper extremity function	51.3%	26.8%	< 0.001*
Lower extremity function	38.5%	26.3%	0.039*
Bladder function	32.4%	20.2%	0.034*
Quality of life	25.3%	15.8%	0.053

MCID, minimal clinically important difference; BMI, body mass index; JOA score, Japanese Orthopedic Association score; OR, odds ratio; CI, confidence interval; *p<0.05. JOACMEQ, the JOA Cervical Myelopathy Evaluation Questionnaire; *p<0.05.

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Mark Bernhardt, MD.....2020
Elliott E. Blinderman, MD 2002
Henry H. Bohlman, MD.....2010
Mario Boni, MD.....1986
Francis R. S. Boumphrey, MD.....2012
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Lourens Penning, MD 2010
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CALL FOR ABSTRACTS March 6-April 24, 2024

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