52ND FIFTY-SECOND ANNUAL MEETING

OF THE

CERVICAL SPINE RESEARCH SOCIETY ®

FOUNDED 1973

ABSTRACT BOOK

52ND ANNUAL MEETING

DECEMBER 11 - 14, 2024

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Erica F. Bisson, MD, MPH; Jason W. Savage, MD; Barrett I. Woods, MD

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Barrett S. Boody, MD; Matthew W. Colman, MD

www.csrs.org

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CME Information

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Physicians may claim credit for sessions he or she attended in the attendee portal or meeting mobile app once the overall meeting evaluation has been completed. The overall meeting evaluation and certificates will be available after the completion of the Annual Meeting on Saturday, December 14.

For the smoothest process, access the attendee meeting portal by clicking on your direct link in any of the daily emails sent. Click on the "Credit Claiming and Evaluations" button on the home screen. Complete the "Overall Meeting Evaluation," then select credits for each session you attended. You may then access your certificates by clicking on the "My Certificates" button on the top bar or the home screen button.

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CERVICAL SPINE RESEARCH SOCIETY ®

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About CSRS

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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SHERATON GRAND CHICAGO RIVERWALK - CHICAGO, ILLINOIS

President: Alpesh A. Patel, MD, MBA

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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, December 12, 2024

Abstract Session 1: Outcomes 1

Time: 8:05 AM - 9:20 AM
Location: General Session - Level 4
Moderators: Alpesh A. Patel, MD, MBA; Michael Daubs, MD

8:05 AM **Introduction**

8:10 AM **1. Postoperative Improvement in Neck Pain Following Decompression Without Fusion in Patients with Cervical Myelopathy**
Hiroyuki Nakarai, MD

8:15 AM **2. What Predicts Attainment of Substantial Clinical Benefit in Neck Pain-Related Disability 24 Months after Surgery for Cervical Spondylotic Myelopathy?**
Harrison J. Howell, BA

8:20 AM **3. Could Indirect Decompression Occur for Cord Compression by Ligamentum Flavum with Anterior Cervical Discectomy and Fusion?**
Sehan Park, MD, PhD

8:25 AM **4. Residual Anterior Compression on Postoperative MRI After Laminoplasty for Multilevel Degenerative Cervical Myelopathy**
Liang Jiang, MD

8:30 AM **5. Patients With and Without Severe Systemic Illness, Measured by ASA Grade, Benefit from Surgery for CSM: A Report from the Quality Outcomes Database**
Vardhaan S. Ambati, BS

8:35 AM **Discussion**

8:45 AM **6. Re-analysis of the CSM-PROTECT Multicentre Randomized Controlled Trial Reveals a Global Treatment Benefit of Riluzole in Patients Undergoing Surgery for Degenerative Cervical Myelopathy**
Michael G. Fehlings, MD, PhD

8:50 AM **7. Degenerative Cervical Myelopathy Patients' Six-month and Twelve-month Outcomes: Follow-up Analysis from the MYelopathy NAtural History (MYNAH) Registry**
Nashwa Najib, MD

8:55 AM **8. Temporal Trends of Improvement in Patients With Cervical Spondylotic Myelopathy After Anterior Cervical Discectomy and Fusion**
Chad Z. Simon, BS

9:00 AM **9. Who Gets Better after Surgery for Degenerative Cervical Myelopathy? A Responder Analysis from the Multicenter Canadian Spine Outcomes and Research Network**
Husain Shakil, MD

9:05 AM **10. Comparative Analysis of Patient-Reported Outcomes in Myelopathy and Myeloradiculopathy: A Quality Outcomes Database Study**
Ken Porche, MD

9:10 AM **Discussion**

Thursday, December 12, 2024

Abstract Session 2: Trauma

Time: 10:40 AM - 11:55 AM
Location: General Session - Level 4
Moderators: Gregory Schroeder, MD; Jefferson R. Wilson, MD, PhD

10:40 AM **CSRS Publications Committee and Journal Overview**
Gregory Schroeder, MD

10:44 AM **Introduction**

10:45 AM **11. Surgical Versus Conservative Treatment for Odontoid Fractures in the Elderly: An International Prospective Comparative Study**
Jeroen GJ. Huybregts, MD

10:50 AM **12. Profiling of Cerebrospinal Fluid and Blood EVs-miRNAs for Predicting Natural Recovery from Acute Spinal Cord Injury in Rat Models**
Tomoharu T. Tanaka, MD/PhD student

10:55 AM **13. Comparative Analysis of ACDF and PCDF for Traumatic Cervical Facet Fractures/Dislocations: 90-Day Medical Complications, Surgical Outcomes, and Trends Over the Last Decade**
Andrew S. Zhang, MD

11:00 AM **14. Simultaneous Fractures of the Atlas and Axis: Presentation, Management, and Outcomes of a Series of 103 Consecutive Patients**
Michael B. Cloney, MD, MPH

11:05 AM **15. Comparison of Treatment Modalities Managing Odontoid Fractures: An Analysis of Timing and Fracture Morphology**
Anirudh K. Gowd, MD

11:10 AM **Discussion**

11:20 AM **16. Technique Note of a Three-dimensional Reduction Method with a Modified C2 Isthmus Screw in Irreducible Atlantoaxial Dislocation**
Bo Yuan, MD

11:25 AM **17. What Facilitates Successful Reduction with Closed Skeletal Traction for Unilateral Locked Subaxial Cervical Facet and What Operative Approach is Superior When Closed Reduction Fails: Anterior or Posterior?**
Timothy Chryssikos, MD, PhD

11:30 AM **18. Bone Density Measurements Show No Significant Association with Presence of Dens Fractures: Case-Control Study Using Opportunistic CT Osteoporosis Indices**
Andrew Sauer, BA

11:35 AM **19. Development of a Web Application for Predicting Neurological Outcome at Hospital Discharge in Spinal Cord Injury Patients: A Machine Learning Approach**
Kyota Kitagawa, MD

11:40 AM **20. Type 2 Odontoid Fractures: Atlantodental Arthrosis as a Novel Risk Factor for Failure of Conservative Management**
Taylor Paziuk, MD

11:45 AM **Discussion**

Thursday, December 12, 2024

Abstract Session 3: Top 10

Time: 1:05 PM - 2:20 PM
Location: General Session - Level 4
Moderators: Andrew Dailey, MD; Samuel C. Overley, MD

1:05 PM **Introduction**

1:10 PM **21. Anterior Compared to Posterior Surgery for Degenerative Cervical Myelopathy: A Cost-Utility Analysis from the Multicenter Canadian Spine Outcomes and Research Network**
Husain Shakil, MD

1:15 PM **22. Therapeutic Efficacy of Clinically Relevant Human iPSC-derived Neural Stem/Progenitor Cell Transplantation for Chronic Cervical Spinal Cord Injury**
Ryo Ogaki, MD

1:20 PM **23. Spinal Cord Metrics Derived from Diffusion-weighted MRI Improves Prognostication in Cervical Spondylotic Myelopathy Compared to Conventional MRI**
Justin Zhang, MD

1:25 PM **24. Association of Pre-injury Depression History with Functional Independence After Spinal Cord Injury**
Braeden Benedict, MD

1:30 PM **25. Outcomes of Non-Union Type 2 Odontoid Fractures – A Multi-Institutional Study**
Benjamin Johnston, MD, PhD

1:35 PM **Discussion**

1:45 PM **26. Therapeutic Effects of Combined Therapy Involving Scar Resection, Decellularized Scaffold, and Human Induced Pluripotent Stem Cell-derived-neural Stem/Progenitor Cells Transplantation in Chronic Complete SCI**
Keitaro Ito, MD

1:50 PM **27. Evaluating Incidence and Predictors of Postoperative Dysphagia Following Cervical Surgery Using EAT-10: A Multi-institutional Study**
Ken Porche, MD

1:55 PM **28. Incidence, Risk Factors and Long-term Consequence of Neurological Complication and Symptom Worsening After Surgery for Degenerative Cervical Myelopathy (DCM): Evidence for a Protective Effect of the Sodium-Glutamate Antagonist Riluzole**
Karlo Pedro, MD

2:00 PM **29. Trends in Cervical Laminoplasty Incidence and Reimbursement in the United States from 2009-2019**
Prashant V. Rajan, MD

2:05 PM **30. Are Postoperative Neck Pain and Kyphotic Change After Laminoplasty Affected by Degree of Facet Joint Degeneration?**
San Kim, MD

2:10 PM **Discussion**

Thursday, December 12, 2024

Abstract Session 4: Motion Preservation

Time: 3:15 PM - 4:30 PM
Location: General Session - Level 4
Moderators: Michael H. McCarthy, MD, MPH; Neill M. Wright, MD

3:15 PM **CSRS Education Committee Overview & Introduction**
Michael H. McCarthy, MD, MPH; Neill M. Wright, MD

3:20 PM **31. Pre- and Intraoperative Factors Associated with Improvement of Neck Pain after Laminoplasty for the Treatment of Cervical Myelopathy**
Arnold Joseph Cagulada, MD, FPOA

3:25 PM **32. Efficacy of Laminectomy and Fusion Versus Laminoplasty for the Treatment of K-line Negative Cervical Ossification of the Posterior Longitudinal Ligament**
San Kim, MD

3:30 PM **33. Open-door Cervical Laminoplasty with Skip-fixation Can Be Considered as a Cost-effective Procedure: 2-year Outcomes of a Multicenter Randomized Controlled Trial**
Koji Tamai, MD, PhD

3:35 PM **34. Evaluation of Radiographically Relevant Heterotopic Ossification Following One-Level Cervical Disc Arthroplasty with a PEEK-on-Ceramic Artificial Disc**
Andrew Park, MD

3:40 PM **35. Impact of CDR and ACDF on the Global Spinal Alignment in Degenerative Spinal Disorder**
Tomoyuki Asada, MD, PhD

3:45 PM **Discussion**

3:55 PM **36. Influence of Cervical Disc Prosthesis Design and 1- Versus 2-level Disc Replacements on ROM Outcomes 2-year Post Disc Arthroplasty in 835 Patients from 4 US IDE Clinical Trials**
Avinash G. Patwardhan, PhD

4:00 PM **37. Surgeons' Views on Cervical Disc Arthroplasty for Elite Athletes: A Survey of Cervical Spine Research Society Members**
Alexander M. Satin, MD

4:05 PM **38. Does Baseline Severity of Arm Pain Affect PROMIS Scores Following Cervical Disc Replacement?**
Gregory A. Snigur, MS

4:10 PM **39. Cervical Disc Replacement Can Improve Neck Pain Similarly to Anterior Cervical Discectomy and Fusion in Patients with Prominent Neck Pain: Propensity Score Matching Analysis with Overlap Weighting**
Tomoyuki Asada, MD, PhD

4:15 PM **40. Disc to Disc: Early Results of the Multi-center, Prospective, Randomized Clinical Investigational Device Exemption Trial Comparing a Novel Total Disc Replacement (TDR) to an Approved TDR Control at Two Contiguous Levels of the Cervical Spine**
Jad Khalil, MD

4:20 PM **Discussion**

Friday, December 13, 2024

Abstract Session 5: Complications

Time: 8:05 AM - 9:20 AM
Location: General Session - Level 4
Moderators: Addisu Mesfin, MD; Rory K. Murphy, MD

8:10 AM **41. Reason for Revision Surgery After Cervical Disc Arthroplasty Based on Medical Device Reports Maintained by the United States Food and Drug Administration**
Darren R. Lebl, MD, MBA

8:15 AM **42. Preoperative Selective Nerve Root Injections Do Not Increase Risk of Postoperative Infection After Anterior Cervical Decompression and Fusion**
Graham J. Beutler, MD

8:20 AM **43. Prognostic Value of Onodera's Prognostic Nutritional Index (OPNI) in Predicting Postoperative Complications in Cervical Spine Surgery**
Isaiah Hughes, BS

8:25 AM **44. Graft Migration and Subsidence in ACDF Surgery**
Omar Zakieh, MBBS

8:30 AM **45. All-Cause Revision Surgery After Single Level Anterior Cervical Discectomy and Fusion with Plate vs. Stand-Alone Cage**
Wesley M. Durand, MD

8:35 AM **Discussion**

8:45 AM **46. Primary Repair of Delayed Esophageal Perforation Following Anterior Cervical Discectomy and Fusion**
Christopher Lucasti, MD

8:50 AM **47. Impact of Added Morbidity when Performing Cervical Circumferential Cervical Fusion (CCF) Compared to ACDF Alone: Results from 227 Prospectively Randomized Enrolled Subjects Treated with 3-level Fusion**
Alexander C. Lemons, MD

8:55 AM **48. Complications, Morbidity, and Mortality Following Corrective Surgery for Cervical Deformity Among Geriatric Cohorts**
Wesley M. Durand, MD

9:00 AM **49. Preoperative Chronic Steroid Use Predicts Increased Infections and Readmissions After Anterior Cervical Discectomy and Fusion**
Neil V. Shah, MD, MS

9:05 AM **50. Malnutrition as a Risk Factor for Anterior Cervical Discectomy and Fusion Complications: A Large Propensity-Matched Retrospective Cohort Study**
Nischal Acharya, BS

9:10 AM **Discussion**

Friday, December 13, 2024

Abstract Session 6: Deformity/Outcomes 2

Time: 10:50 AM - 12:05 PM
Location: General Session - Level 4
Moderators: Serena S. Hu, MD; Christopher I. Shaffrey, MD

10:50 AM **CSRS Communications Committee Overview**
Brian W. Su, MD

10:54 AM **Introduction**
Serena S. Hu, MD; Christopher I. Shaffrey, MD

10:55 AM **51. So Close Yet So Far: The Impact of cSVA Undercorrection During Adult Cervical Deformity Surgery - An Incremental Correction Analysis**
M Burhan Janjua, MD

11:00 AM **52. Analysis of Success Versus Poor Realignment in Patients with Cervical Deformity: In-Construct Angles Provide Novel Targets for Correction**
Themistocles S. Protopsaltis, MD

11:05 AM **53. Quantifying the Importance of Upper Cervical Extension Reserve in Adult Cervical Deformity Surgery and Its Impact on Baseline Presentation and Outcomes**
Peter Passias, MD

11:10 AM **54. Limited Improvement Following Anterior Cervical Discectomy and Fusion in Patients with Age-adjusted Spinopelvic Malalignment: A Propensity Score and Inverse Probability Weighted Cohort Study**
Chad Z. Simon, BS

11:15 AM **55. Sex, Age and Ethnicity Affect Cervical Spine Sagittal Alignment: Results of a Systematic Review and Meta-Analysis of >35,000 Asymptomatic Participants**
Alexandra Dionne, BS

11:20 AM **Discussion**

11:30 AM **56. Fusion Outcomes of GLP-1 Agonist Therapy in Multi-Level Cervical Spinal Fusion: A Propensity-Matched Analysis**
Sohrab Vatsia, MD, MS

11:35 AM **57. Should We Re-Instrument the Originally Fused Level in Adjacent-Segment ACDF?: A Quality Outcomes Database Study**
Mitchell Bowers, MD

11:40 AM **58. Differences in European and North American Results in Secondary Surgery Following Cervical Disc Arthroplasty vs. Anterior Cervical Discectomy and Fusion: Systematic Review and Meta-analysis of Randomized Controlled Trials**
Brandon A. Sherrod, MD

11:45 AM **59. An Economic Analysis of the Cervical Spondylotic Myelopathy Surgical (CSM-S) Trial: Cost-Effectiveness of Anterior and Posterior Approaches**
Zoher Ghogawala, MD

11:50 AM **60. Upper Level Instrumentation at C2 versus C3 Does Not Influence Radiographic or Clinical Outcomes after Posterior Cervical Fusion**
Mark Plantz, MD

11:55 AM **Discussion**

Saturday, December 14, 2024

Abstract Session 7: Fun Facts

Time: 10:40 AM - 11:55 AM
Location: General Session - Level 4
Moderators: Matthew W. Colman, MD; Robert F. Heary, MD

10:40 AM **Introduction**

10:45 AM **61. Does Spinal Canal – Cord Mismatch Adversely Affect Clinical Outcomes of Anterior Cervical Discectomy and Fusion for the Treatment of Cervical Myelopathy?**
Hyuk-joon HJ. Sohn, MD

10:50 AM **62. Outcomes After Cervical Laminectomy and Fusion Versus Cervical Laminoplasty in Patients of Advanced Age**
Stephen Selverian, MD

10:55 AM **63. Ossification of Posterior Longitudinal Ligament (OPLL) Growth in C1/2 Segment and its Effect on Clinical Outcome: Is C2 Laminectomy Really Necessary?**
Dongkyu Kim, MD

11:00 AM **64. Virtual Reality Hand Dexterity Training to Augment Post-surgical Neurological Recovery in Degenerative Cervical Myelopathy: A Prospective Clinical Trial**
Aditya Vedantam, MD

11:05 AM **65. Radiographic Outcomes and Subsidence Rate in Hyperlordotic Versus Standard Lordotic Interbody Spacers in Patients Undergoing Anterior Cervical Discectomy and Fusion**
Rajkishen Narayanan, MD

11:10 AM **Discussion**

11:20 AM **66. Impact of Obstructive Sleep Apnea on Outcomes after ACDF: A Propensity Matched Analysis**
Rajkishen Narayanan, MD

11:25 AM **67. Understanding the Impact of Low-Density Lipoprotein Levels and Lipid-Lowering Agents on Rates of Pseudarthrosis After Anterior Cervical Discectomy and Fusion**
Vikas V. Patel, MD

11:30 AM **68. Clinical Determinants of Neurological Recovery after Acute Traumatic Cervical Spinal Cord Injury: Analysis of 655 Prospectively-Accrued Cases from the NASCIS 2 and NASCIS 3 Trials.**
Julio C. Furlan, MD, LLB, MBA, MSc, PhD

11:35 AM **69. Shifting Trends and Regional Disparities in Intraoperative Neuromonitoring Usage for Anterior Cervical Discectomy and Fusion**
Dana G. Rowe, BA

11:40 AM **70. Neuromonitoring in Cervical Spine Surgery: Demographics and Geographical Trends - A Survey of the Cervical Spine Research Society**
Daniel Robinson, MD

11:45 AM **Discussion**

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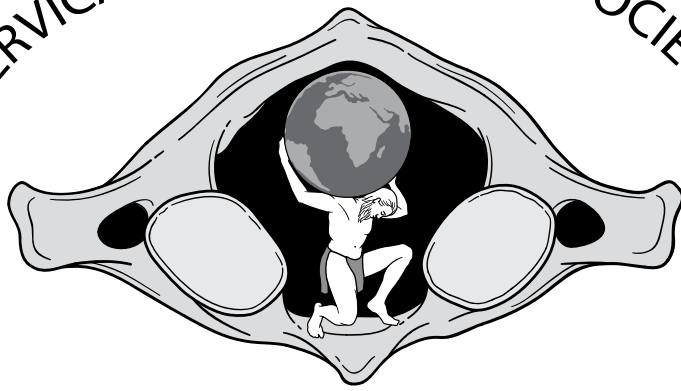

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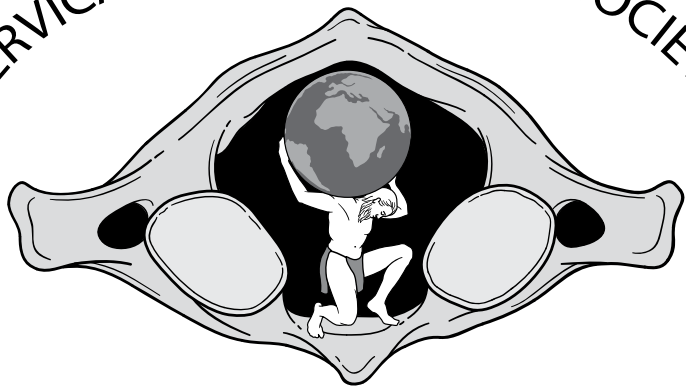

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Podium and Virtual Poster Abstracts

PAPER 1

Postoperative Improvement in Neck Pain Following Decompression Without Fusion in Patients with Cervical Myelopathy

Hiroyuki Nakarai, MD[1], *So Kato, MD[1], Yasushi Oshima, MD[1]*
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Introduction: Neck pain (NP) is a frequent complaint in patients with cervical spondylotic myelopathy (CSM). Although multiple factors contribute to NP, previous studies have suggested that the myelopathy itself may be one of the causes of NP. However, it is still unclear whether decompression surgery without fusion can alleviate NP by improving myelopathic symptoms. The objectives of this study are (1) to clarify the patient characteristics of CSM patients with NP and (2) to investigate the postoperative changes in NP following decompression surgery without fusion.

Materials and Methods: This is a multicenter retrospective cohort study using a registry database of all spine surgeries performed at 13 tertiary referral hospitals. The analysis included CSM patients who underwent primary laminoplasty or laminectomy without fusion between 2019 and 2022 and completed questionnaires before and 1 year after surgery. The questionnaire included Numerical Rating Scale (NRS), Neck Disability Index (NDI), Short Form 12 items (SF-12), and Japanese Orthopaedic Association (JOA) score. Patient characteristics and outcomes were compared between those with and without NP (NRS-NP≥1 vs. 0). The minimum clinically important difference (MCID) for NP was defined as a >30% improvement from baseline. Multivariate logistic regression was performed to evaluate the prognostic factor for achieving MCID in NRS-NP. Age, sex, BMI, smoking habit, preoperative NRS-NP were selected as adjustment confounders based on previous literature.

Results: A total of 562 patients, (71 ± 11 years, 66% male) were analyzed. Preoperative NP was present in 347 patients (61.2%). The proportion of current smokers was significantly higher in patients with concurrent NP (10.1% vs. 4.7%, P=0.02). Patients with concurrent NP were also younger (69.6 vs. 73.8 yo, P<.001), had worse preoperative NDI (39.5 vs. 32.1, P=0.03), worse SF-12 mental component score (MCS) (48.8 vs. 53.8, P<0.001), and worse JOA score (11.0 vs. 11.6, P=0.003). Among the 347 patients with pre-existing NP, NRS-NP improved significantly from baseline (3.9 ± 2.5 vs. 2.3 ± 2.3, P<0.001), and a total of 215 (62%) patients achieved the MCID at 1 year postoperatively. Univariate analysis showed that patients who achieved the MCID had a significantly better postoperative JOA recovery rate (JOA-RR) (30.2% vs 7.3%, P=0.01). The logistic regression analysis revealed that achieving a postoperative JOA-RR greater than 50% was an independent prognostic factor for MCID compared to JOA-RR less than 0% (adjusted odds ratio [aOR] = 2.45, 95% confidence interval [CI] 1.39-4.41, P = 0.003).

Conclusion: More than 60% of CSM patients had NP preoperatively, which was more frequent in younger and smoking patients with worse myelopathic symptoms. However, NP was significantly reduced postoperatively, and 60% of patients achieved MCID, especially those with better postoperative JOA-RR. Decompression surgery without fusion may be sufficient to mitigate NP in CSM patients.

PAPER 2

What Predicts Attainment of Substantial Clinical Benefit in Neck Pain-Related Disability 24 Months After Surgery for Cervical Spondylotic Myelopathy?

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Introduction: Surgery for cervical spondylotic myelopathy (CSM) intends to halt neurological deterioration, but some patients experience significant improvements in functional status and disability. Through an analysis of Neck Disability Index (NDI) scores for patients undergoing CSM surgery, this study intends to identify factors that predict which patients will experience substantial clinical benefit (SCB) for disability.

Materials and Methods: Data was obtained from the Quality Outcomes Database CSM dataset, a prospective registry cohort of 1141 patients from 14 sites. Patients were excluded if they had missing baseline or 24-month NDI scores, baseline NDI below 20, or no baseline neck pain. Remaining patients were partitioned into a training (n = 591) or test set (n = 131). Logistic regression and random forest models, with and without principal component analysis (PCA), were trained to predict whether patients achieved SCB at 24 months. SCB was defined as a 20-point reduction from baseline NDI score (100-point scale) following CSM surgery.

Results: Overall, 722 patients met inclusion criteria: mean age 59.8±11.4, 52.8% female, mean BMI 30.6±6.4, mean baseline NDI 45.7±16.2, mean baseline VAS neck pain 6.2±2.8, and mean baseline mJOA 11.8±2.8. Logistic regression without PCA had AUROC of 0.678±0.035 and AUPRC of 0.733±0.032. Logistic regression with PCA had AUROC of 0.686±0.031 and AUPRC of 0.731±0.043. Random forest without PCA had AUROC of 0.670±0.033 and AUPRC of 0.707±0.044. Random forest with PCA had AUROC of 0.683±0.031 and AUPRC of 0.725±0.028. Significant positive predictors of SCB attainment were baseline neck pain intensity (OR 1.76, 95%CI: 1.68-1.84, p=0.002), neck pain interfering with recreation (OR 1.51, 95%CI: 1.45-1.56, p=0.002), neck pain interfering with work (OR 1.36, 95%CI: 1.31-1.41, p=0.032), and neck pain interfering with lifting (OR 1.36, 95%CI: 1.31-1.40, p=0.022). Significant negative predictors were current unemployment (OR 0.53, 95%CI: 0.49-0.58, p=0.034) and undergoing a fusion at C7 (OR 0.26, 95%CI: 0.22-0.30, p=0.045).

Conclusion: Standard logistic regression without PCA was non-inferior to more complex models. We found that higher baseline neck pain and higher neck pain interference with recreation, work, and lifting were associated with substantial improvements in NDI. Patients who were unemployed or who underwent fusion at C7 were at risk of not attaining SCB. This study helps uncover features associated with substantial clinical improvement in disability following CSM surgery and may assist in patient counseling.

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Variable	Training (N = 591)	Test (N = 131)	p-value
Age - mean (SD)	59.4 (11.3)	61.8 (11.8)	0.029
BMI - mean (SD)	30.7 (6.5)	30.0 (5.9)	0.196
SES Index Quartile - mean (SD)	2.6 (1.0)	2.5 (1.0)	0.611
Baseline NDI - mean (SD)	45.9 (16.1)	45.1 (16.6)	0.486
Baseline neck pain intensity - mean (SD)	2.4 (1.2)	2.4 (1.0)	0.627
Female (%)	313 (53.0)	68 (51.9)	0.847
Non-Smoker (%)	468 (79.2)	113 (86.3)	0.068
Diabetes (%)	134 (22.7)	28 (21.4)	0.817
CAD (%)	61 (10.3)	16 (12.2)	0.532
COPD (%)	51 (8.6)	10 (7.6)	0.862
Unemployed (%)	323 (54.7)	74 (56.5)	0.771
SCB Attainment (%)	337 (57.0)	75 (57.3)	1.00

Table A. Demographics and baseline characteristics of patients in the training and test sets for the first randomized seed out of 11 total. P-values are calculated via Wilcoxon signed-rank test for means and Fisher's exact test for categorical variables, and none are significant after Holm–Bonferroni correction for multiple-comparison.

Model	Area Under the ROC Curve (AUROC)	Area Under the Precision-Recall Curve (AUPRC)
Logistic Regression	0.678 ± 0.035	0.733 ± 0.032
Logistic Regression w/PCA	0.686 ± 0.031	0.731 ± 0.043
Random Forest	0.670 ± 0.033	0.707 ± 0.044
Random Forest w/PCA	0.683 ± 0.031	0.725 ± 0.028

Table B. Performance metrics for the four trained models, reported as averages with standard deviation from 11 randomized runs.

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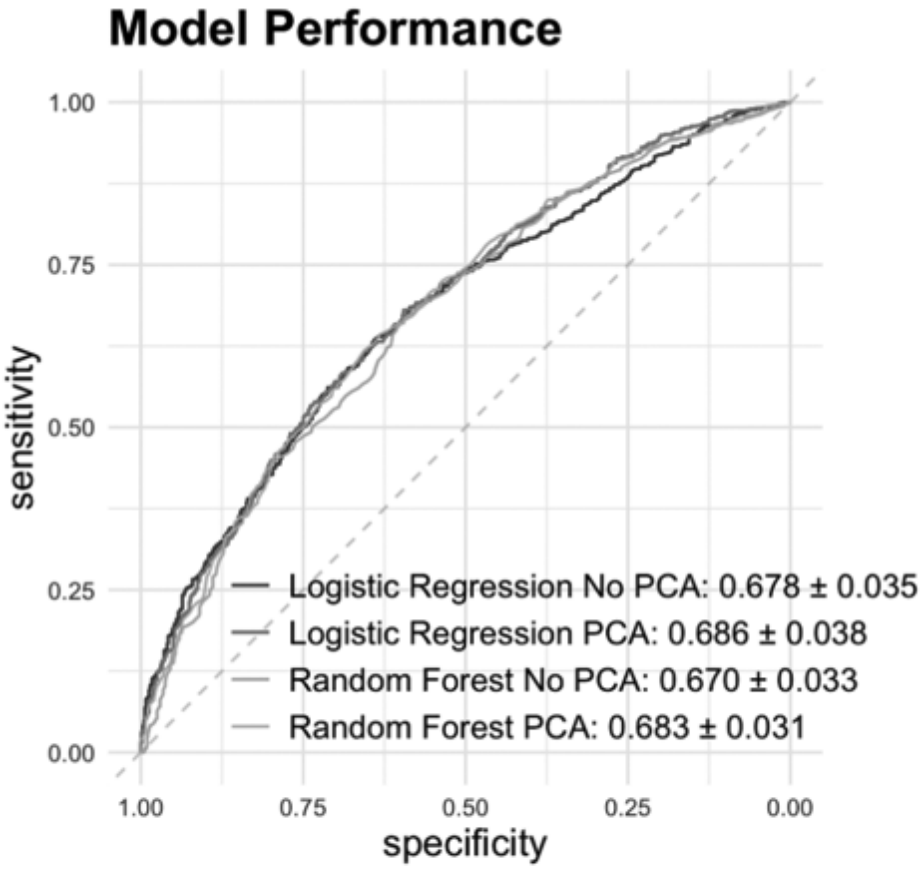

Figure 1. Receiver operating characteristic curve for logistic regression and random forest models, with and without PCA. Performance is reported as average AUROC with standard deviation.

PAPER 3

Could Indirect Decompression Occur for Cord Compression by Ligamentum Flavum with Anterior Cervical Discectomy and Fusion?

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Introduction: While anterior cervical discectomy and fusion (ACDF) effectively removes anterior compressive lesions, it cannot address posterior compressive lesions such as the ligamentum flavum. Previous studies have shown that posterior cord compression by the ligamentum flavum (CCLF) is a poor prognostic factor for neurological recovery after ACDF. In such cases, posterior surgery or an anterior-posterior combined operation may be considered. However, sagittal alignment and preoperative symptoms may favor anterior surgery despite the presence of CCLF. Understanding the postoperative changing pattern of CCLF after ACDF and identifying factors hindering its improvement could optimize surgical techniques to prevent remaining cord compression by CCLF. Therefore, this study aimed to (1) demonstrate the postoperative changing pattern of CCLF after ACDF and (2) elucidate perioperative factors associated with the improvement of CCLF.

Materials and Methods: A total of 175 patients who underwent ACDF and were followed up for more than 2 years were retrospectively reviewed. Preoperative CCLF was graded on a 0-2 scale as suggested by a previous study. One hundred nineteen patients assessed as CCLF grade 1 or 2 were included in the study. Patients whose CCLF grade improved after ACDF were classified as the 'improved group,' while those without improvement were classified as the 'unimproved group.' Patient characteristics, cervical sagittal parameters including C2-C7 lordosis, C2-C7 sagittal vertical axis (SVA), segmental lordosis, disc height, spondylolisthesis, and the location of the allograft within the disc space were assessed.

Results: AAmong the 119 included patients, 69 (57.9%) demonstrated improvement in CCLF grade and were included in the improved group, while the remaining 50 patients (42.0%) who did not show improvement were classified as the unimproved group (Table 1). Patients with postoperative CCLF grade 0 had significantly better JOA scores (15.2±2.0 vs. 14.4±2.4, p=0.048) and JOA recovery rates (36.7±33.6 vs. 10.2±24.8, p=0.045) at 3 months postoperatively compared to patients with postoperative CCLF grade 1 or 2 (Table 2). The improved group showed significantly less spondylolisthesis (7/69,10.1% vs. 17/50,34.0%; p=0.002) and postoperative segmental lordosis (4.5±2.7 vs. 6.8±4.3, p=0.001) compared to the unimproved group. Spondylolisthesis (odds ratio, 0.252; p=0.009) and postoperative segmental lordosis (odds ratio, 0.835, p=0.008) also showed significant associations as risk factors for CCLF improvement failure in logistic regression analysis.

Conclusion: Although CCLF grade improved in 57.9% of patients after ACDF, 42.0% failed to demonstrate improvement. A higher postoperative CCLF grade was associated with a poorer postoperative JOA score. A higher postoperative segmental lordosis was identified as a risk factor for CCLF improvement failure. Increasing disc height with the insertion of an interbody spacer could stretch the ligamentum flavum, but with greater segmental lordosis, this effect could be eliminated, distracting only the anterior column of the spinal column. Therefore, when anterior surgery is favored considering sagittal alignment and preoperative symptoms

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for patients with preoperative CCLF, efforts should be made to decrease the amount of segmental lordosis (Figure 1). Furthermore, since preoperative spondylolisthesis was identified as a risk factor for CCLF improvement failure, more emphasis should be placed on care when performing ACDF for patients with combined CCLF and spondylolisthesis.

Table 1. Patient baseline characteristics

	Unimproved (n = 50)	Improved (n = 69)	P value
Age	65.5±10.5	62.0±9.8	0.067
Sex (M:F)	27:23	42:27	0.460
BMI (kg/m2)	25.6±3.1	24.7±3.9	0.169
HTN	24 (48.0%)	23 (33.3%)	0.130
DM	13 (26.0%)	15 (21.7%)	0.664
Smoking status	10 (20.0%)	15 (21.7%)	1.000
Number of levels fused	1.9±0.7	2.0±0.8	0.839
Follow-up period	54.6±36.2	58.0±34.6	0.600

M, male; F, female; BMI, body mass index; HTN, hypertension; DM, diabetes mellitus

Categorical variables were compared using a chi-square test

Continuous variables were compared using a Student's t-test

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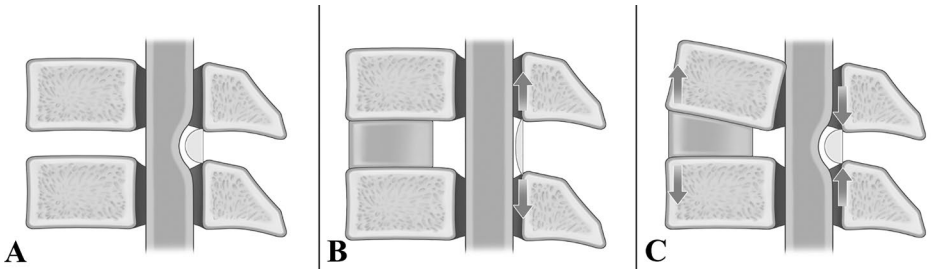
Table 2. Patient reported outcome measures

		Comparison by improvement			Comparison by preoperative CCLF grade			Compa
		Unimproved	Improved	P value	Grade 1	Grade 2	P value	Grade
Neck pain VAS	Preop	3.0±2.9	3.3±2.6	0.629	3.0±2.8	3.9±2.3	0.127	3.1±2
	Postop 3M	2.1±2.5	1.5±1.9	0.139	1.7±2.1	1.8±2.4	0.786	1.4±1
	Postop 2Y	1.9±2.5	2.0±2.4	0.910	1.9±2.3	2.2±2.9	0.500	2.2±2
Arm pain VAS	Preop	4.4±2.8	3.8±2.6	0.199	3.7±2.8	5.1±1.8	0.025*	3.6±2
	Postop 3M	2.7±3.0	2.0±2.5	0.217	2.3±2.7	2.4±2.7	0.833	2.0±2
	Postop 2Y	3.2±3.2	3.4±3.2	0.743	3.2±3.2	4.0±3.4	0.266	3.7±3
JOA score	Preop	13.6±2.2	13.8±2.8	0.683	13.6±2.7	14.0±2.0	0.510	13.7±
	Postop 3M	14.3±2.2	15.1±2.2	0.089	14.9±2.1	14.3±2.4	0.194	14.8±
	Postop 2Y	14.6±2.3	14.7±2.3	0.852	15.0±2.1	13.7±2.6	0.014*	15.2±
JOA recovery rate	Postop 3M	5.8±21.0	35.5±20.2	0.082	29.2±19.4	3.4±23.2	0.200	15.9±4
	Postop 2Y	6.5±23.1	16.3±27.3	0.594	24.2±34.7	-28.7±45.4	0.013*	36.7±3

CCLF, cord compression by ligamentum flavum; VAS, visual analogue scale; JOA, Japanese Orthopedic Association

All variables were analyzed using a Student's t-test

* $p<0.05$



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PAPER 4

Residual Anterior Compression on Postoperative MRI After Laminoplasty for Multilevel Degenerative Cervical Myelopathy

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Introduction: Expansive open-door laminoplasty (LAMP) is one of the most widely used procedures for treating multilevel degenerative cervical myelopathy (MDCM). However, previous studies have suggested that the presence of residual anterior spinal cord compression (RASCC) may lead to poor clinical outcomes after LAMP. In this study, we reviewed early postoperative MRI to evaluate the effect of RASCC on clinical outcomes and identify risk factors of RASCC.

Materials and Methods: We retrospectively reviewed MDCM patients (≥3 levels, excluded OPLL, deformity, trauma and previous spine surgery) with LAMP by a single surgeon. All patients had MRI at 3-month follow-up after the index surgery. The RASCC was defined as the anterior compression leading to absence of cerebrospinal fluid and cord deformity. The neurological function before and after surgery was evaluated using the modified Japanese Orthopedic Association (mJOA) score and the JOA recovery rate (JOARR). Each item of the mJOA score was also investigated. The intensity of neck pain was evaluated using the numeric rating scale (NRS). The cobb angle between C2 and C7 was measured on the neutral lateral radiographic. The spinal cord compression was evaluated by maximum spinal cord compression (MSCC) on MRI. The preoperative INTmin was defined as lowest interval (INT) between the mK-line and the anterior compression(Figure 1).

Results: From January 2017 to November 2023, two hundred and eighty MDCM patients with LAMP were enrolled. A total of 182 patients underwent MRI examination at 3-month follow-up including 42 (23.08%) patients with RASCC. 6 patients had C5 palsy and 2 had deep infection.

There was no significant difference in demographic data between the RASCC (+) group and RASCC (-) group (Table 1). The preoperative mJOA scores were similar in these two groups (13.01±1.87 vs. 12.81±1.99, p= 0.58). However, the postoperative mJOA scores was higher in RASCC (-) group at the follow-up (15.44±1.00 vs. 15.84±1.06, p = 0.011). The recovery rates of the mJOA scores were also higher in RASCC (-) group (61.40% vs. 73.89%, p<0.001), especially in both the JOARR of lower extremity motor function (50.29% vs. 72.77%, p=0.003) and sensation of trunk (54.24% vs 86.19, p<0.001). None of the 182 patients showed deterioration of myelopathy after surgery. The preoperative and postoperative neck NRS scores were equivalent in both groups (Table 2).

For radiologic results, the C2-C7 cobb angle, preoperative INTmin and MSCC were lower in the RASCC (+) group (Table 3). Multivariate logistic regression analysis revealed preoperative INTmin was the significant risk factor for RASCC (Table 4).

In the RASCC (+) group, 16 (38.10%) patients with unsatisfactory neurological recovery were recommend to perform a second-stage anterior surgery to achieve better recovery, while only 3 (7.14%) actually accepted the anterior surgery and the JOARR increased 16.67%, 21.00%, 25.00% after secondary surgery.

Conclusion: Presence of residual anterior spinal cord compression after laminoplasty for

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MDCM could usually lead to unsatisfactory neurological recovery, and the preoperative INTmin, C2-C7 cobb angle and maximum spinal cord compression were risk factors for RASCC. In patients with RASCC and unsatisfactory neurological recovery, only less than 10% patients would accept the suggested second-stage anterior surgery.

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Table 1 Demographic data for each group

	RASCC Group(n=42)	Non-RASCC Group(n=140)	P
Age(yrs)	51.86±13.87	54.35±10.48	0.29
Sex(female/male)	31/11	94/46	0.41
BMI(kg/m^2)	24.59±3.24	24.43±3.03	0.77
Following time	106.00±18.56	111.07±26.06	0.59
Number of operated laminae	4.93±0.34	4.92±0.38	0.99
Comorbidities(%)			
Hypertension	18.6	26.19	0.28
Diabetes mellitus	11.43	16.67	0.37
Cardiac disease	2.11	0	0.34
Smoke history	10.7	4.76	0.25

Table 2 Clinical data comparison of RASCC Versus Non-RASCC Groups

		RASCC Group(n=42)	Non-RASCC Group(n=140)	P
mJOA score(pts)				
Preoperative		13.01±1.87	12.81±1.99	0.58
Postoperative		15.44±1.00	15.84±1.06	0.011*
JOARR (%)		61.66±17.91	73.89±18.60	<0.001
JOARR of each function				
Motor function	Upper extremity	83.82±33.70	90.80±23.05	0.28
	Lower extremity	50.29±38.29	72.77±34.20	0.003*
Sensation	Upper extremity	55.56±37.73	62.50±35.18	0.39
	Trunk	54.24±45.86	86.19±26.96	0.007*
	Lower extremity	54.76±41.79	68.67±40.53	0.10
Bladder function		100	69.70±45.83	0.33

Table 3 Radiographic Data comparison of RASCC Versus Non-RASCC Groups

	RASCC Group(n=42)	Non-RASCC Group(n=140)	P
C2-C7 cobb angle(°)			
Preoperative	7.34±9.68	11.63±10.36	0.018*
Postoperative	6.79±10.43	12.33±9.58	0.002*
Preoperative T1 hypointensity	11(26.19%)	42(30.00%)	0.634
INTmin (mm)	3.07±2.19	4.36±2.11	<0.001*
MSCC			
Preoperative	0.48±0.15	0.58±0.14	<0.001*
Postoperative	0.72±0.15	0.86±0.14	<0.001*

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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Table 4 Multivariate Logistic Regression Analyses for the Risk Factors of Residual Anterior Cord Compression

	OR (95% CI)	P
Preoperative C2-C7 cobb angle		0.253
INTmin (mm)	0.784(0.650-0.946)	0.011*
Preoperative MSCC		0.133

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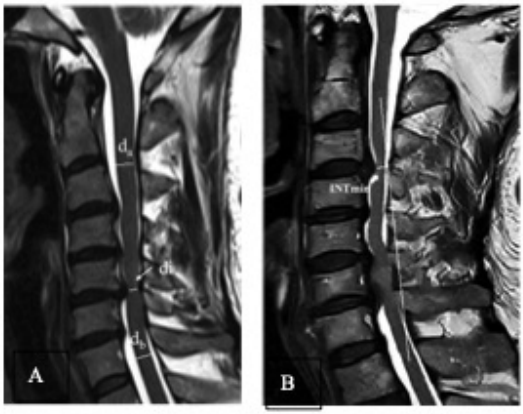

Figure 1 A: Midsagittal image showing the measurements of the residual anterior spinal cord compression (MSCC). The sagittal diameters of the cord (di) at the region of greatest compression and the normal cord diameters above (da) and below (db) are measured (MSCC=di/ (da +db)/2). B The INTmin was defined as lowest interval between the mK-line and the anterior compression.

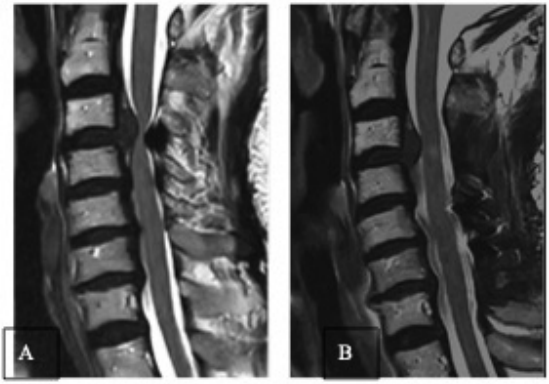

Figure 2 Case presentation: A 70 years-old female complicated with coronary heart disease presented with bilateral hand clumsiness, bilateral arm numbness, trunk numbness, lower limb extremities numbness and weakness in both legs. The preoperative mJOA score was 7.5. Sagittal view on MRI showed cord compression at C3/C4, C4/C5, C5/6 and C6/7 (Figure 2A), LAMP at C3–C7 was performed. At 3 months postoperatively, the C3/4 showed RASCC (Figure 2B) and the RR of mJOA was 73.68%. While she still had bilateral arm numbness and numbness in both feet. The second-stage C3/4 ACDF was performed and the JOARR increase to 94.73%.

PAPER 5

Patients With and Without Severe Systemic Illness, Measured by ASA Grade, Benefit from Surgery for CSM: A Report from the Quality Outcomes Database

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Introduction: Despite the prevalence of cervical spinal myelopathy (CSM), it is unclear if patients with poor physical status or severe systemic illness benefit from surgery to the same extent as patients with better overall health.

Materials and Methods: Prospectively collected data from the Quality Outcomes Database registry CSM cohort were used. American Association of Anesthesiology (ASA) grade was used as a surrogate for patients' overall physical status and illness burden. For univariate analysis, the study cohort was split into patients with mild systemic disease (ASA 1 or 2) and severe systemic disease (ASA 3 or 4). The primary outcome measures were 90-day readmission rates and 24-month rate of achieving minimal clinically important differences (MCID) for patient-reported outcomes (PROs) of numerical rating score (NRS) for arm and neck, neck disability index (NDI), and quality of life (EQ-5D questionnaire).

Results: Overall, 1141 CSM patients were enrolled, and 1062 patients had preoperative ASA grade available: 521 patients (49%) were in the mild systemic illness cohort (ASA 1 or 2), and 541 (51%) patients had severe systemic illness (ASA 3 or 4). The severe disease cohort was older (63.3±11.0 vs 57.4±11.7), had higher BMI (31.4±7.0 vs 28.9±5.6), had higher rates of diabetes (32% vs 12%), coronary artery disease (16% vs 4%), and depression (25% vs 20%), and was more likely to require ambulation assistance (21% vs 9%)($p<0.05$). There were no significant differences in gender, smoking history, symptom duration, and presence of motor deficiency. At baseline, the severe disease cohort had higher NRS arm (5.2±3.5 vs 4.7±3.4) and neck (5.5±3.2 vs 5.1±3.3) pain, as well as worse NDI (40.5±20.1 vs 36.8±21.0) and EQ5D (0.53±0.22 vs 0.59±0.22) scores ($p<0.05$). Perioperatively, the cohort with severe systemic disease had longer hospitalization lengths (2.4±2.6 vs 1.7±2.0 days) and higher rates of non-home discharge (17% vs 5%) ($p<0.05$).

The study cohort had an overall readmission rate of 5%. The severe systemic disease cohort had higher 90-day readmissions (7.6% vs 2.5%) ($p<0.001$), including medical (non-surgery related) indications (3.9% vs 1%)($p<0.05$). Multivariate analysis, controlling for variables with $p<0.2$ on univariate analysis, found ASA grade was the only significant predictor of 90-day readmissions (OR:2.5 per 1-grade increase, 95% CI: 1.4–4.5).

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Despite these differences, both the high and low systemic disease cohorts had similarly high rates of achieving MCID for NRS arm (70.4% vs 71.9%) and neck (69.5% vs 69.4%) pain, NDI (62.2% vs 67.7%), and EQ5D (67.9% vs 66.9%) (all p-values >0.05).

Conclusion: Patients undergoing CSM surgery have relatively low (5%) 90-day readmission rates regardless of illness severity. Patients with severe systemic illness (higher ASA grades) have worse baseline PROs and higher rates of 90-day readmissions. However, they achieve similar rates of MCID for all measured PROs. These findings indicate that surgery for CSM is beneficial—As long as patients are stable for surgery, they should not be denied surgery based on systemic illness burden or ASA grade. Careful discharge planning, thorough patient education, and medical management for patients with higher ASA grades may reduce readmission rates in the acute postoperative period.

PAPER 6

Re-analysis of the CSM-PROTECT Multicentre Randomized Controlled Trial Reveals a Global Treatment Benefit of Riluzole in Patients Undergoing Surgery for Degenerative Cervical Myelopathy

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Introduction: While the primary analysis of the CSM-PROTECT Trial did not demonstrate improved recovery with the adjunctive use of riluzole on the modified Japanese Orthopedic Association (mJOA) scale in patients with degenerative cervical myelopathy (DCM) undergoing surgical intervention, interesting observations emerged in secondary analyses, suggesting the possibility of other therapeutic benefits not captured by the mJOA scale. (1-2) This study seeks to re-evaluate the efficacy of Riluzole through a global statistical analysis encompassing multiple outcomes, with the intent of providing a more comprehensive assessment of potential treatment efficacy.

Materials and Methods: In this re-analysis, we conducted a detailed examination of data from the multicenter, double-blind, placebo-controlled phase III CSM-PROTECT study. This trial included 290 patients who underwent decompressive surgery for DCM and were randomly allocated to receive either Riluzole or placebo. Our focus was to evaluate clinical improvement over one year using five distinct assessment scales: SF-36 Physical Component Summary (PCS), Numeric Rating Scale for Neck and Arm pain, ASIA motor score and Nurick grade. We employed a global statistical test (GST) that utilizes a nonparametric rank sum test to assess treatment efficacy. (3-5) The resulting global treatment effect (GTE, ranging from -1 to 1) indicates the net gain in probabilities that one arm outperforms the other arm across multiple endpoints. A GTE greater than zero indicates a more favorable global treatment response with Riluzole compared to placebo.

Results: A total of 290 patients in the original CSM-PROTECT trial were included in the analysis, with a mean (SD) age of 59(10.1) years, including 129 (44%) females. In the trial, 141 patients received Riluzole, while 149 were administered placebo. There was a significantly higher probability of global improvement at 1-year among patients treated with Riluzole compared with the placebo group [GTE = 0.08 (SD 0.04), p=0.02]. A similar trend of favorable global response with Riluzole was identified at 35 days and 6 months (GTE = 0.07), although the difference was not statistically significant (p=0.04). Overall, Riluzole-treated patients had at least a 54% [=(1+GTE)/2] higher likelihood of achieving improved outcomes at 1 year compared to those receiving placebo. The triple combination of ASIA Motor score, Neck and Arm pain NRS at 1 year provided the best-fit parsimonious model for the detection of Riluzole's greatest overall benefit [GTE = 0.11 (SD 0.05), p=0.007].

Conclusion: This re-analysis of the CSM-PROTECT trial demonstrates that perioperative administration of Riluzole leads to an overall improvement in clinical outcomes compared to placebo using global treatment effect. Based on these data, clinicians may wish to consider the option of using riluzole as an adjunctive treatment in patients with DCM undergoing surgical treatment.

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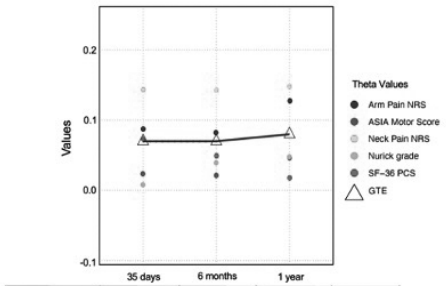
Figure 1. Application of a global statistical approach in the estimation of GTE (global treatment effect) and in significance testing at 35 days, 6 months, and 1 year. Each theta value (θ_v) quantifies the difference between the probability that treatment is better than control (p) and the probability that the control is better than the treatment (q) [i.e $\theta_v = (p - q)$]. The GTE represents the mean of the five theta values at each time-point. *p-values* were derived using O' Brien's rank sum type test with variance adjustment for testing the general nonparametric Behrens-Fisher hypothesis. The sign indicates the direction of values prior to coding, with larger values signifying better outcomes in (+), while higher values indicate worse results in (-).



Arm Pain NRS	0.09	0.08	0.13	-
ASIA Motor Score	0.02	0.02	0.05	+
Neck Pain NRS	0.14	0.14	0.15	-
Nurick grade	0.01	0.04	0.05	-
SF-36 PCS	0.07	0.05	0.02	+
GTE (SD)	0.07 (0.04)	0.07 (0.04)	0.08 (0.04)	
Mean Rank sum (placebo)	704.10	703.20	698.80	
Mean Rank sum (riluzole)	752.30	753.20	757.80	
p value	0.04	0.04	0.02	

Table 1. Variations in GTE values across different outcome scale combinations at 1 year: (A) Five-outcome combinations, (B) Three-outcome combinations

A. Five outcomes

Outcome Scales						GTE	p value
Combination 1	Sf-36 PCS	Neck pain NRS	Arm pain NRS	ASIA motor	Nurick grade		
θ_v	0.02	0.15	0.13	0.05	0.05	0.08	0.02
Combination 2	Sf-36 PCS	Neck pain NRS	Arm pain NRS	ASIA sensory	Nurick grade		
θ_v	0.02	0.15	0.13	0.02	0.05	0.07	0.03
Combination 4	Sf-36 PCS	Neck pain NRS	Arm pain NRS	ASIA motor	mJOA		
θ_v	0.02	0.15	0.13	0.05	-0.13	0.04	0.27
Combination 3	Sf-36 PCS	NDI score	ASIA motor	ASIA Sensory	Nurick grade		
θ_v	0.02	- 0.02	0.05	0.02	0.05	0.02	0.28

B. Three outcomes

Outcome Scales				GTE	p value
Combination 1	ASIA Motor	Neck pain NRS	Arm pain NRS		
θ_v	0.05	0.15	0.13	0.11	0.007
Combination 2	ASIA Motor	Neck pain NRS	SF-36 PCS		
θ_v	0.05	0.15	0.02	0.07	0.05
Combination 3	ASIA Motor	Neck pain NRS	Eq-5D		
θ_v	0.05	0.15	- 0.02	0.06	0.10

PAPER 7

Degenerative Cervical Myelopathy Patients' Six-month and Twelve-month Outcomes: Follow-up Analysis from the Myelopathy Natural History (MYNAH) Registry

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Introduction: Degenerative Cervical Myleopathy (DCM) is the most common cause of non-traumatic, chronic spinal cord dysfunction, causing severe neurological disability worldwide. Patients may present with gait dysfunction, paresthesia in upper and lower limbs to complete quadriplegia along with a stepwise decline in the quality of life. Given the masquerading presentation and progression of DCM, it is imperative to closely monitor patients to monitor outcomes, and understand DCM's natural history in a longitudinal manner; which is among the research priorities recommended by AO Spine RECODE DCM (1).

Materials and Methods: The MYelopathy NAtural History (MYNAH) Registry is Australia's first observational registry for operative and non-operative DCM patients with follow-ups every six months. The Registry does not intervene in the surgeon's management plan. Patients are recruited via an opt-in approach and are eligible to participate if they have a clinical diagnosis of DCM by a spine/neurosurgeon. Outcome variables are modified Japanese Orthopaedic Association (mJOA) score, Nurick Grade, Neck Disability Index (NDI) and EQ-5D-5L. Ethical approval has been obtained from the University of New South Wales (UNSW) Human Research Ethics Committee (HREC) (iRECS3634). The Registry was developed according to the Framework for Australian Clinical Quality Registries as recommended by the Australian Commission on Safety and Quality in Health Care (2) and is listed on the Australian Register of Clinical Registries (Registry ID: ACSQHC-ARCR-258). All statistical analysis was performed using R V4.2.2 (3, 4) and SAS V9.4.

Results: Participant recruitment is ongoing from eleven approved study sites across Australia. We included fifty participants (n=50) of which baseline data has been collected 100%, six-month follow-up has been completed for 34 (68%) and twelve-month follow-up for 18 (36%). Male participants are 31 (62%) and females are 19 (38%) with a mean age of 63 years (SD 13.6). At baseline, 18 participants have had a previous cervical spine surgery. Using a censored normal regression model with random intercept for individual, no change in mJOA score at 6-month and 12-month follow-ups was observed within the operated and non-operated groups ($p>0.05$). Using the Generalised Linear Mixed Model; at 6-month follow-up, NDI among the non-operated group was found to be 25% less than compared to the operated group ($p=0.28$) and this did not change at 12 months ($p=0.75$). In the operated group, an improvement in Nurick grade by 53% and 55% was noted at 6-month and 12-month follow-ups respectively compared to the non-operated group ($p>0.05$). In the operated group,

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EQ5D5L was found to be 14% and 18% lower compared to the non-operated group (p>0.05) at 6-month and 12-month follow-ups, respectively.

Conclusion: We have established a longitudinal clinical registry in Australia for subjects with DCM, that will progressively recruit subjects and present preliminary results to generate awareness among surgeons of the importance of Registry. This is an ongoing study and further analysis is needed with more follow-up time points for impactful results.

Outcomes over Time by Baseline Surgery

	Non Operated			Operated		
	0 (N=32)	1 (N=23)	2 (N=11)	0 (N=18)	1 (N=11)	2 (N=7)
NDI						
Mean (SD)	13.7 (9.48)	8.87 (9.28)	8.27 (10.4)	18.2 (13.3)	11.9 (12.4)	11.3 (10.5)
Median [Min, Max]	12.0 [0, 36.0]	8.00 [0, 35.0]	3.00 [0, 31.0]	19.0 [0, 45.0]	10.0 [0, 37.0]	6.00 [1.00, 29.0]
mjoa_score						
Mean (SD)	15.9 (2.46)	15.7 (2.67)	15.1 (2.81)	15.4 (2.68)	15.0 (3.10)	15.4 (2.44)
Median [Min, Max]	17.0 [8.00, 18.0]	17.0 [10.0, 18.0]	15.0 [10.0, 18.0]	16.5 [9.00, 18.0]	15.0 [10.0, 18.0]	14.0 [13.0, 18.0]
nurick_grade						
Mean (SD)	0.719 (1.25)	0.391 (1.08)	0.636 (1.50)	0.944 (1.76)	0.182 (0.405)	0.286 (0.488)
Median [Min, Max]	0 [0, 5.00]	0 [0, 5.00]	0 [0, 5.00]	0 [0, 5.00]	0 [0, 1.00]	0 [0, 1.00]
eq5d5lscore						
Mean (SD)	0.811 (0.212)	0.835 (0.239)	0.783 (0.320)	0.598 (0.418)	0.716 (0.435)	0.641 (0.345)
Median [Min, Max]	0.899 [0.259, 1.00]	0.924 [0.153, 1.00]	0.929 [0.0860, 1.00]	0.760 [-0.288, 1.00]	0.956 [-0.0810, 1.00]	0.583 [0.108, 1.00]

Table 1: Summary Statistics of Neck Disability Index (NDI), mJOA score, Nurick Grade and EQ5D5L at baseline (0), 6-months (1) and 12 months (2) follow-up.

PAPER 8

Temporal Trends of Improvement in Patients with Cervical Spondylotic Myelopathy After Anterior Cervical Discectomy and Fusion

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Hospital for Special Surgery[1]

Introduction: Although several studies have shown good outcomes in patients with cervical spondylotic myelopathy (CSM) after anterior cervical discectomy and fusion (ACDF), evidence regarding the temporal trends and course of improvement is still largely lacking. As such, spine surgeons lack clarity on these frequently asked questions in preoperative and postoperative visits – How much time will it take for my disability and physical function to improve? Until how much time after surgery is there a scope for improvement? Is there a likelihood that I may not improve further? The objective of this study was therefore to analyze temporal trends of improvement in patients with CSM after ACDF.

Materials and Methods: This was a retrospective review of prospectively collected data. Patients who underwent primary one-level or multilevel level ACDF for CSM and had a minimum of 1-year follow-up were included. Outcome measures were: 1) patient reported outcome measures (PROMs) (Neck Disability Index, NDI; Visual Analog Scale, VAS neck and arm; 12-Item Short Form Survey Physical Component Score, SF-12 PCS); 2) global rating change (GRC); and 3) return to activities. Timepoints analyzed were preoperative, 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and 2 years. Improvement trends across these timepoints were plotted on graphs. All analyses were done separately for one-level and multilevel ACDF.

Results: 330 patients (112 one-level ACDF, 218 multilevel ACDF) were included. Following one-level ACDF, VAS neck, VAS arm, NDI, and SF-12 PCS were found to have statistically significant improvement compared to the previous timepoint ($p<0.05$) up to 6 weeks, 6 weeks, 3 months, and 6 months, respectively. Following multilevel ACDF, VAS neck, VAS arm, NDI, and SF-12 PCS were found to have statistically significant improvement compared to the previous timepoint ($p<0.05$) up to 6 weeks, 6 weeks, 6 months, and 6 months, respectively. Beyond these timepoints, there was no significant improvement in PROMs in both cohorts and the plotted graphs of improvement showed a plateau. >70% of patients reported feeling better compared to preoperative on the GRC scale by 6 weeks following both one-level and multilevel ACDF. 97%, 92%, and 100% of one-level ACDF patients returned to driving (average 16 days), returned to work (average 24 days), and discontinued narcotics (average 4 days), respectively, after surgery. 92%, 87%, and 94% of multilevel ACDF patients returned to driving (average 25 days), returned to work (average 29 days), and discontinued narcotics (average 6 days), respectively, after surgery.

Conclusion: Patients with cervical spondylotic myelopathy are expected to improve up to 6 months after both one-level and multilevel ACDF. Neck pain and arm pain improve up to 6 weeks and disability and physical function improve up to 6 months. Beyond these timepoints, the trends in improvement tend to reach a plateau. >70% of patients feel better compared to preoperative by 6 weeks after both one-level and multilevel ACDF.

PAPER 9

Who Gets Better after Surgery for Degenerative Cervical Myelopathy? A Responder Analysis from the Multicenter Canadian Spine Outcomes and Research Network

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Introduction: Degenerative cervical myelopathy (DCM) is the most common cause of acquired non-traumatic spinal cord injury worldwide.[1] Evidence from prospective trials have shown that surgery, overall, is effective in reducing neck pain related disability measured through the Neck Disability Index (NDI), and Health Related Quality of Life (HRQoL) measured through the EuroQol-5D (EQ-5D). [2–4] However, recovery trajectories have been shown to vary between individuals, with one-quarter to one-half of patients not responding to treatment with at least the minimal clinically important difference (MCID) in patient reported outcomes (PROs).[5] To inform preoperative education and counseling, we performed a responder analysis to identify factors associated with treatment response measured using patient-reported outcomes (PROs) such as Neck Disability Index (NDI) and EuroQol-5D (EQ-5D) at 12 months post-surgery.

Materials and Methods: An observational cohort study was conducted utilizing prospectively collected data from the Canadian Spine Outcomes Research Network (CSORN) registry collected between 2015-2022. We included all surgically treated DCM patients with complete follow-up and PROs available at 1-year. A Least Absolute Shrinkage and Selection Operator (LASSO) machine learning model was used to identify significant associations with likelihood of treatment response measured by achievement of the minimal clinically important difference (MCID) in NDI, and EQ-5D. Variable importance was measured using standardized coefficients. To test robustness of findings we trained a separate XGBOOST machine learning model. Variable importance for the XGBoost model was measured using SHAP values.

Results: Among the 554 DCM patients included, 41.3% responded to treatment with respect to NDI, and 59.6% for EQ-5D (Table 1). LASSO regression for likelihood of treatment response measured through NDI found the variable importance rank order to be baseline NDI, then symptom duration (Figure 1). For EQ-5D, the variable importance rank order was baseline EQ-5D, living arrangement, then symptom duration. A separate XGBoost model of treatment response measured through NDI, corroborated findings that patients with higher baseline NDI, and shorter symptom duration were more likely to respond to treatment, and additionally found older patients, and those with kyphosis on baseline upright x-ray were less likely to respond. Similarly, an XGBoost model for treatment response measured through EQ-5D corroborated findings that patients with higher baseline EQ-5D, shorter symptom duration, and living alone were more likely to respond to treatment, and additionally found older patients were less likely to respond (Figure 2).

Conclusion: Our findings suggest patients with higher baseline patient NDI, lower EQ-5D, shorter symptom duration, younger age, living alone, and without kyphosis on pre-operative x-ray are more likely to respond to treatment. Timing of surgery with respect to patient symptoms is underscored as a crucial and modifiable patient factor that is associated with an

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increased likelihood of achieving clinically meaningful outcomes for patients with DCM.

Table 1: Comparisons between patients who achieved and did not achieve the minimal clinically important difference (MCID) in patient reported outcomes (PROs) at 12-month post-surgery follow-up. Abbreviations: BMI, Body Mass Index; mJOA, modified Japanese Orthopaedic Association Scale; SD, standard deviation; NDI, Neck Disability Index; EQ-5D, EuroQol-5D; MCID, Minimal Clinically Important Difference; MRI, Magnetic Resonance Imaging; [1] Mean (SD); n (%) [2] Welch Two Sample t-test; Fisher's exact test

	MCID in NDI = No N = 325[1]	**MCID in NDI = Yes** N = 229[1]	**p-value[2]**	**MCID in EQ-5D = No** N =224[1]	**MCID in EQ-5D = Yes** N = 330[1]	**p-value[2]**
Age (years)	61.1 (11.9)	59.4 (11.1)	0.08	61.6 (11.0)	59.6 (12.0)	**0.04**
Sex			0.06			0.50
Male	208 (64.0%)	128 (55.9%)		132 (58.9%)	204 (61.8%)	
Female	117 (36.0%)	101 (44.1%)		92 (41.1%)	126 (38.2%)	
Body Mass Index	28.9 (5.4)	28.8 (5.6)	0.80	28.3 (5.0)	29.2 (5.7)	**0.03**
Comorbidities	2.9 (1.9)	3.3 (1.9)	**0.01**	2.9 (1.8)	3.1 (2.0)	0.20
Active Smoker	87 (26.8%)	66 (28.8%)	0.60	61 (27.2%)	92 (27.9%)	>0.90
Employment Status			0.40			0.50
Unemployed	218 (67.1%)	162 (70.7%)		150 (67.0%)	230 (69.7%)	
Employed	107 (32.9%)	67 (29.3%)		74 (33.0%)	100 (30.3%)	
Living Arrangement			0.20			**<0.01**
Living alone	60 (18.5%)	32 (14.0%)		25 (11.2%)	67 (20.3%)	
Living with others	265 (81.5%)	197 (86.0%)		199 (88.8%)	263 (79.7%)	
Baseline mJOA	13.1 (2.5)	12.4 (2.4)	**<0.01**	13.2 (2.4)	12.6 (2.6)	**<0.01**
Symptom Duration			0.07			**<0.01**
Less than 2 years	97 (29.8%)	86 (37.6%)		59 (26.3%)	124 (37.6%)	
Greater than 2 years	228 (70.2%)	143 (62.4%)		165 (73.7%)	206 (62.4%)	
MRI Signal Change	266 (81.8%)	183 (79.9%)	0.60	178 (79.5%)	271 (82.1%)	0.40
Alignment			0.50			0.60
Lordotic or Neutral	262 (80.6%)	190 (83.0%)		180 (80.4%)	272 (82.4%)	
Kyphotic	63 (19.4%)	39 (17.0%)		44 (19.6%)	58 (17.6%)	
Baseline NDI	32.8 (18.4)	49.2 (15.6)	**<0.01**	33.5 (18.9)	43.7 (18.1)	**<0.01**
12-month NDI	32.1 (19.2)	21.6 (15.6)	**<0.01**	30.8 (19.0)	25.7 (17.9)	**<0.01**
Baseline EQ-5D	0.62 (0.20)	0.52 (0.22)	**<0.01**	0.69 (0.17)	0.50 (0.21)	**<0.01**
12-month EQ-5D	0.68 (0.20)	0.75 (0.17)	**<0.01**	0.63 (0.20)	0.76 (0.16)	**<0.01**
MCID in NDI	0 (0.0%)	229 (100%)	**<0.01**	41 (18.3%)	188 (57.0%)	**<0.01**
MCID in EQ-5D	142 (43.7%)	188 (82.1%)	**<0.01**	0 (0.0%)	330 (100%)	**<0.01**

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Figure 1: Patient clinical and imaging variable importance for predicting likelihood of achieving the minimal clinically important difference in Patient Reported Outcomes (PROs). Bolded predictors within least absolute shrinkage and selection operator (LASSO) model panels signify significant associations with respective PROs using Wald's test. Bolded predictors within XGBoost panels signify an association with PROs on inspection of partial dependency plots. Abbreviations: BMI, Body Mass Index; mJOA, modified Japanese Orthopaedic Association Scale; NDI, Neck Disability Index; EQ-5D, EuroQol-5D; MRI, Magnetic Resonance Imaging; ML, Machine Learning.

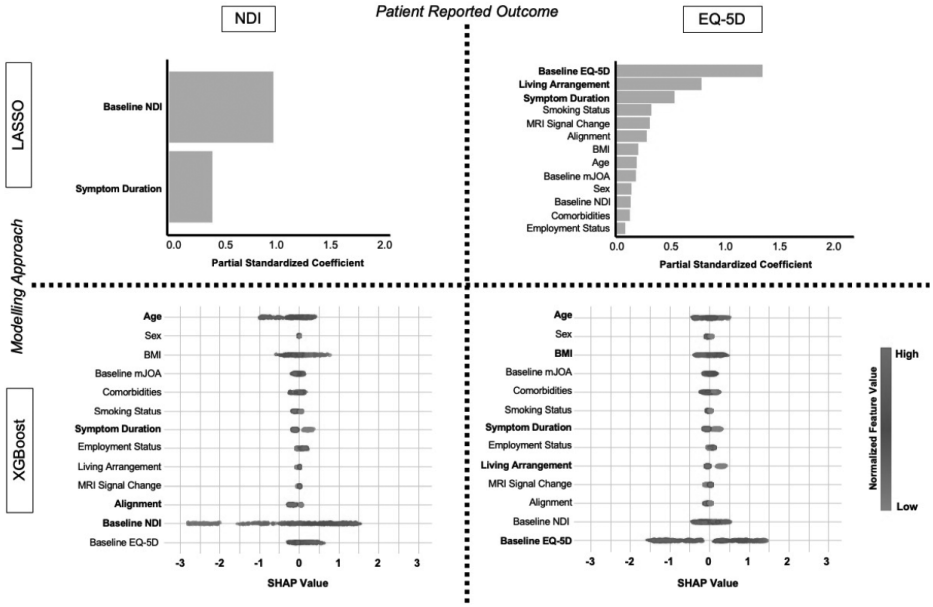

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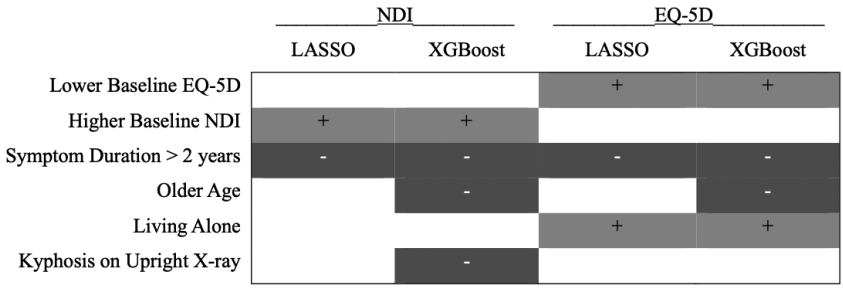
Figure 2: Matrix summarizing significant associations between predictors and patient reported outcome (PROs) identified through both least absolute shrinkage and selection operator (LASSO) and XGBoost modelling approaches. Predictor and outcome relationships were measured through a Wald's test for regression models, and inspection of partial dependency plots for machine learning models. Abbreviations: EQ-5D, EuroQol-5D; NDI, Neck Disability Index; ML, Machine Learning



PAPER 10

Comparative Analysis of Patient-Reported Outcomes in Myelopathy and Myeloradiculopathy: A Quality Outcomes Database Study

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University of Utah[1] University of Tennessee[2] Columbia University Irving Medical Center[3] Duke University[4] Mayo Clinic[5] Carolina Neurosurgery & Spine Associates[6] Goodman Campbell Brain and Spine[7] Semmes-Murphey Neurologic and Spine Institute[8] University of Miami[9] Weill Cornell Medical Center[10] Atlantic Neurosurgical Specialists[11] University of North Carolina School of Medicine[12] University of Virginia[13] Barrow Neurologic Institute[14] Atlanta Brain and Spine Care[15] University of California, San Francisco[16]

Introduction: Myelopathy in the cervical spine can present with diverse symptoms, many of which can be debilitating for patients. Patients with radiculopathy symptoms demonstrate added complexity because of the overlapping symptoms and treatment considerations. We sought to assess outcomes in myelopathy patients presenting with or without concurrent radiculopathy.

Materials and Methods: The Quality Outcomes Database (QOD), a prospectively collected, multi-institutional database, was used to analyze demographic, clinical, and surgical variables of patients presenting with myelopathy or myeloradiculopathy as a result of degenerative pathology. Outcome measures included arm (VAS-arm) and neck (VAS-neck) visual analog scale scores, modified Japanese Orthopedic Association (mJOA) score, EuroQol VAS (EQ-VAS) score, and Neck Disability Index (NDI) at 3, 12, and 24 months compared with baseline.

Results: A total of 1015 patients were included in the study: 289 patients with myelopathy alone (M_0), 239 with myeloradiculopathy but no arm pain (MR_{AP-}), and 487 patients with myeloradiculopathy and arm pain (MR_{AP+}). M_0 patients were older than the myeloradiculopathy cohorts combined ($MR_{\pm}$) (M_0: 64.2 vs. $MR_{\pm}$: 59.5[KK1] years, $p<0.001$) while MR_{AP+} had higher BMI and greater incidence of current smoking[KK2] compared to the other cohorts. There were more anterior approaches used in in MR_{AP+} patients and more posterior approaches used in M_0 patients. In severely myelopathic patients (mJOA ≤ 10), posterior approaches were used more often for M_0 ($p<.0001$) and MR_{AP+} ($p<.0001$). Patients with myelopathy and myeloradiculopathy both exhibited significant improvement at 1 and 2 years across all outcome domains. The amount of improvement did not vary based on surgical approach. In comparing cohort outcomes, postoperative outcome differences were associated with patient-reported scores at baseline.

Conclusion: Patients with myelopathy and those with myeloradiculopathy demonstrated significant and similar improvement in arm and neck pain scores, myelopathy, disability, and quality of life at 3 months that was sustained at 1- and 2-year follow-up intervals. More radicular symptoms and arm pain increases the likelihood of a surgeon choosing an anterior approach whereas more severe myelopathy increases the likelihood of approaching posteriorly. Surgical approach itself was not an independent predictor of outcome.

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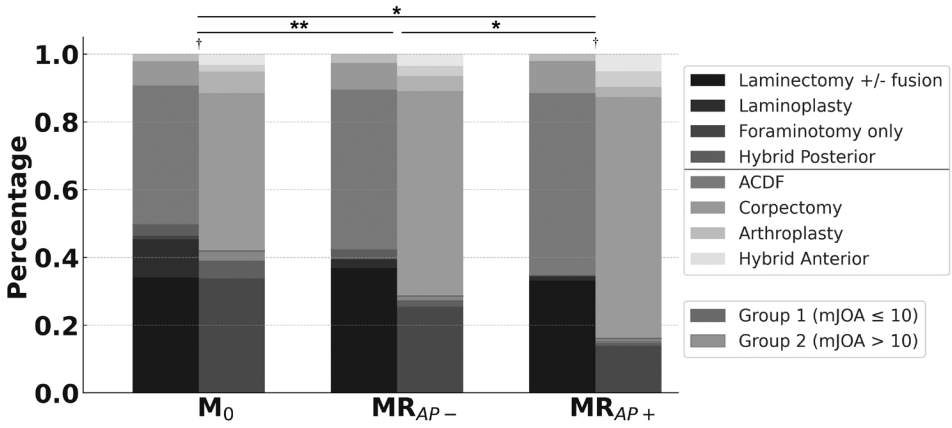

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or medical device he or she wishes to use in clinical practice.

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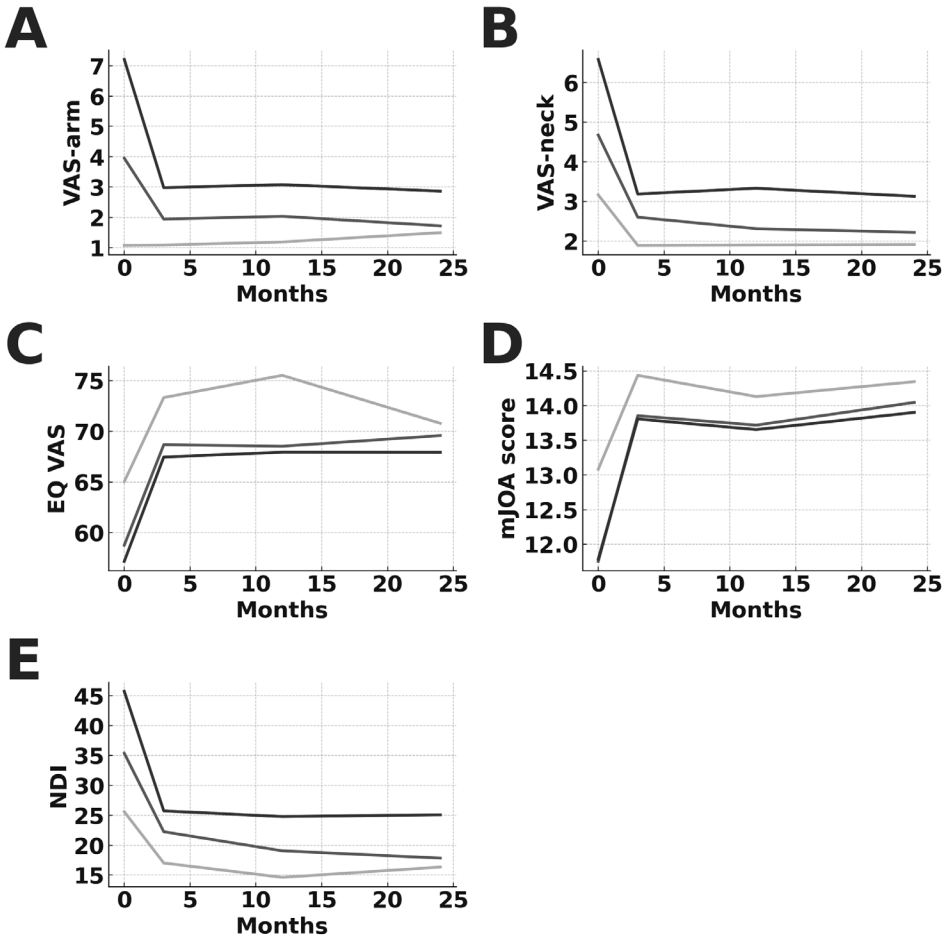

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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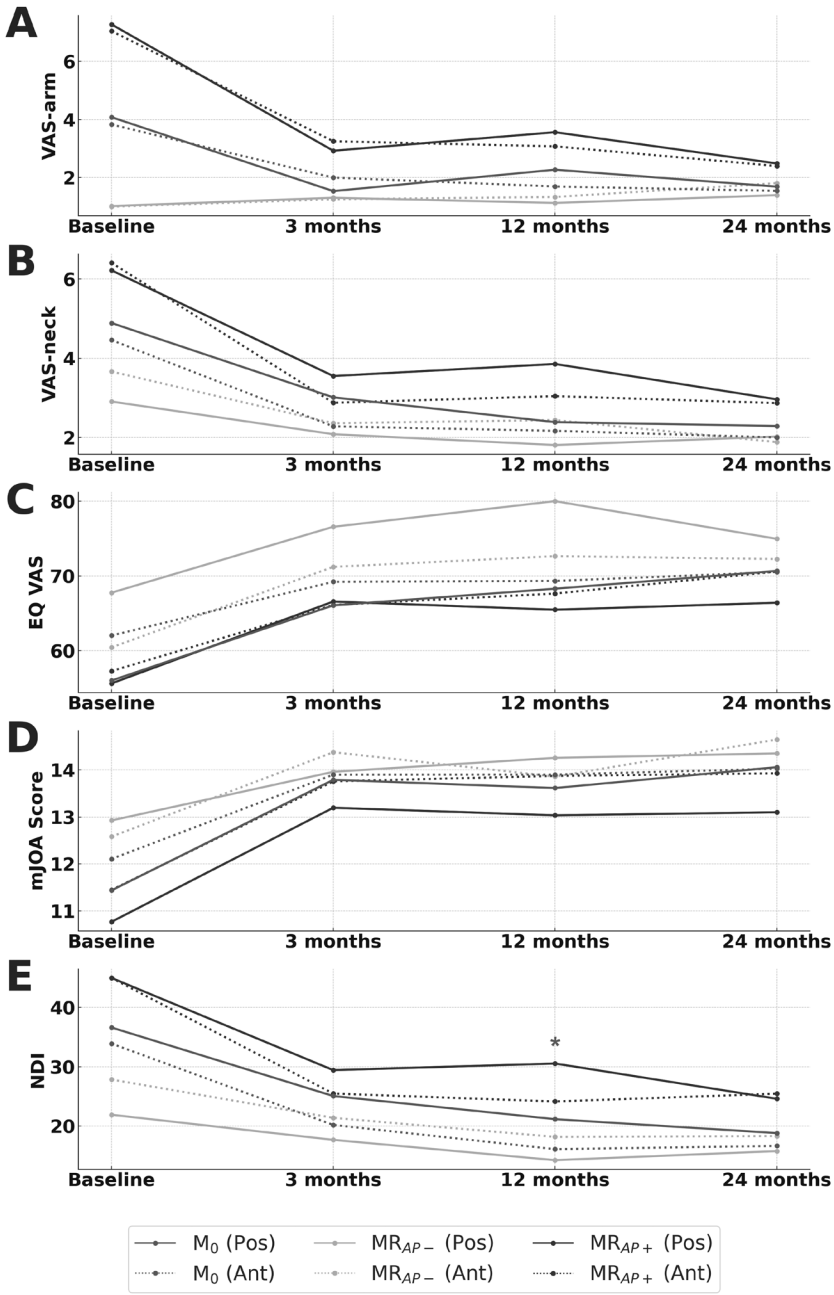

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or medical device he or she wishes to use in clinical practice.

PAPER 11

Surgical Versus Conservative Treatment for Odontoid Fractures in the Elderly: An International Prospective Comparative Study

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Introduction: Odontoid fractures are the most common cervical spine fractures in the elderly. The optimal treatment remains debated, while being increasingly relevant to clinical practice in the ageing population. The aim of the INNOVATE trial was to compare clinical outcome and fracture healing between surgically and conservatively treated patients.

Materials and Methods: An international prospective comparative study was conducted in fifteen European centers, involving patients aged ≥55 years, with type II/III odontoid fractures, no rheumatoid arthritis/ankylosing spondylitis, and no previous fracture treatment. The attending surgeon and patient made a shared decision on the applied treatment. Five follow-up moments were scheduled between 6 and 104 weeks. Primary outcomes were Neck Disability Index (NDI) improvement, fracture union and fracture stability at 52 weeks. Secondary outcomes were VAS neck pain, Likert patient-perceived recovery, and EuroQol-5D-3L at 52 weeks. Subgroup analyses considered age, type II fractures and displaced fractures. Multivariable regression analyses adjusted for age, gender and fracture characteristics.

Results: The study included 276 patients, of which 144 (52%) were treated surgically and 132 (48%) conservatively (mean (SD) age 77.3 (9.1) vs. 76.6 (9.7), p=0.56). NDI improvement (decrease) was largely similar between surgical and conservative treatments (mean (SE) -11 (2.4) vs. -14 (1.8), p=0.08), as were union (86% vs. 78%, aOR 2.3, 95% CI 0.97-5.7), and stability at 52 weeks (99% vs. 98%, aOR NA). NDI improvement did not differ between patients with union and persistent non-union (mean (SE) -13 (2.0) vs. -12 (2.8), p=0.78). There was no difference between treatments for any of the secondary outcomes or subgroups (Figure 1).

Conclusion: Clinical outcome and fracture healing at 52 weeks were similar between surgical and conservative treatments. Clinical outcome and fracture union were not associated. Conservative treatment is justified as primary treatment for odontoid fractures, prioritizing favorable clinical over radiological outcomes.

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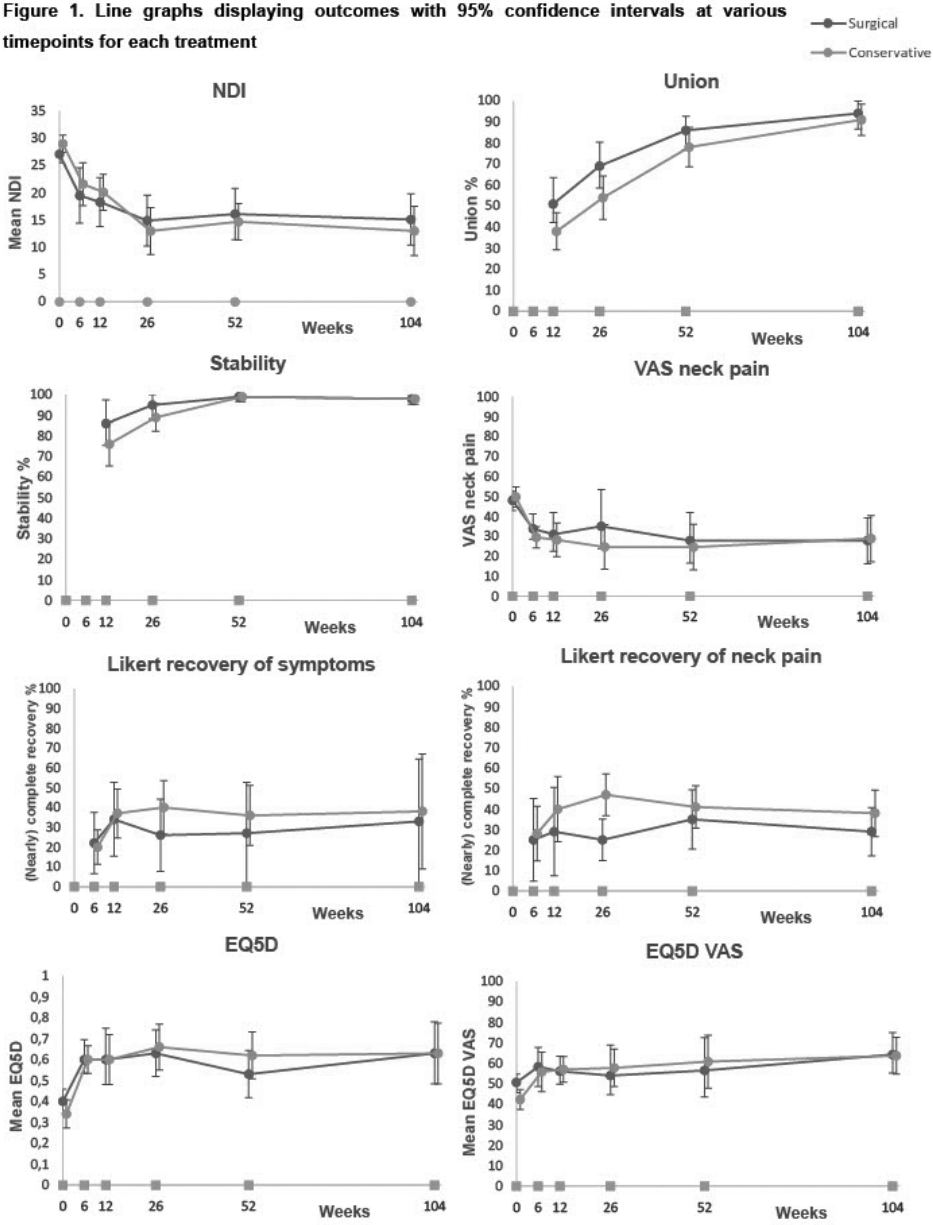
Figure 1. Line graphs displaying outcomes with 95% confidence intervals at various timepoints for each treatment



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

PAPER 12

Profiling of Cerebrospinal Fluid and Blood EVs-miRNAs for Predicting Natural Recovery from Acute Spinal Cord Injury in Rat Models

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Introduction: Predicting the natural recovery process of motor functions in patients with acute spinal cord injury (ASCI) is crucial for guiding clinical trials and determining effective treatment strategies. The investigation focuses on changes in miRNAs within extracellular vesicles (EVs) in body fluids, which could serve as novel biomarkers for assessing the condition and predicting the prognosis of ASCI. This study aims to comprehensively analyze miRNAs in extracellular vesicles from cerebrospinal fluid and plasma in ASCI rat models to identify biomarkers that reflect the natural recovery process.

Materials and Methods: The study utilized female Sprague-Dawley rats, eight weeks old, to create a thoracic spinal cord contusion injury model at the T10 level, alongside an uninjured sham model for controls. Three days post-injury, 100 µL of cerebrospinal fluid (CSF) and 500 µL of plasma were collected from each rat. Extracellular vesicles were then isolated using size-exclusion chromatography. The presence of EVs was confirmed using nano FCM and electron microscopy, followed by the extraction of RNA from these vesicles. Subsequent miRNA sequencing was performed to compare the miRNA expression levels between the injured and control groups.

Results: Analysis revealed no significant differences in particle size or content of the isolated EVs between the CSF and plasma samples from both groups. However, miRNA sequencing identified 42 differentially expressed miRNAs in the CSF and 2 in the plasma, all with q values less than 0.1 and a fold change greater than 2.0. These miRNAs are suggested as potential biomarkers that could reflect either the damage or the natural recovery process of ASCI.

Conclusion: The profiling of miRNAs within EVs from cerebrospinal fluid and plasma after spinal cord injury offers promising insights into potential new biomarkers. These biomarkers could play a significant role in reflecting the natural recovery process during the acute phase of ASCI, thus helping to shape treatment strategies and monitor the efficacy of therapeutic interventions. This study underscores the potential of EV-miRNAs as tools for enhancing the understanding of ASCI recovery dynamics, contributing to more tailored and effective treatment approaches for patients suffering from this debilitating condition.

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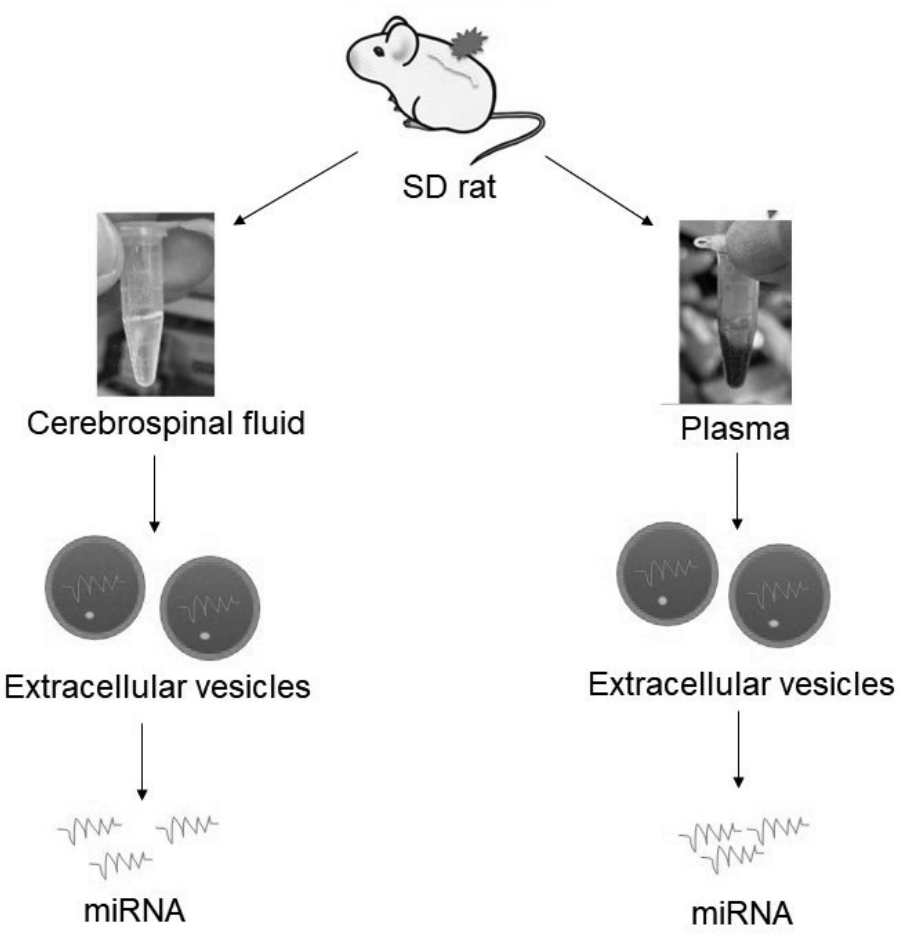

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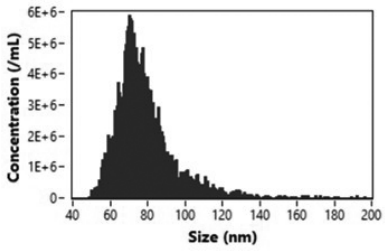
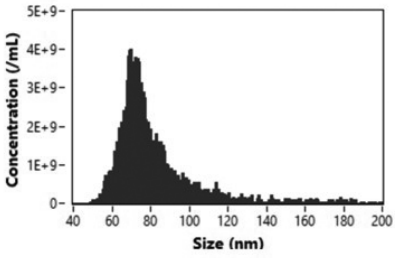
Nano FCM

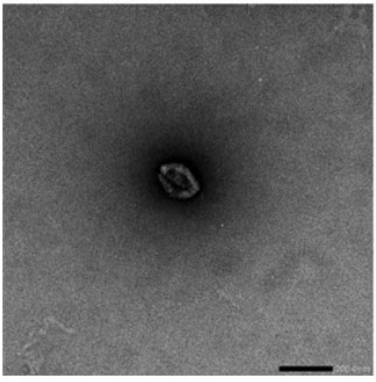


CSF (sham)

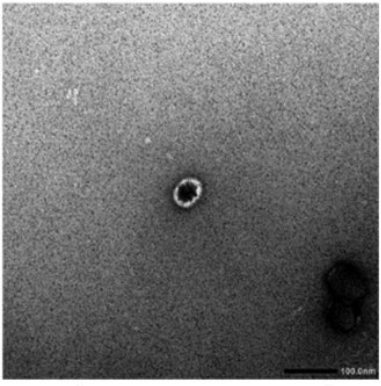


Plasma (sham)

Negative staining



CSF (sham)



Plasma (sham)

PAPER 13

Comparative Analysis of ACDF and PCDF for Traumatic Cervical Facet Fractures/ Dislocations: 90-Day Medical Complications, Surgical Outcomes, and Trends Over the Last Decade

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Introduction: The preferred treatment for traumatic cervical facet fracture and/or dislocation, with or without spinal cord injury, remains controversial. Recent trends for surgical treatment with anterior cervical discectomy and fusion (ACDF) versus posterior

Materials and Methods: The PearlDiver database was queried to identify patients that sustained a traumatic cervical facet fracture and/or dislocation, with and without spinal cord injury, who underwent ACDF or PCDF between 2010 and 2020. Patients were then matched 1:1 based on age, gender, and Charlson comorbidity index (CCI). Comparative analyses were performed on the entire cohort and a sub analysis was performed to compare outcomes of the procedures in patients with spinal cord injury (SCI). Variables compared included demographics, comorbidities, 90-day medical complications, and surgical outcomes from 90 days to 2-years. Finally, epidemiologic yearly trends in the procedure choice for cervical trauma were identified and significance of change was assessed with Mann-Kendall testing.

Results: The overall cohort included 5,010 matched patients with the same age (54.3±17.0), CCI (1.6±1.9), and proportion of females (35.2%). PCDF patients had a greater proportion of chronic pulmonary disease, congestive heart failure, depression, and hypertension. At 90-days PCDF patients had more wound dehiscence (RR 3.3, 95% CI 2.3-4.5), surgical site infection (RR 3.0, 95% CI 2.3-3.9), hematoma (RR 2.0, 95% CI 1.3-3.1), instrument failure (RR 1.5, 95% CI 1.0-2.1), and nerve injury (RR 3.2, 95% CI 1.2-8.8), $p<0.05$. At 1-year, instrument failure (RR 1.9, 95% CI 1.2-2.9), hardware removal (RR 1.9, 95% CI 1.1-3.1), and SCI sequelae (RR 1.7, 95% CI 1.3-2.3) were higher in PCDF patients and instrument failure (RR 2.6, 95% CI 1.3-5.2) and SCI sequelae (RR 1.7, 95% CI 1.2-2.3) continued to be higher at 2-years, $p<0.05$. Sub analysis of the 1,939 matched patients with SCI, revealed a similar age (47.6±17.8), CCI (1.7±2.1), and proportion of females (27.6%), $p>0.05$. In addition, medical and surgical complications not statistically different between ACDF and PCDF with exception of irrigation and debridement. Finally, Mann-Kendall testing revealed increased usage of both ACDF and PCDF techniques within the last decade with PCDF demonstrating a greater rise recently, $p<0.001$. The average age of patients who underwent ACDF was 51.935 whereas patients who underwent PCDF were 56.929.

Conclusion: Surgery for cervical facet fractures and/or dislocations has increased over the past decade reflecting the more aggressive proclivity for surgeons to operate on these injuries, with an oscillating preference for ACDF and PCDF. Despite similar baseline characteristics, patients who underwent PCDF experienced higher rates of 90-day medical complications and instrument failure at all time points. However, when stratified by fractures associated with spinal cord injury, ACDF and PCDF had comparable outcomes.

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	Dislocation or Fracture N = 5010			Dislocation or Fracture with Spinal Cord Injury N = 1939		
	ACDF	**PCDF**	**P-value**	**ACDF**	**PCDF**	**P-value**
1 Day to 90 Day Complications						
Wound Dehiscence	48 (0.96)	153 (3.05)	**<0.001**	46 (2.37)	50 (2.58)	>0.05
SSI	73 (1.46)	214 (4.27)	**<0.001**	47 (2.42)	54 (2.78)	>0.05
Hematoma	29 (0.58)	57 (1.14)	**0.003**	15 (0.77)	17 (0.88)	>0.05
Instrument Failure	48 (0.96)	71 (1.42)	**0.042**	12 (0.62)	10 (0.52)	>0.05
Hardware Removal	56 (1.12)	75 (1.50)	>0.05	17 (0.88)	13 (0.67)	>0.05
Irrigation and Debridement	65 (1.30)	100 (2.00)	**0.008**	50 (2.58)	61 (3.15)	>0.05
Anterior Reoperation	55 (1.10)	53 (1.06)	>0.05	15 (0.77)	18 (0.93)	>0.05
Posterior Reoperation	145 (2.89)	114 (2.28)	>0.05	62 (3.20)	47 (2.42)	>0.05
Dural Tear	5 (0.10)	6 (0.12)	>0.05	3 (0.15)	2 (0.10)	>0.05
Nerve Injury	5 (0.10)	16 (0.32)	**0.029**	4 (0.21)	4 (0.21)	>0.05
SCI Sequelae	31 (0.62)	59 (1.18)	>0.05	55 (2.84)	57 (2.94)	>0.05
1 Year Complications						
Instrument Failure	32 (0.64)	59 (1.18)	**0.006**	10 (0.52)	11 (0.57)	>0.05
Pseudoarthrosis	43 (0.86)	56 (1.12)	>0.05	4 (0.21)	5 (0.26)	>0.05
Hardware Removal	24 (0.48)	45 (0.90)	**0.016**	6 (0.31)	9 (0.46)	>0.05
Irrigation and Debridement	79 (1.58)	146 (2.91)	**<0.001**	81 (4.18)	101 (5.21)	**0.044**
Anterior Revision	26 (0.52)	34 (0.68)	>0.05	5 (0.26)	9 (0.46)	>0.05
Posterior Revision	39 (0.78)	50 (1.00)	>0.05	17 (0.88)	14 (0.72)	>0.05
Dural Tear	6 (0.12)	6 (0.12)	>0.05	0 (0.00)	0 (0.00)	>0.05
Nerve Injury	7 (0.14)	18 (0.36)	**0.045**	5 (0.26)	5 (0.26)	>0.05
SCI Sequelae	83 (1.66)	145 (2.89)	**<0.001**	105 (5.42)	121 (6.24)	>0.05
2 Year Complications						
Implant Complications	32 (0.64)	36 (0.72)	>0.05	15 (0.77)	15 (0.77)	>0.05
Instrument Failure	12 (0.24)	32 (0.64)	**0.004**	2 (0.10)	7 (0.36)	>0.05
Pseudoarthrosis	73 (1.46)	130 (2.59)	**<0.001**	17 (0.88)	17 (0.88)	>0.05
Hardware Removal	17 (0.34)	31 (0.62)	>0.05	5 (0.26)	6 (0.31)	>0.05
Irrigation and Debridement	76 (1.52)	114 (2.28)	**0.007**	65 (3.35)	69 (3.56)	>0.05
Anterior Revision	19 (0.38)	17 (0.34)	>0.05	6 (0.31)	8 (0.41)	>0.05
Posterior Revision	16 (0.32)	19 (0.38)	>0.05	7 (0.36)	6 (0.31)	>0.05
Dural Tear	6 (0.12)	6 (0.12)	>0.05	3 (0.15)	2 (0.10)	>0.05
Nerve Injury	8 (0.16)	18 (0.36)	>0.05	9 (0.46)	9 (0.46)	>0.05
SCI Sequelae	108 (2.16)	188 (3.75)	**<0.001**	152 (7.84)	173 (8.92)	>0.05

Table 1. Complications following ACDF and PCDF for cervical dislocation or fracture with and without associated spinal cord injury.

PAPER 14

Simultaneous Fractures of the Atlas and Axis: Presentation, Management, and Outcomes of a Series of 103 Consecutive Patients

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Introduction: Simultaneous fractures of the atlas and axis are increasingly common, but contemporary series are limited in their size and scope of analysis. The majority of studies on this pathology are series including fewer than 10 patients, which precludes statistically rigorous analysis of the outcomes associated with a given management strategy.

Materials and Methods: All patients with simultaneous, traumatic fractures of the atlas and axis admitted to the University of Pittsburgh Medical Center from 2012 to 2022 were retrospectively analyzed. Clinical, demographic, and radiographic data was collected. Multivariable regression was used to identify demographic and clinical characteristics relevant to the management and outcomes of patients with these fractures.

Results: 103 patients were identified, most of whom (52.4%) were age ≥80 years, suffered ground-level falls (80.6%), and had minor associated injuries (median Injury Severity Score of 1). Landell Type 1 fractures were the most common C1 fracture (50.5%), and dens fractures were the most common C2 fracture (71.8%). C1 lateral mass fractures were associated with atypical C2 fractures (OR=6.18, p=0.011), most of which (84.2%) were C2 lateral mass fractures. 21 patients (20.4%) underwent surgical stabilization, of whom 15 (14.6%) were selected for surgery during their index hospitalization, and 6 (5.8%) underwent surgical intervention after a trial of nonoperative management. Selection for surgery was positively associated with having neurologic deficits (OR=5.94, p=0.041) and negatively associated with age (OR=0.91, p=0.006). Dens fracture patients were more likely to have C2 as their lower instrumented vertebra (LIV)(p=0.0150), and hangman's fracture patients were more likely to have C3 as their LIV (p=0.0351). Dens fractures (OR=6.82, p=0.038) and hangman's fractures (OR=37.29, p=0.019) were positively associated with nonunion, and upfront surgery was negatively associated with nonunion (OR=0.04, p=0.034). C1 fracture morphology did not affect surgical decision-making, or fracture nonunion.

Conclusion: Simultaneous atlantoaxial fractures most commonly occur in elderly patients after ground level falls with minor associated injuries. Lateral mass fractures of C1 and C2 are associated with one another. Surgical selection is driven by the presence of a neurologic deficit and younger age, and C2 fracture type affects the choice of surgical procedure, but C1 fracture type does not. Having surgery decreases the odds of fracture nonunion.

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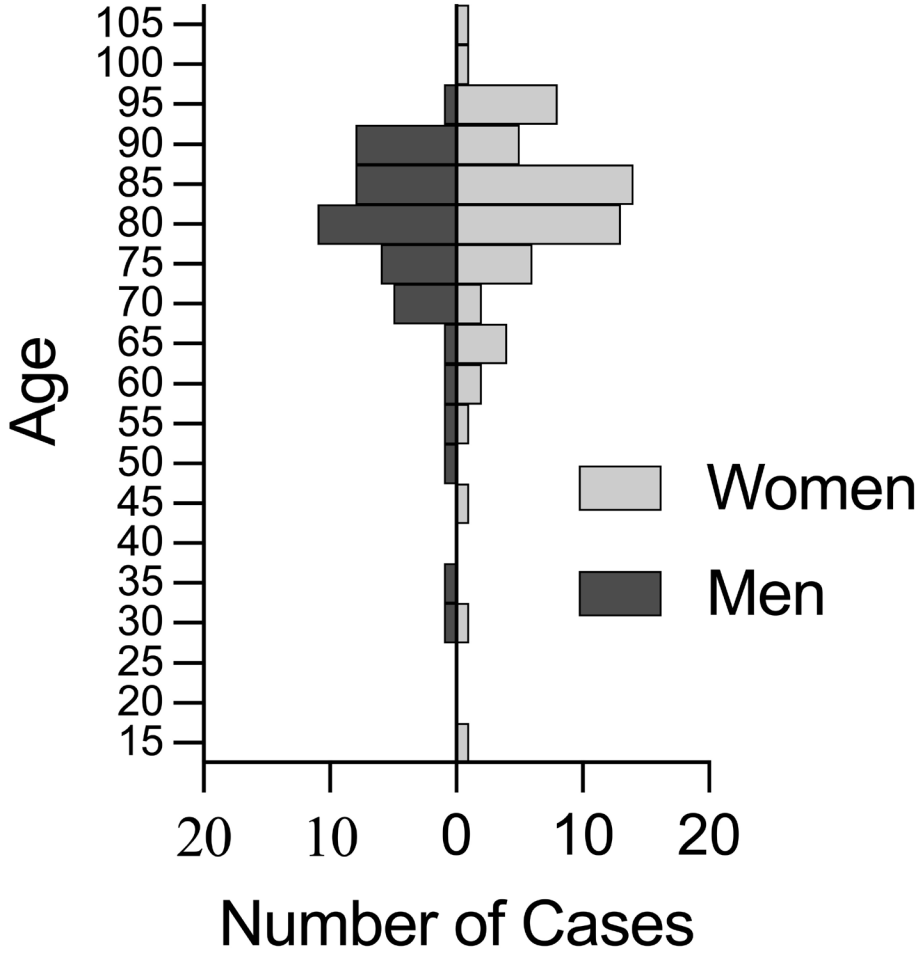

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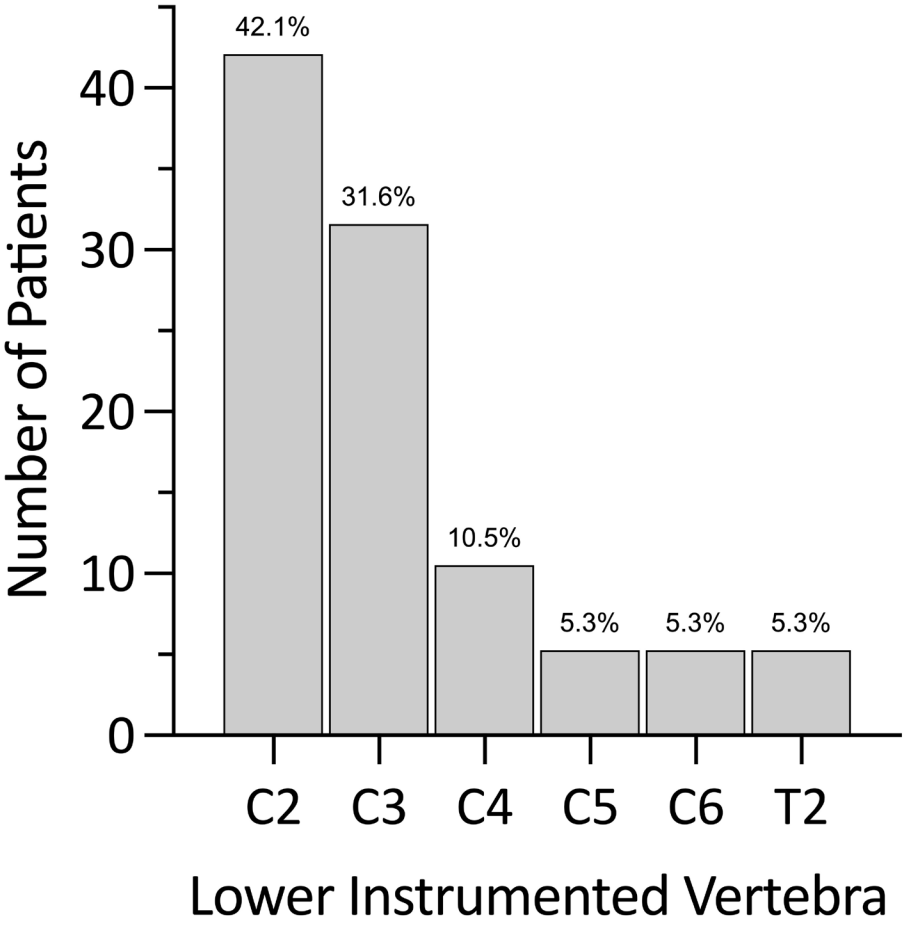

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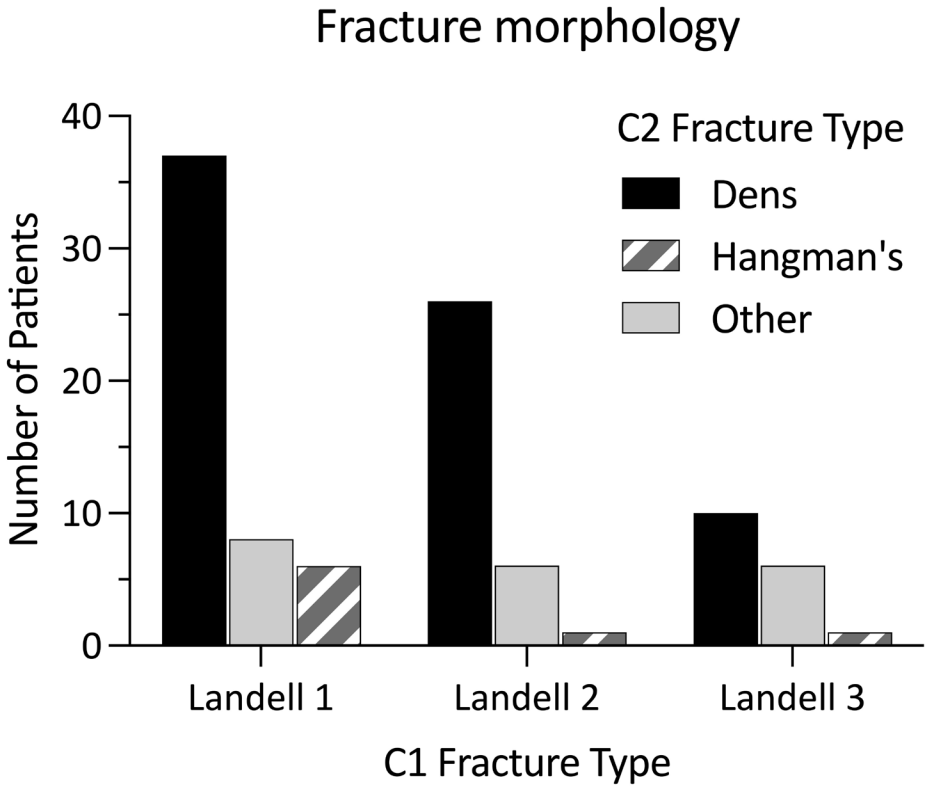

PAPER 15

Comparison of Treatment Modalities Managing Odontoid Fractures: An Analysis of Timing and Fracture Morphology

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Introduction: Odontoid fractures, particularly those in geriatric patients, are challenging to treat due the acuity of injury, complication risk associated with intervention, and patient frailty. While the benefit of operative treatment has been established in this population, timing of treatment has not been thoroughly investigated.

Materials and Methods: The present institution was retrospectively queried for all odontoid fractures treated either nonoperatively or operatively from 2008 – 2022 at a level I academic trauma center. Three cohort groups were compared: those with acute surgery, delayed surgery, and nonoperative management. Those that failed initial nonoperative management were either due to symptomatic non-union or interval displacement of fracture. Patient charts were reviewed for treatment modality, demographics, Charlsson Comorbidity Index (CCI), attendance to the fracture liaison clinic, addition of new bone health medications, fracture morphology, and number of months in hard collar. Radiographic parameters were evaluated on presenting computed tomography (CT) scan: horizontal displacement, angulation, and comminution. Union was evaluated for evidence of osseous bridging on final AP, lateral, and open-mouth odontoid views or CT scan if available. In cases without bony union, flexion/extension radiographs were utilized to evaluate stability. Primary outcomes used for multivariate analysis were osseous union and failure of primary treatment.

Results: A total of 110 patients met inclusion/exclusion criteria. For the overall cohort, the mean age at injury was 69.4±19.3 years old and mean BMI was 26.7±6.0 kg/m^2. In total, 22 patients were managed acutely with surgery, 9 managed with surgery after failure of nonoperative management, and 79 patients managed nonoperatively. Of those managed with acute surgery, 14 underwent open reduction internal fixation (ORIF) with odontoid screw, 6 underwent posterior spinal fusion (PSF), and 2 received halo fixation. Of those managed with delayed surgery, 2 were managed with ORIF and 7 with PSF. There were 3 failures in the acute surgery group (2 initially managed with halo and 1 with ORIF). There were 2 failures in delayed surgery group (both initially managed with ORIF). There were statistical differences between the three groups with respect to age ($p<0.001$), CCI ($p<0.001$), and horizontal displacement ($p=0.002$), respectively. There were no differences with respect to hard collar duration between treatment groups ($p=0.44$) (Table 1). At final radiographic follow-up, there was evidence of osseous union in 68.2%, 55.5%, and 64.6% in patients that underwent acute surgery, delayed surgery, and non-operative management, respectively. All patients without osseous union had no motion on flexion/extension suggestive of fibrous union. On multivariate analysis, osseous union was associated with decreased CCI (OR: 0.69, 95% CI: 0.48, 0.99, $p=0.046$). No variables were associated with failure of initial treatment modality.

Conclusion: Odontoid fractures remain associated with high rates of morbidity and mortality regardless of treatment. Acute, delayed, and nonoperative management remain effective modes of treatment, though ORIF in a delayed fashion was not successful within this cohort.

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Lastly, fracture morphology was not associated radiographic union, while comorbidity classification was. These findings should be used to counsel patients considering surgical intervention.

	Acute (n=22)	Delayed (n=9)	Non-operative (n=79)	p-value
Demographics				
Age	62.9±22.6	72.3±8.0	76.7±17.4	<0.001
BMI (kg/m^2)	26.7±5.2	29.5±6.0	26.4±6.2	0.35
CCI	2.8±2.5	5.2±2.4	5.4±2.4	<0.001
Treatment				
Initial surgery	Halo: 2 ORIF*: 14 PSF: 6	ORIF: 2 PSF: 7	n/a	--
Days to OR	7.6±8.9	193.7±163.1	n/a	--
Failure of primary surgery	3 (halo: 2, ORIF: 1)	2 (ORIF)	n/a	--
Hard collar duration (months)	2.4±1.8	3.7±2.1	3.2±2.9	0.44
Death within 12mo (N)	2 (9%)	0	15 (20.0%)	--
Radiology				
Radiographic Follow-up (months)	26.5±41.0	27.1±22.4	8.6±20.0	P<0.001
Horizontal Displacement (mm)	3.7±3.2	0.28±0.8	2.5±15.5	0.002
Angulation	11.4±11.6	17.9±13.2	2.5±14.9	0.41
Comminution (deg)	0	0	30	--
Bony Union (N)	Y: 15 (68.2%) Fibrous: 6 (27.3%) N/A: 1 (4.5%)	Y: 5 (55.5%) Fibrous: 4 (44.4%) N/A: 0	Y: 51 (64.6%) Fibrous: 23 (29.1%) N/A: 5 (6.3%)	--
Bone Health				
Attended Clinic	2	3	11	--
Addition of medication	Bisphosphonate: 1 Teriparatide: 1 SERMs: 0 Calcitonin: 0	Bisphosphonate: 1 Teriparatide: 1 SERMs: 0 Calcitonin: 0	Bisphosphonate: 2 Teriparatide: 5 SERMs: 2 Calcitonin: 4	--

PAPER 16

Technique Notes of a Three-Dimensional Reduction Method with a Modified C2 Isthmus Screw in Irreducible Atlantoaxial Dislocation

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Introduction: Three-dimensional reduction plays a vital role in surgical reduction of irreversible atlantoaxial dislocation (IAAD). The difficulty of reduction of IAAD was caused by the following two reasons: (1) the anteroposterior distance between heads of C1 and C2 screws is too short to draw the C1 posteriorly (Fig. 1a); (2) the vertical distance between heads of C1 and C2 screws is too short to manipulate the vertical distraction (Fig. 1b). Therefore, to increase the anteroposterior and vertical distance between the heads of C1 and C2 screws is the key to achieve atlantoaxial reduction. However, the most commonly used combination of C1 pedicle screw (PS) or lateral mass screw (LMS) and C2 PS or isthmus screw often fails to achieve satisfactory reduction at one time. In our clinical practice, we modified C2 isthmus screw and set the insertion point at the intersection of caudal edge of C2 lamina and lateral mass, with a trajectory towards C2 isthmus, via lateral mass. The objective of this study is to describe a three-dimensional reduction method with the modified C2 isthmus screw and to illustrate its advantage and effectiveness for IAAD.

Materials and Methods: Fourteen patients with IAAD underwent reduction and fixation with modified C2 isthmus screw combined with C1 PS or LMS, fusion with autologous bone graft. The entry point was the intersection of caudal edge of C2 lamina and lateral mass. The trajectory is in cephalad direction towards the C2 isthmus, via lateral mass (Fig. 2a). The anterior wall of C2 lamina and superior articular surface of C2 should not be injured or perforated (Fig. 2b). The three-dimensional reduction was achieved through pulling and distracting. Radiographic evaluation included anteroposterior and direct distance between different insertion points, the occipitoaxial angle (O-C2A), clivus-canal angle (CCA) and cervicomedullary angle (CMA). Clinical outcomes evaluation included the Japanese Orthopaedic Association (JOA) score, Visual analog scale (VAS) and Neck Disability Index (NDI).

Results: The mean duration of follow-up was 62.2 months (range from 12 to 95 months) and all the patients maintained effective reduction during the follow-up. The anteroposterior and direct distance was significantly higher in modified C2 isthmus screw than C2 PS whether combined with C1 PS or LMS ($P<0.05$). The degree of O-C2A, CCA and CMA, JOA score, NDI, and VAS were significantly improved after the surgery ($P<0.05$).

Conclusion: Three-dimensional reduction method with a modified C2 isthmus screw is effective and safe in managing IAAD. Modified C2 isthmus screw made some modifications on the basis of Magerl screw and short isthmus screw. It can increase the anteroposterior and vertical distance between the heads of C1 and C2 screws, which is benefit for the three-dimensional reduction operation of AAD shown as anteroposterior, vertical, and angulated dislocation in the sagittal plane, especially for irreducible cases.

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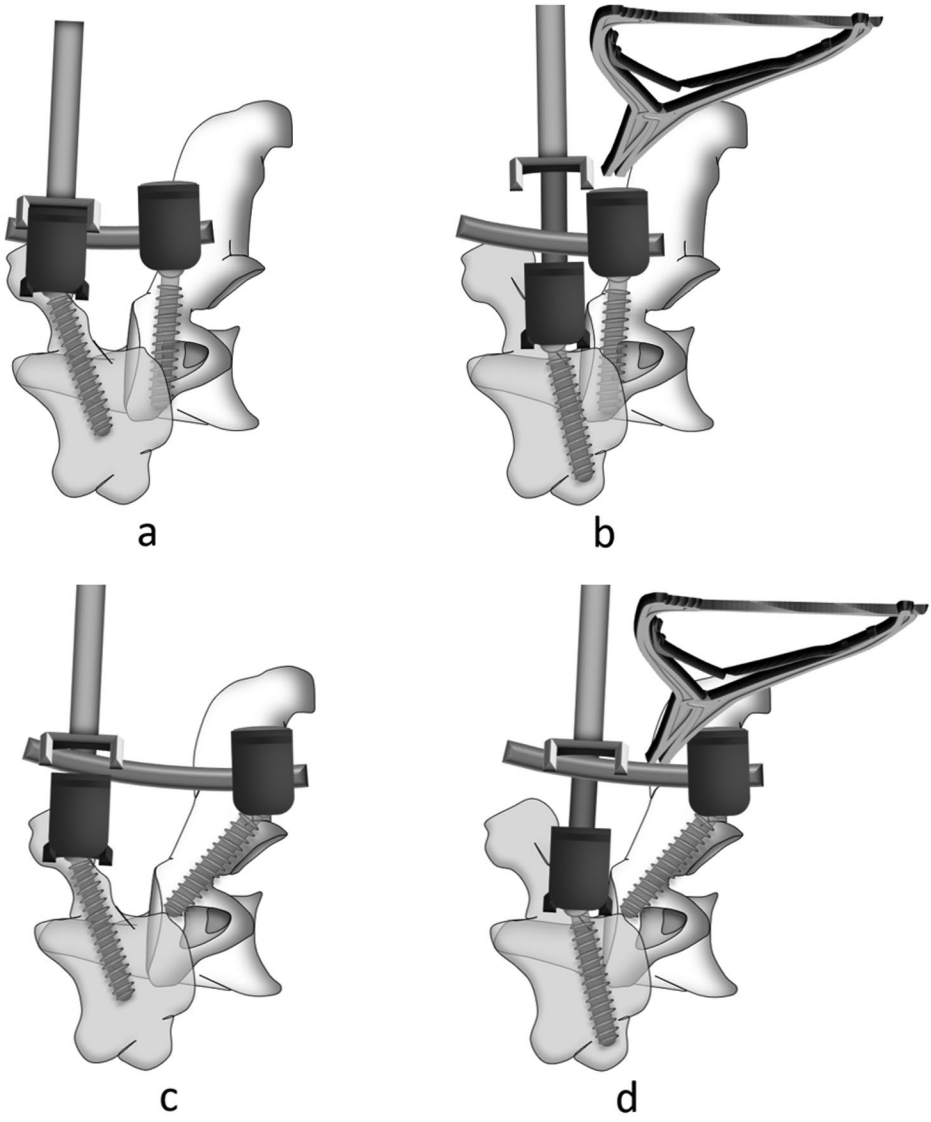

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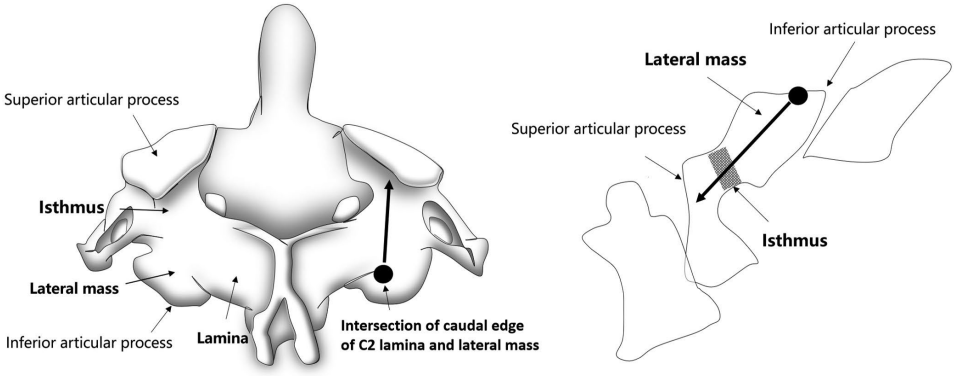

PAPER 17

What Facilitates Successful Reduction with Closed Skeletal Traction for Unilateral Locked Subaxial Cervical Facet and What Operative Approach is Superior when Closed Reduction Fails: Anterior or Posterior?

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UMMC[1]

Introduction: Closed skeletal traction (CST) for reduction of unilateral locked facet (ULF) of the subaxial cervical spine can expedite realignment of the spinal column prior to definitive surgery but is frequently unsuccessful. What predicts successful closed reduction is not completely understood. In addition, whether anterior or posterior surgery is superior after failed closed reduction is not known. This study sought to assess variables associated with successful closed reduction and to compare the efficacy of anterior vs. posterior surgery after failed closed reduction.

Materials and Methods: Retrospective analysis of patients presenting with ULF to a single Level I trauma center from 2008 through 2023. Patients with complex facet fracture without locked facet and isolated perched facet were excluded. Individual fractures involving structurally relevant bony elements and other pathological features were noted in each case. Mechanism of injury was noted as ground-level fall or not ground level fall. CST was performed with Gardner-Wells tongs and incremental weight using a rapid protocol (less than 30 minutes). Neuromonitoring with continuous SSEP and iterative MEPs was performed during all closed reduction procedures under general anesthesia. Reduction was assessed by fluoroscopy during closed skeletal traction and surgery and confirmed on postoperative CT.

Results: 71 patients met inclusion criteria. The population was predominantly male, middle-aged (49±19 years old) and presented after high energy trauma. Maximum weight used was 49±24lbs in successful reductions compared to 75±41 in failed reductions. Closed reduction was successful in 55% of patients. Awake CST had a 46% success rate and CST under general anesthesia had an overall success rate of 58%. Further examination showed that upfront CST under anesthesia was more successful than awake CST (83% vs 46%), but no cases of failed awake CST were reduced using CST under general anesthesia (0/5 cases). Multivariate analysis demonstrated that attempting CST under general anesthesia upfront improved odds of successful CST 7-fold and presence of contralateral perched facet did so 32-fold when controlling for fracture morphologies, AIS grade, and age. No fracture patterns were found to be significantly associated with CST outcome. In patients requiring open reduction after failed CST, posterior approach was significantly more successful than anterior approach (92% vs 42%). This difference was not seen in patients undergoing upfront open reduction (100% vs 88% for posterior and anterior, respectively). In total, 95% of patients had successful open reduction from posterior approaches compared to 60% from anterior approaches. All eight patients who failed open reduction via an anterior approach were reduced during subsequent posterior surgery.

Conclusion: Contralateral perched facet as a morphological factor and general anesthesia as a technical adjunct independently increased the likelihood of successful reduction of unilateral

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locked facet with closed skeletal traction. For patients that failed closed reduction, open posterior surgery was superior to open anterior surgery for reduction of unilateral locked facet.

	Failed CST (n=24)	Successful CST (n=29)	p-value
Age, mean±sd	45±18	48±18	0.58
Sex, n (%)			0.92
Female	7 (29%)	7 (24%)	
Male	17 (71%)	22 (76%)	
Mechanism, n (%)			0.52
Ground level fall	4 (17%)	7 (25%)	
All other mechanisms	20 (83%)	21 (75%)	
Admission AIS grade, n (%)			**0.014**
A	7 (29%)	12 (43%)	
B	6 (25%)	2 (7%)	
C	0 (0%)	2 (7%)	
D	11 (46%)	6 (21%)	
E	0 (0%)	6 (21%)	
Level, n (%)			0.164
C3-4	3 (12%)	1 (3%)	
C4-5	3 (12%)	7 (24%)	
C5-6	4 (17%)	10 (34%)	
C6-7	14 (58%)	11 (38%)	
C7-T1	0 (0%)	0 (0%)	
Max listhesis (mm) , mean±sd	6.6±3.2	6.5±1.8	0.868
Max weight, mean±sd	75±41	49±24	**0.009**
Bedside	22 (92%)	19 (66%)	0.564
General anesthesia	7 (29%)	10 (34%)	
Upfront	2 (28%)	10 (100%)	
After failed bedside CST	5 (72%)	0 (0%)	
Fractures, n (%):			
Superior SP	3 (12%)	5 (18%)	0.933
Inferior SP	1 (4%)	0 (0%)	0.921
Superior VB	7 (30%)	3 (10%)	0.164
Inferior VB	11 (48%)	10 (36%)	0.556
Superior lamina	12 (50%)	5 (17%)	**0.036**
Inferior lamina	0 (0%)	1 (3%)	1
Superior LM LS	5 (22%)	13 (45%)	0.073
Superior LM NLS	6 (26%)	5 (17%)	0.664
Inferior LM LS	6 (26%)	7 (24%)	1
Inferior LM NLS	8 (35%)	11 (38%)	1
Contralateral perched facet, n (%)	0 (0%)	9 (31%)	**0.002**
DISH, n (%)	5 (22%)	2 (7%)	0.238
Prior C-spine fusion, n (%)	2 (6%)	0 (0%)	0.318

HE, high energy; LE, low energy; SP, spinous process; VB, vertebral body; LM, lateral mass; LS, locked side; NLS non-locked side; DISH, diffuse skeletal hyperostosis

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

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Logistic regression after stepwise variable selection		
Variable	**OR (95% CI)**	**p-value**
Contralateral perched facet	32.079 (3.485-4283.2)	**0.001**
CST while awake	0.141 (0.024-0.604)	**0.007**

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Variable	Anterior approach (n = 20)	Posterior approach (n = 22)	p-value
Age, mean±sd	44±16	53±22	0.163
Sex, n (%)			0.585
F	8 (40%)	6 (27%)	
M	12 (60%)	16 (73%)	
Mechanism of injury, n (%)			0.187
Ground level fall	1 (5%)	5 (23%)	
All other mechanisms	19 (95%)	17 (77%)	
AIS Grade, n (%)			0.79
A	4 (20%)	3 (14%)	
B	4 (20%)	5 (24%)	
C	1 (5%)	1 (5%)	
D	8 (40%)	11 (52%)	
E	3 (15%)	1 (5%)	
Level, n (%)			0.507
C3-4	3 (15%)	2 (9%)	
C4-5	3 (15%)	3 (14%)	
C5-6	3 (15%)	6 (27%)	
C6-7	11 (55%)	9 (41%)	
C7-T1	0 (0%)	2 (9%)	
Fractures, n (%):			
Superior SP	2 (10%)	4 (19%)	0.665
Inferior SP	1 (5%)	1 (5%)	1
Superior VB	5 (25%)	2 (10%)	0.229
Inferior VB	8 (40%)	11 (52%)	0.551
Superior lamina	10 (50%)	7 (33%)	0.346
Inferior lamina	0 (0%)	1 (5%)	1
Superior LM LS	6 (30%)	7 (33%)	1
Superior LM NLS	6 (30%)	4 (19%)	0.472
Inferior LM LS	5 (25%)	8 (38%)	0.514
Inferior LM NLS	4 (20%)	8 (38%)	0.315
Contralateral perched facet, n (%)	1 (5%)	1 (5%)	1
DISH , n (%)	3 (15%)	5 (25%)	0.693
Prior C-spine fusion, n (%)	1 (5%)	1 (5%)	1
Attempted CST, n (%)	12 (60%)	12 (55%)	0.964
Successful open reduction (initial approach), n (%)	12 (60%)	21 (95%)	**0.008**

HE, high energy; LE, low energy; SP, spinous process; VB, vertebral body; LM, lateral mass; LS, locked side; NLS non-locked side; DISH, diffuse skeletal hyperostosis

PAPER 18

Bone Density Measurements Show No Significant Association with Presence of Dens Fractures: Case-Control Study Using Opportunistic CT Osteoporosis Indices

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Introduction: The odontoid process is essential for 50% of axial rotation and 10-20 degrees of sagittal motion, and fractures of this bony feature continue to grow.[1–4] Previous research suggests that osteoporosis is a risk factor for dens fractures, however, there is no quantitative research to date that has shown this relationship.[5–7] While DEXA scan is the current gold standard for determining bone density, previous research has shown that bone density can be opportunistically measured using computed tomography using the Hounsfield Unit (HU).[8,9]

This study aimed to characterize vertebral body bone density using CT and determine if there is a correlation between odontoid process bone density and the occurrence of dens fractures.

Materials and Methods: This case-control study examined adult patients admitted to one tertiary academic medical center emergency department between 2009 and 2023 who subsequentially underwent cervical spine CT as entry into the trauma system. 96 patients with dens fractures were identified during this time, and fracture type was cataloged according to the Anderson and D'Alonzo system and displacement.[10] These patients were propensity matched at a 1:1 ratio by age, sex, and mechanism of injury to other patients in the trauma system as controls. Patient demographics including history of tobacco use and diabetes were collected. Afga Xero CT software was used to measure transverse and sagittal cross-sectional bone density in HU at C2 (dens), C2 (body), and the bodies of C4, C6, T8, T12, and L2. Measurements were taken midline of the vertebral body and at the first plane that the pedicle was visible bilaterally. When degenerative changes made this impractical, measurements were made in the middle of the vertebral body. The measurement area comprised of whole trabecular bone and excluded the cortex. Univariate independent t-tests and chi-square were used to compare those with dens fractures to those without.

Results: Among fracture patients, 1% were classified as type I, 75% were classified as type II, and 24% were classified as type III. No difference between age, gender, mechanism of injury, diabetes, or tobacco use between samples and controls was noted (Table 1). No statistically significant difference between bone density among dens fracture patients and controls was noted at any of the vertebral levels (Table 2). Our values are consistent with other studies that utilized CT opportunistic bone density screening.[11–13] Bone mineral density was highest in the dens and trended lower throughout the cervical, thoracic, and lumbar portions of the spine.

Conclusion: This study indicates that there is no correlation between osteoporotic changes and the incidence of dens fractures. Surprisingly, bone density of the odontoid process was generally higher than other vertebral levels. This finding contradicts the prevailing belief that osteoporosis significantly contributes to the risk of odontoid process fractures. Greater bone density does not necessarily correlate with bone health—osteosclerosis, osteopetrosis, avascular necrosis, and degenerative changes alter bone density and morphology which makes them more susceptible to fracture.[14–18] Additional factors, such as sagittal alignment and degeneration, should be investigated further to understand their roles in contributing to fracture risk.

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	Control (N = 96)	Dens Fracture (N = 96)	Odds ratio	p-value
Age	77.4 (13.0)	77.4 (13.2)		0.965
Gender			1.00 (0.57 - 1.76)	1
Female	51 (53%)	51 (53%)		
Male	45 (47%)	45 (47%)		
Mechanism of Injury				1
Ground Level Fall	75 (78%)	75 (78%)		
Higher than Ground Level Fall	6 (6%)	6 (6%)		
Motor Vehicle Crash/Trauma	15 (16%)	15 (16%)		
Tobacco Use			0.78 (0.44 - 1.37)	0.4681
Yes	40 (42%)	46 (48%)		
No	56 (58%)	50 (52%)		
Diabetes			0.86 (0.45 - 1.61)	0.7468
Yes	68 (71%)	71 (74%)		
No	28 (29%)	25 (26%)		

Table 1. Summary of patient demographic data

	Control (N = 96)	Dens Fracture (N = 96)	p-value
C2 Dens Transverse (HU)	416.2 (162.0)	466.5 (200.5)	0.0581
C2 Dens Sagittal (HU)	419.2 (156.6)	468.0 (198.2)	0.0607
C2 Body Transverse (HU)	276.0 (117.4)	313.0 (155.2)	0.0648
C2 Body Sagittal (HU)	253.5 (106.2)	257.9 (99.9)	0.7693
C4 Body Transverse (HU)	311.8 (110.1)	307.1 (131.3)	0.7905
C4 Body Sagittal (HU)	284.8 (114.8)	273.7 (118.8)	0.5137
C6 Body Transverse (HU)	264.3 (99.0)	263.0 (112.6)	0.9325
C6 Body Sagittal (HU)	237.8 (94.6)	237.7 (111.9)	0.9899
T8 Body Transverse (HU)	144.9 (73.9)	129.3 (61.3)	0.2069
T8 Body Sagittal (HU)	147.2 (81.4)	133.8 (68.8)	0.3267
T12 Body Transverse (HU)	135.2 (66.2)	120.3 (64.0)	0.2157
T12 Body Sagittal (HU)	135.3 (67.7)	122.7 (71.8)	0.3294
L2 Body Transverse (HU)	131.8 (64.6)	110.0 (68.6)	0.0861
L2 Body Sagittal (HU)	125.1 (68.1)	113.8 (76.7)	0.4171

Table 2. Summary of bone density data

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

PAPER 19

Development of a Web Application for Predicting Neurological Outcome at Hospital Discharge in Spinal Cord Injury Patients: A Machine Learning Approach

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Introduction: Accurate prediction of the American Spinal Injury Association (ASIA) Impairment Scale (AIS) at discharge is useful for guiding treatment decisions, indicating the potential for regenerative medicine, and setting realistic rehabilitation goals in spinal cord injury (SCI) patients. However, the complex interplay of multiple factors in SCI makes precise prognostic prediction challenging. This study aimed to leverage machine learning (ML) techniques to develop a robust model for predicting AIS at discharge, identify key predictive factors, and integrate the model into a user-friendly, publicly accessible web application to support clinical decision-making and patient communication in the future.

Materials and Methods: A retrospective cohort study was conducted using data from the Japan Rehabilitation Database (JARD), a comprehensive nationwide database of SCI patients from specialized SCI centers and rehabilitation hospitals across Japan between 1991 and 2015. JARD had information such as patient demographics, SCI-specific characteristics, and detailed neurological evaluations at admission being used for ML model training. Exclusion criteria included patients without AIS data at discharge, those with atraumatic injuries, those who expired during hospitalization, and those who were graded AIS E at admission. Data preprocessing and model validation were performed using the PyCaret library. The best-performing algorithm was selected based on key performance metrics, including the coefficient of determination (R^2), accuracy, and weighted Kappa coefficient, which accounts for the ordinal nature of the AIS. Shapley additive explanations (SHAP), a game theory-based approach, were used to determine the contribution of individual variables to the model's predictions. The optimal ML model was converted into a web application using the Streamlit library.

Results: Of the 4,181 SCI cases, the study included 3,703 cases through the exclusion criteria. Table 1 presents the baseline characteristics of the study, which included 3,703 patients with an average age of 50.5±18.7. At admission, the distribution of AIS grades was 1,318 (35.6%) cases of grade A, 393 (10.6%) of grade B, 928 (25.1%) of grade C, and 1,047 (28.3%) of grade D. The dataset was divided into a training set of 2,592 cases and a testing set of 1,111 cases. All models in the PyCaret library were evaluated (Table 2). The Gradient Boosting Regressor (GBR) was identified as the top-performing model, achieving the highest R^2 of 0.869. The model achieved an accuracy of 0.814 and a weighted Kappa of 0.940. SHAP analysis revealed eleven key variables significantly influencing the model's predictions, including AIS at admission, days from injury to admission, and the L3 motor score (Figure 1). Using the Streamlit library, the best-performing ML model was integrated into an open-access web application (http://3.138.174.54:8502/).

Conclusion: This study developed an accurate ML model with eleven items for predicting AIS at discharge in SCI patients. The accuracy of our model was almost the same as the performance of the previous predicting models, including the binary classification model.

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Our model also identified 11 factors essential for predicting AIS. These items were previously considered factors related to neurological outcomes, and our results emphasize the importance of the initial severity of the neurological prognosis.

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Table 1. Characteristics of the study participants (N=3,703).

	Values	Missing count, n (%)
Patient background		
Age, mean (SD)	50.5 (18.7)	14 (0.4)
Sex (male), n (%)	3,119 (84.2)	1 (0.0)
Academic background (Final education), n (%)		
Elementary school, n (%)	68 (1.8)	
Junior high school, n (%)	462 (12.5)	
High school, n (%)	946 (25.5)	1855 (50.1)
University, n (%)	351 (9.5)	
Graduate school, n (%)	21 (0.6)	
Characteristics of SCI		
Days from injury to admission, mean (SD)	83.1 (354.6)	25 (0.7)
Presence of radiographic abnormalities, n (%)	2,150 (58.1)	125 (3.4)
Neurological assessment		
Neurological level of injury, n (%)		
C1-C8	2,565 (69.3)	
T1-T12	706 (19.1)	84 (2.3)
L1-L5	284 (7.7)	
S1-S4	64 (1.7)	
Total FIM score, score (SD)	62.7 (24.2)	66 (1.8)
FIM comprehension, score (SD)	6.6 (1.2)	68 (1.8)
ASIA motor score, mean (SD)	47.4 (27.8)	27 (0.7)
L3 motor score, score (SD)	2.0 (2.0)	13 (0.4)
ASIA sensory score (light touch), mean (SD)	63.4 (33.2)	200 (5.4)
AIS, n (%)		
AIS A	1,318 (35.6)	
AIS B	393 (10.6)	17 (0.5)
AIS C	928 (25.1)	
AIS D	1,047 (28.3)	

Abbreviations: AIS, American Spinal Cord Injury Association Impairment Scale; ASIA, American Spinal Cord Injury Association; C, cervical; FIM, functional independence measure; L, lumbar; S, sacral; SCI, spinal cord injury; SD, standard deviation; T, thoracic.

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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Table 2. Performance of each models.

Model	R^2
Gradient Boosting Regressor	0.8692
Light Gradient Boosting Machine	0.8663
Random Forest Regressor	0.8628
Extra Trees Regressor	0.8619
Linear Regression	0.8366
Ridge Regression	0.8366
Bayesian Ridge	0.8366
Least Angle Regression	0.834
Huber Regressor	0.8032
AdaBoost Regressor	0.7906
Decision Tree Regressor	0.7373
K Neighbors Regressor	0.631
Elastic Net	0.6002

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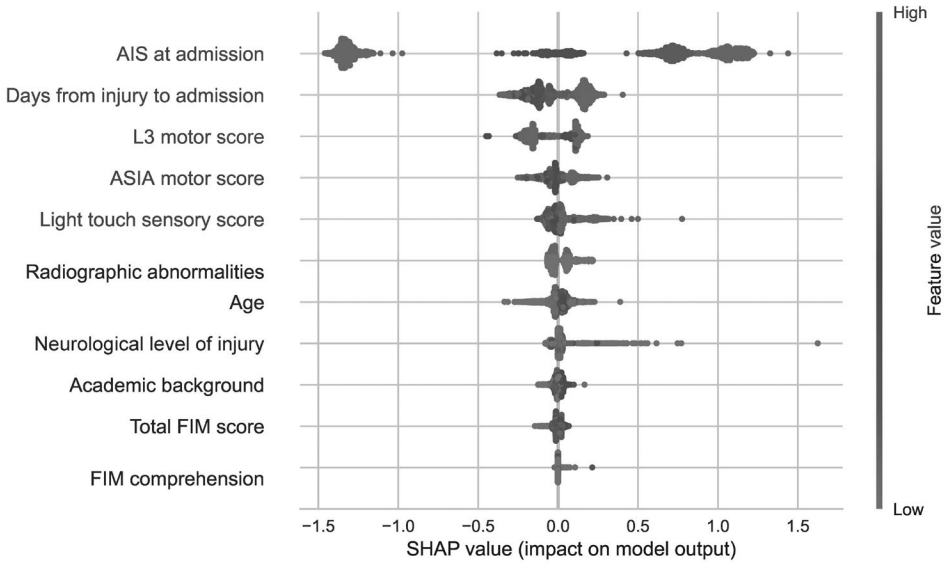

PAPER 20

Type 2 Odontoid Fractures: Atlantodental Arthrosis as a Novel Risk Factor for Failure of Conservative Management

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Introduction: No current consensus exists regarding the optimal management of type 2 odontoid fractures in th elderly as the potenital morbidity associated with both operative and nonoperative treatment is signicant. Therefore, it is imperative that treating providers identify all variables associated with improved outcomes with either treatment modality to optimize patient outcomes and avoid failures of either index treatment modality. Radiologic atlantodental arthrosis is one such variable that may impact fracture healing given the fact that a more rigid lever arm adajcent to a fracture site induces greater biomechanical strain on what is an already tenuous fracture healing environment. Therefore, the purpose of this study is to assess how both the presence and grade of atlantodental arthrosis relate to outcomes of non-operatively managed Type 2 odontoid fractures.

Materials and Methods: Patients presenting to an emergency room of a single level-1 trauma center with a Type 2 odontoid fracture treated between 2017-2023 were retrospectively identified using ICD-10 codes. Patients with an infectious, oncologic, or iatrogenic etiology of fracture were excluded along with individuals who received initial surgical treatment. Demographic and comorbidity information was collected. Radiologic evaluation was conducted on index CT and initial upright x-rays of the cervical spine for initial fracture angulation and displacement. Atlantodental arthrosis severity on index CT was scored based on the classification system established by Liu et al., which qualitatively graded the degree of arthrosis as 1 for mild, 2 for moderate, 3 for severe, and 4 for fused, based on osteophyte formation and imposition on the atlantodental and dental-basion intervals[1]. Failure of conservative treatment was defined by surgical stabilization within 6 months of injury due to functionally limiting pain in the setting of concordant fracture nonuion and mobility. Multivariable regression and Pearson correlation were utilized to assess the relationship between atlantodental arthrosis and failure of conservative management.

Results: 81 patients were included in the study, with an average length of radiographic follow up from the date of injury of 180 days. There was no difference in demographics between the conservative treatment failure and success groups ($p>0.05$). Patients who failed conservative treatment were more likely to have an atlantodental osteoarthritis (OA) grade >2 ($p<0.001$) and increased posterior displacement on index imaging ($p=0.008$). Following multivariable regression, OA grade 3 (OR 4.4, 95% CI: 1.6 to 11.9, $p=0.004$) and grade 4 (OR 13.9, 95% CI: 1.5 to 127.9, $p=0.02$) were independently associated with increased risk for failing conservative management. Additionally, increased OA grade was correlated with failure of conservative management ($r=0.519$, $P<0.001$).

Conclusion: This study represents the first of its kind to identify atlantodental arthrosis as a risk factor for failure of conservatively managed type 2 odontoid fractures. Further prospective studies are necessary to evaluate this metric as a possible data point in determining treatment modality of patients with type 2 odontoid fractures.

PAPER 21

Anterior Compared to Posterior Surgery for Degenerative Cervical Myelopathy: A Cost-Utility Analysis from the Multicenter Canadian Spine Outcomes and Research Network

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University of Toronto[1] CSORN[2] University of Calgary[3] University of British Columbia[4]

Introduction: Degenerative cervical myelopathy (DCM) is the most common cause of acquired non-traumatic spinal cord injury worldwide.[1] Evidence from prospective trials have shown that surgery, overall, is effective at improving patient reported Health Related Quality of Life (HRQoL) measured through EuroQol-5D (EQ-5D). [2–4] However, in select patients with 2-3 level DCM without kyphosis, there remains uncertainty around whether anterior or posterior surgery is a favourable approach.[5]

Materials and Methods: A cost-utility analysis was conducted to compare anterior and posterior surgery for treatment of DCM from the healthcare payer perspective. We utilized data from the prospective observational cohort of DCM patients enrolled in the Canadian Spine Outcomes Research Network (CSORN) from 2015-2022. We conducted a 1:1 propensity score match of patients by treatment group. HRQoL was subsequently measured at 12-months post-surgery using patient reported EQ-5D. Additionally, we conducted a systematic review and meta-analysis of North American studies from 2010-2024 in PUBMED reporting direct costs of anterior and posterior surgery for 2-3 level DCM. Costs were inflated to the January 2024 United States Dollar (USD) and pooled by treatment group through random effects meta-analysis. A time homogenous Markov state transition model was subsequently used to estimate lifetime quality adjusted life years (QALYs) and costs associated with each treatment group. A cost-utility analysis was conducted to obtain the incremental cost utility ratio (ICUR) associated with anterior relative to posterior surgery. Deterministic one-way and probabilistic sensitivity analyses were conducted using parameter estimate distributions with Monte-Carlo microsimulation (10,000 trials). Costs and utilities were discounted at 3% per annum.

Results: We included 142 matched patients (71 anterior group, 71 posterior group) treated with surgery for DCM that were balanced across baseline covariates (Table 1). At 12-months post-surgery, there was no significant difference in EQ-5D between treatment groups (mean difference 0.05, 95% CI -0.01 to 0.11, p = 0.055 t-test). Costs were estimated from 10 observational studies comprising 192,225 patients treated for DCM. The pooled mean direct cost of anterior surgery was found to be $30,031.59 USD (95% CI $21,233.74 to 38,829.45 USD), and the pooled mean direct cost of posterior surgery was $33,972.15 USD (95% CI 15,139.84 to 52,804.45 USD). There were no significant differences in costs between the treatment groups with respect to initial in-patient care (mean difference -$3,950.56 USD, 95% CI -$24,733 to $16,582.10 USD, p = 0.645 t-test). However, Markov modelling found that anterior surgery was associated with an incremental lifetime increase of 0.83 QALYs compared to posterior surgery, with a lifetime cost difference of $5814.60 USD accrued to the healthcare payer. The average ICUR of anterior relative to posterior surgery was $6,979.54/QALY. Utilizing a willingness to pay threshold in keeping with the World Health Organization definition of "very cost-effective" ($74,161 USD), probabilistic sensitivity analysis demonstrated that 98.3% of cases favor anterior surgery.

Conclusion: Our findings suggest that in the presence of equipoise around surgical approach

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at the time of assessment for a patient with 2-3 level DCM, there is cost-utility rationale to support anterior surgery.

Table 1. Baseline demographics of patients included stratified by anterior and posterior surgical approach. P values reflect baseline differences in characteristics between propensity score matched groups. Abbreviations – Modified Japanese Orthopedic Association (mJOA), EuroQol 5D (EQ-5D), standard deviation (SD).

	Anterior Group (N=71)	Posterior Group (N=71)	Overall (N=142)	p-Value
Male Sex, n (%)	50 (70.4)	52 (73.2)	102 (71.8)	0.852
Age (Years), Mean (SD)	62.03 (8.57)	62.35 (9.08)	62.19 (8.80)	0.827
Comorbidities, n (%)				0.684
0	3 (4.2)	1 (1.4)	4 (2.8)	
1	11 (15.5)	11 (15.5)	22 (15.5)	
2	16 (22.5)	20 (28.2)	36 (25.4)	
≥3	41 (57.7)	39 (54.9)	80 (56.3)	
mJOA, Mean (SD)	12.87 (2.47)	12.68 (2.42)	12.77 (2.44)	0.632
Levels of Compression, n (%)				0.863
2	45 (63.4)	43 (60.6)	88 (62.0)	
3	26 (36.6)	28 (39.4)	54 (38.0)	
Pre-Operative Alignment, n (%)				0.732
Lordotic	44 (62.0)	41 (57.7)	85 (59.9)	
Neutral	27 (38.0)	30 (42.3)	57 (40.1)	
Baseline EQ-5D, Mean (SD)	0.594 (0.200)	0.562 (0.200)	0.578 (0.202)	0.353
Post-op EQ-5D, Mean (SD)	0.746 (0.150)	0.698 (0.202)	0.722 (0.179)	0.100

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Figure 1: Random effects meta-analysis of costs ($USD) associated with cervical spine surgery for 2-3 level degenerative cervical myelopathy (DCM). All costs were inflated to January 2024.

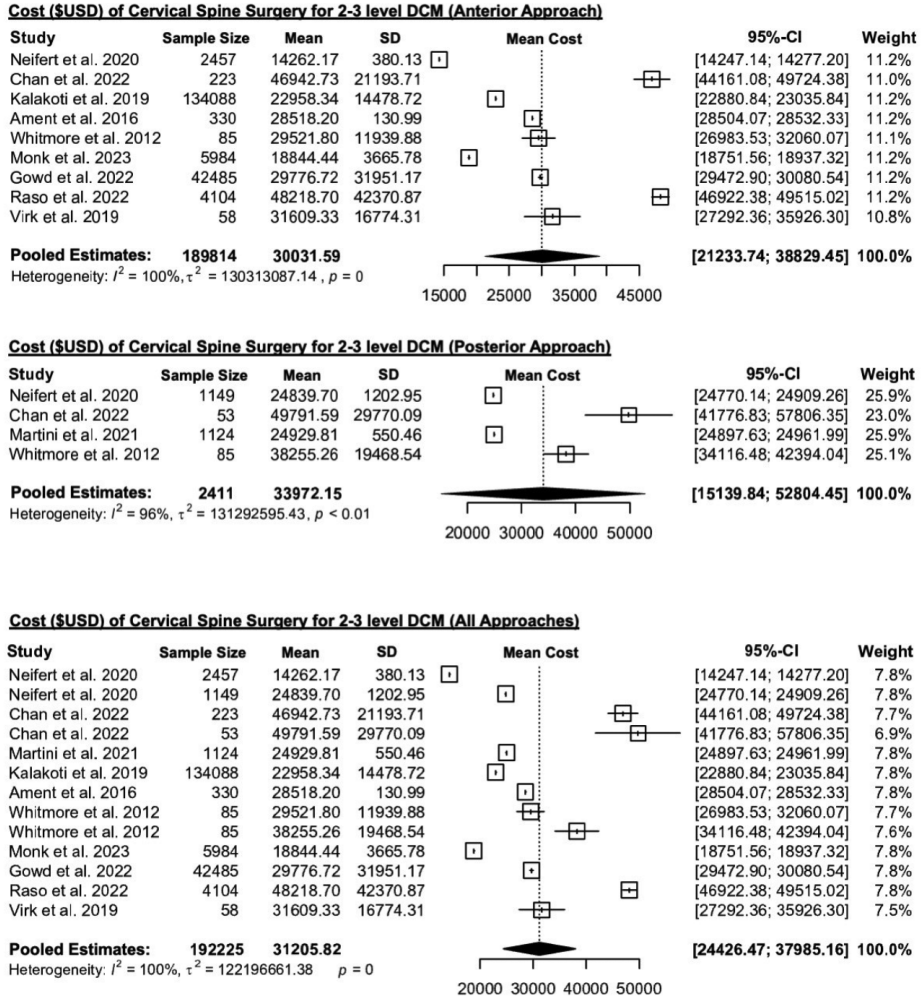

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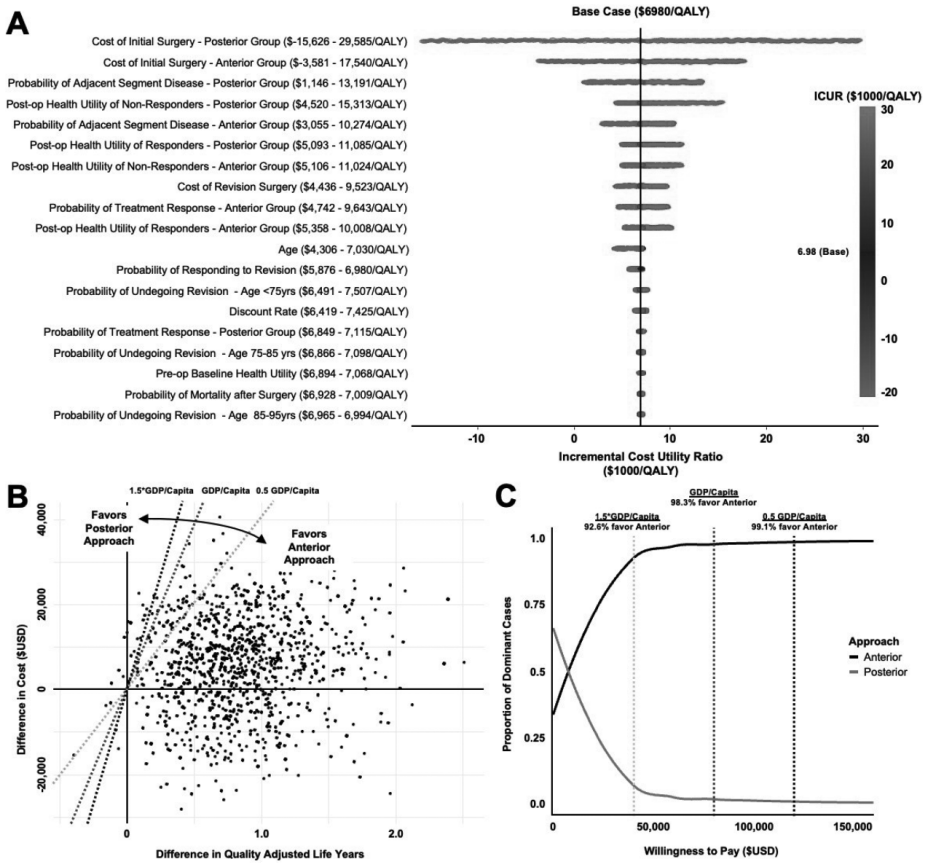
Figure 2: Markov state transition model with deterministic and Monte Carlo probabilistic sensitivity analysis for lifetime estimates of incremental cost-to-utility ratio (ICUR) of surgical intervention for degenerative cervical myelopathy (Model 1 parameters). (A) Results of multiple single-way deterministic sensitivity analyses; (B) Cost-utility plane with results from Monte Carlo probabilistic sensitivity analysis; (C) Cost-utility acceptability curve (dashed lines represents 3 distinct willingness-to-pay thresholds corresponding to 0.5, 1, and 1.5 time the United States Gross Domestic Product (GDP) per Capita.



PAPER 22

Therapeutic Efficacy of Clinically Relevant Human iPSC-derived Neural Stem/Progenitor Cell Transplantation for Chronic Cervical Spinal Cord Injury

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Keio University[1]

Introduction: Ninety-five percent of spinal cord injury (SCI) patients are in the chronic phase, with neural regeneration being extremely difficult due to intramedullary scarring and cavitation. Additionally, over 60% of SCI occur in the cervical region, which differs in pathophysiology from injury in the thoracic region. This study aims to investigate the therapeutic efficacy of clinically relevant human-induced pluripotent stem cell-derived neural stem/progenitor cell (hiPS-NS/PC) transplantation in models of severe cervical SCI in the chronic phase.

Materials and Methods: To establish an animal model, we induced contusion injury to the cervical spinal cord by Infinite Horizon impactor (200kdyn) in adult female athymic nude rats at different vertebral levels (C5, C6, and C7). We then evaluated the behavioral functions at each injury level and decided to use the C6 model, due to its high reproducibility stemming from minimal joint contracture and reduced variability in behavioral function. Six weeks post-injury, clinically relevant hiPS-NS/PCs with gliogenic competence were transplanted at two points rostral and caudal to the injury site. PBS was injected into the control group. Behavioral functions were comparatively evaluated using the Irvine, Beatties, and Bresnahan (IBB) forelimb recovery scale, single-handed grip test, horizontal ladder test, and kinematic analysis of reaching tasks. Ten weeks post-injury, biotinylated dextran amine labeling the host cortico-spinal tract (CST) was injected into the motor area of the cerebral cortex, to perform anterograde neural tracing. Twelve weeks post-injury, the spinal cord was harvested for histological evaluation.

Results: Anterograde neural tracing confirmed the disruption of CST in the control group (fig 1). In the transplantation group, successful engraftment and migration of the transplanted cells occurred, with a substantial amount of differentiation into oligodendrocytes and astrocytes. Tracing also revealed the penetration of host-derived CST axons into the transplant lesion and their subsequent accumulation around the transplanted cells (fig 2), which suggests the formation of synaptic connections between the host CST and transplanted cells. In addition, an increase in transplant-derived neural axons was observed in the CST distal to the lesion. Furthermore, observations in the spinal ventral horn at the distal side of the injury site suggested the presence of synaptic formations extending from the transplanted cells to the motor neurons. Behavioral function assessments demonstrated significant improvements in upper limb motor functions, which was reflected in IBB scale scores (fig 3), error rate of ladder walk, and reaching kinematics especially in time taken to reach, velocity, and correlation values at each joint angle.

Conclusion: Clinically relevant hiPS-NS/PC transplantation into chronic severe cervical SCI models improved motor functions substantially. Immunostaining and anterograde tracing suggest that the formation of synaptic connections between host CST and transplanted cells, and the connections between transplanted cells and host motor neurons, lead to motor

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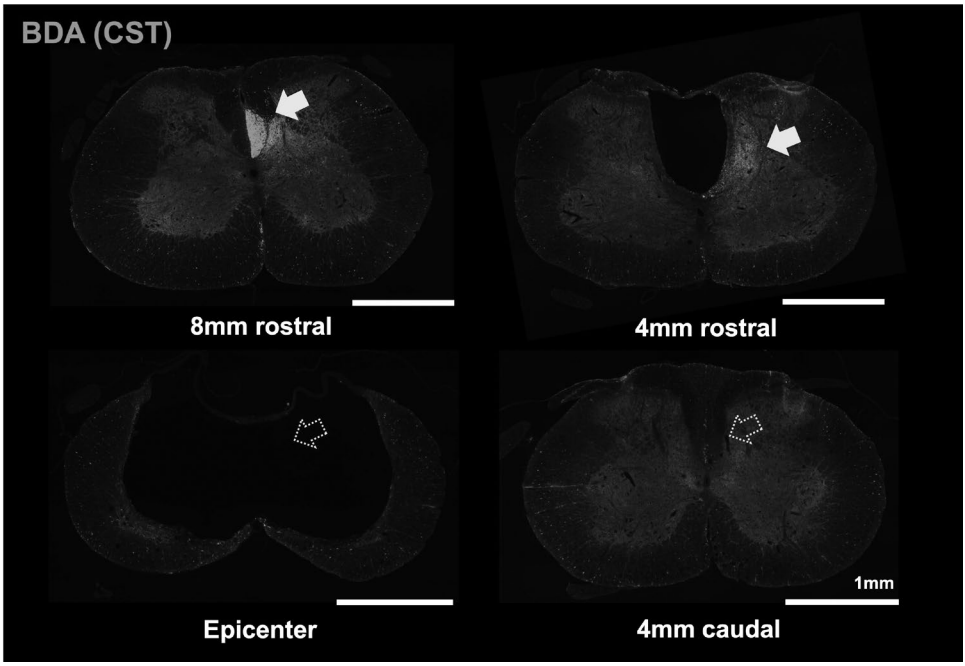
function improvement. Remyelination, resulting from transplanted cell differentiation into oligodendrocyte, also appear to have played a significant role in the observed improvement. This study confirms the therapeutic efficacy of clinical-grade hiPS-NS/PC transplantation for chronic severe cervical SCI, yielding promising insights for the clinical application of hiPS-NS/PC transplantation in chronic SCI.



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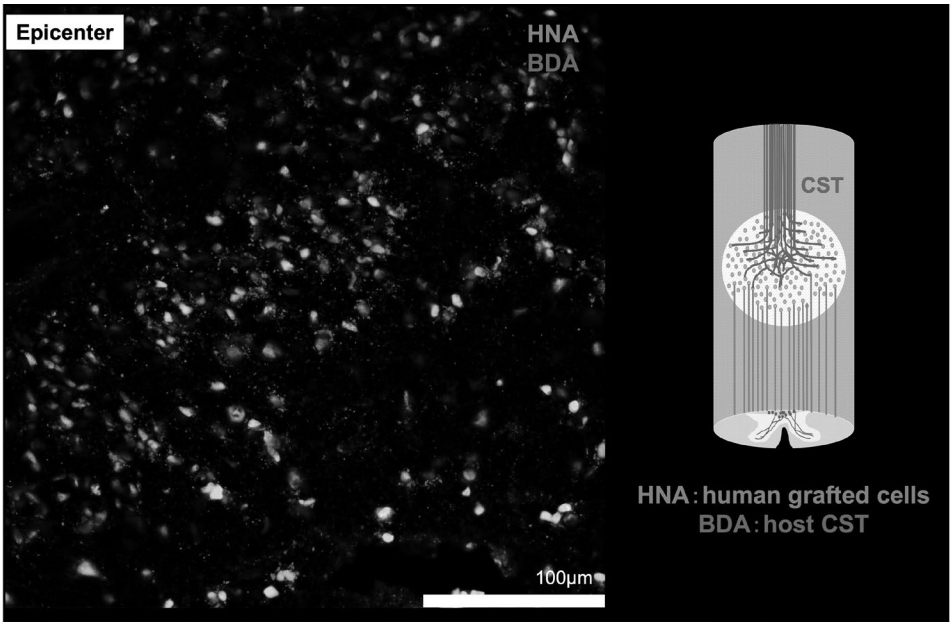

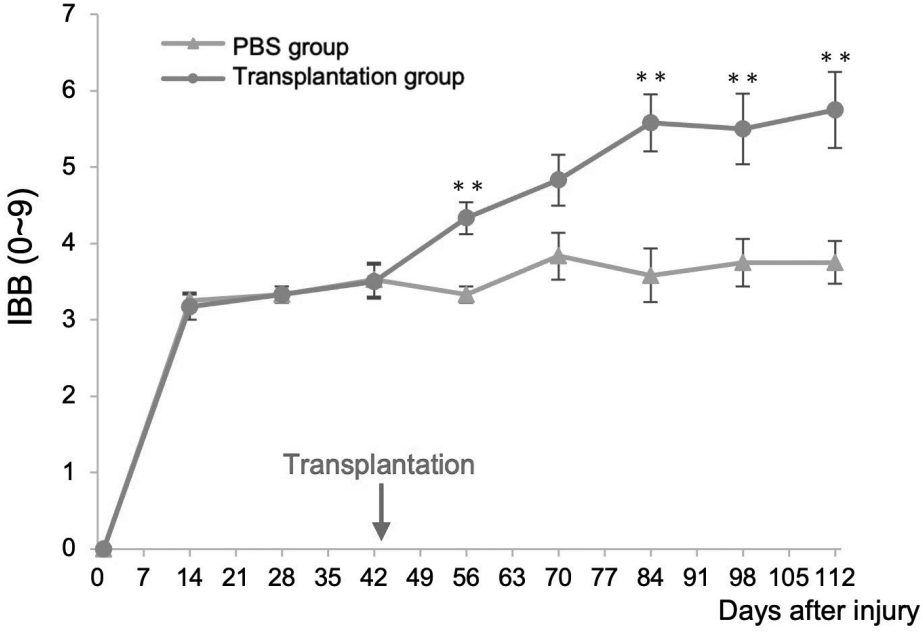

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PAPER 23

Spinal Cord Metrics Derived from Diffusion-Weighted MRI Improves Prognostication in Cervical Spondylotic Myelopathy Compared to Conventional MRI

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Introduction: A major shortcoming in optimizing care for cervical spondylotic myelopathy (CSM) patients is the lack of robust quantitative imaging tools offered by conventional MRI. Advanced MRI modalities, such as diffusion MRI (dMRI), including diffusion tensor imaging (DTI) and diffusion basis spectrum imaging (DBSI), may help address this limitation by providing granular evaluations of spinal cord microstructure in CSM.

Materials and Methods: Forty-seven CSM patients underwent comprehensive clinical assessments and diffusion-weighted MRI, followed by DTI and DBSI modelling (Fig. 1). Conventional MRI metrics included 10 total qualitative and quantitative assessments of spinal cord compression in both the sagittal and axial planes (Fig. 2). dMRI metrics included 12 unique measures including anisotropic tensors, reflecting axonal diffusion, and isotropic tensors, describing extra-axonal diffusion Our primary outcome was the mJOA, measured at two-years postoperatively. XGBoost supervised classification algorithms were used to 1) classify patients into disease group and 2) prognosticate surgical outcomes at two-years follow-up.

Results: Forty-seven CSM, including 24 (51%) mild mJOA, 12 (26%) moderate mJOA, and 11 (23%) severe mJOA, and 21 control patients were included. In the classification task, the traditional MRI metrics correctly assigned patients to healthy control vs. mild CSM vs. moderate/severe CSM with an accuracy of 0.647 [95% CI: 0.64;0.65] (Fig. 3). In comparison, the DTI model performed with an accuracy of 0.52 [0.51;0.52] and the DBSI model, 0.81 [0.808;0.814]. In the prognostication task, the traditional MRI metrics correctly predicted CSM patients who improved at two-year follow-up based on ΔmJOA with an accuracy of 0.58 [95% CI: 0.57;0.58]. In comparison, the DTI model performed with an accuracy of 0.62 [0.61;0.62] and the DBSI model, 0.72 [0.718;0.73] (Fig. 3).

Conclusion: Conventional MRI is a powerful tool to assess structural abnormality in CSM but is inherently limited in its ability to characterize spinal cord tissue injury. Our results demonstrate that advanced imaging techniques, namely diffusion basis spectrum imaging derived metrics from diffusion MRI provide granular assessments of spinal cord microstructure than can offer better diagnostic and prognostic utility.

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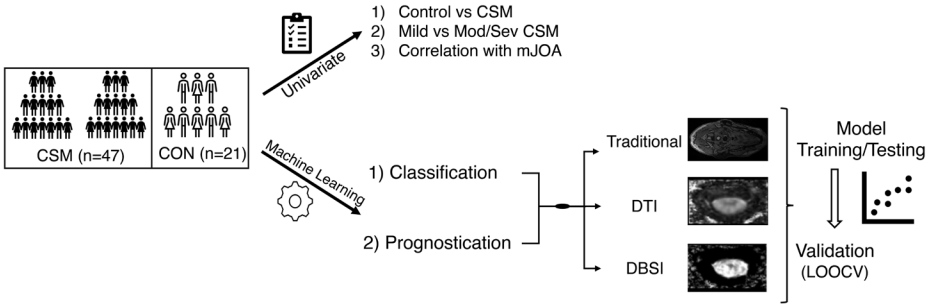

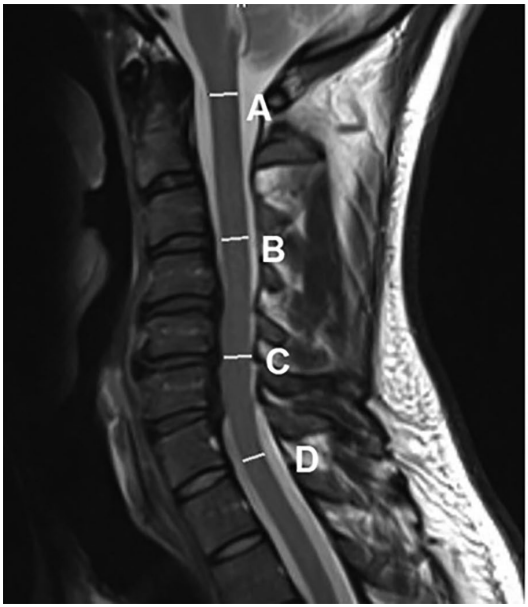

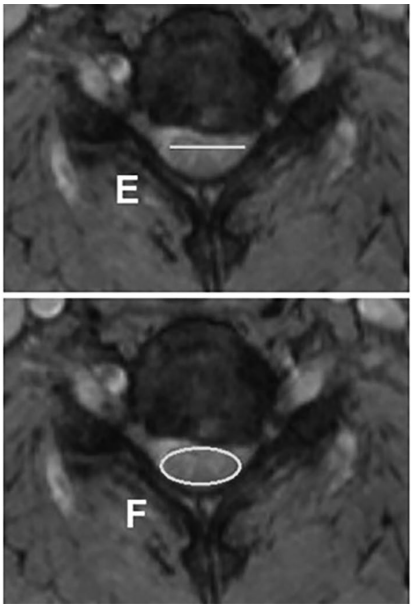

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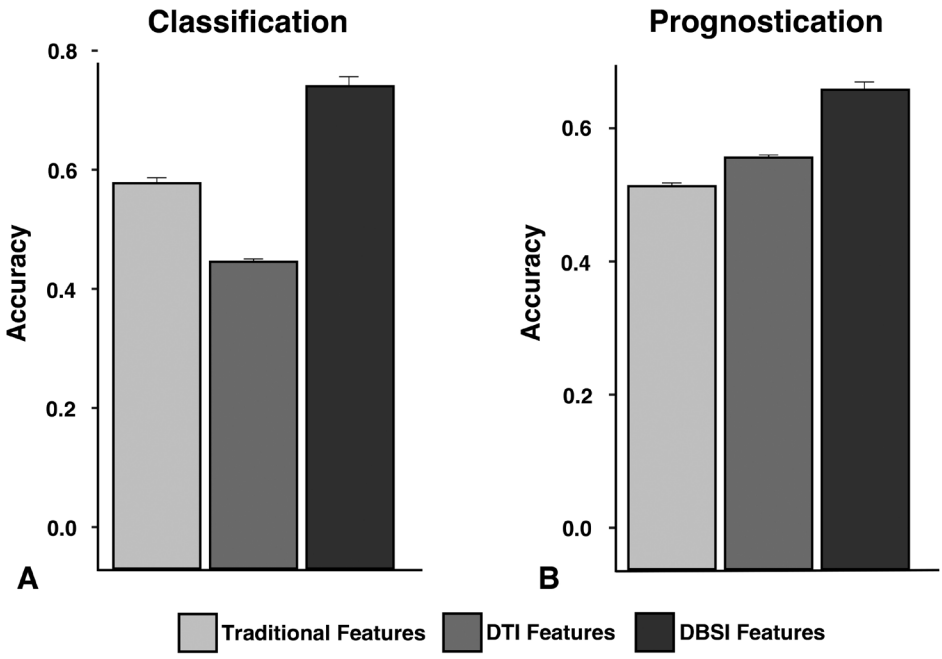

PAPER 24

Association of Pre-Injury Depression History with Functional Independence After Spinal Cord Injury

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Washington University in St. Louis[1] University of Utah[2]

Introduction: Spinal cord injury (SCI) can be devastating for patients. It is well-established that these individuals are at increased risk of depressive disorders,[1] with an estimated 22% receiving a depression diagnosis after SCI.[2] These patients tend to have increased complications such as pressure ulcers and may experience greater mortality.[3–5] However, the effect of pre-injury depression history on functional independence and neurological outcomes after SCI has not been thoroughly examined.

Materials and Methods: The multicenter, prospectively maintained SCI Model Systems (SCIMS) database was used.[6] Adult traumatic SCI patients enrolled through a participating rehabilitation center within 30-days of injury from 2010-2016 were included. Patients missing a neurological exam, functional assessment at admission/follow-up, or mental health history information were excluded. Functional Independence Measure (FIM), which measures degree of independence in activities of daily living, at 1-year after injury was the primary outcome. Secondary outcomes included FIM item scores, ASIA Motor Index Score, whether the patient converted to an improved ASIA Impairment Scale (AIS) grade, Patient Health Questionnaire-2 (PHQ-2) score,[7] and depression diagnosis after SCI. Scores are reported as median [Q1, Q3], and the Mann-Whitney U Test was used to test significance. Multivariable regression was used to estimate the effect of a pre-existing depression diagnosis on each outcome while controlling for covariates such as age, sex, education level, injury severity, and function at rehabilitation admission.

Results: 1642 patients (14.5% with a depression history) were included in the primary outcome analysis. The depressed (D) and non-depressed (ND) groups differed by sex, age, and race, but there were no significant differences in injury level, severity, or etiology. Both groups presented with similar FIM at admission (D: 20 [13,30], ND: 22 [13,30], p=.23). However, the depressed group had less improvement and worse functional independence at 1-year (D: 74 [44,82], ND: 76 [53,85], p=.01) (Table 1). On multivariable regression, depression history was associated with lower FIM at 1-year (-3.2, 95% CI: [-5.7, -0.6], p=.01) (Table 2). Depression history was associated with lower scores for all FIM items, but only bathing, dressing, transfers (bed/chair/wheelchair/tub/shower), and stairs differed significantly. The smallest effects were seen for locomotion, bladder management, and eating (Figure 1). There were no differences between the groups on ASIA Motor Index Score at baseline or 1-year, or the rate of improved AIS grade (Table 1). Patients with a depression history had higher PHQ-2 depression scores (D: 2 [1,4], ND: 1 [0,2]) at 1-year after SCI and were more likely to have depression identified by a healthcare provider after SCI (D: 47.4%, ND: 13.1%).

Conclusion: A history of depression prior to SCI was associated with worse functional independence at 1-year after injury, despite similar recovery in motor function and AIS grade. Due to the increased rates of depression and suicide after SCI, routine screening for mental health conditions is recommended;[8] however, depression likely remains undertreated in this

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population.[5,8] While more research is needed, these results suggest that early interventions may be warranted based on a depression history alone due to its significant impact on outcomes.

Table 1: Comparison of outcomes with and without depression history

Functional Independence Measure			
	No depression history (N=1404)	**Depression history (N=238)**	**P-value**
FIM at Rehab Admission, median [Q1, Q3]	22.0 [13.0, 30.0]	20.0 [13.0, 30.0]	.234
FIM at 1-Year, median [Q1, Q3]	76.0 [52.8, 85.0]	74.0 [44.0, 82.0]	**.01**
FIM Improvement, median [Q1, Q3]	48.0 [29.8, 59.0]	43.0 [26.0, 55.0]	**.014**
ASIA Motor Index Score			
	No depression history (N=669)	**Depression history (N=115)**	**P-value**
Motor Index Score at Rehab Admission, median [Q1, Q3]	50.0 [31.0, 63.0]	50.0 [40.5, 66.5]	.231
Motor Index Score at 1-Year, median [Q1, Q3]	61.0 [50.0, 92.0]	68.0 [50.0, 92.0]	.86
Motor Index Score Improvement, median [Q1, Q3]	9.00 [1.00, 24.0]	9.00 [2.00, 24.0]	.829
Improved AIS Grade			
	No depression history (N=676)	**Depression history (N=123)**	**P-value**
AIS Improved, no. (%)	244 (36.1%)	38 (30.9%)	.314
Patient Health Questionnaire-2 and Depression Diagnosis			
	No depression history (N=1327)	**Depression history (N=228)**	**P-value**
PHQ-2 at 1-Year, median [Q1, Q3]	1.00 [0, 2.00]	2.00 [1.00, 4.00]	**<.001**
PHQ-2 ≥ 3, no. (%)	255 (19.2%)	88 (38.6%)	**<.001**
Depression diagnosis since SCI, no. (%)	174 (13.1%)	108 (47.4%)	**<.001**

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Table 2: Linear regression models for Functional Independence Measure at 1-year.

	Simple linear regression models			Multivariable linear regression model		
	B Coefficient	**95% CI**	**P-value**	**B Coefficient**	**95% CI**	**P-value**
Sex: Female	-1.14	-4.02, 1.73	.44	-2.61	-4.67, -0.55	**.01**
History of depression or anxiety	-3.65	-6.55, -0.74	**.01**	-3.37	-5.45, -1.3	**.001**
Age	-0.07	-0.13, 0	**.04**	-0.25	-0.31, -0.2	**<.001**
Education						
Less than high school diploma	*Reference*			*Reference*		
High school diploma/GED	1.49	-1.8, 4.79	.37	1.83	-0.52, 4.18	.13
More than high school diploma	2.46	-1, 5.92	.16	4.04	1.47, 6.62	**.002**
Neurological level of injury						
C1-4	*Reference*			*Reference*		
C5-T1	14.54	11.76, 17.32	**<.001**	10.42	8.24, 12.59	**<.001**
T2-12	18.06	15.57, 20.54	**<.001**	18.54	16.18, 20.89	**<.001**
L1-5	27.3	22.89, 31.71	**<.001**	19.39	15.66, 23.13	**<.001**
Spine Surgery after SCI	-5.53	-8.55, -2.5	**<.001**	0.68	-1.51, 2.88	.54
AIS (at Rehab Admission)						
AIS A	*Reference*			*Reference*		
AIS B	-4.27	-7.58, -0.96	**.01**	1.64	-1.05, 4.33	.23
AIS C	9.43	6.68, 12.18	**<.001**	16.92	14.6, 19.24	**<.001**
AIS D	23.27	20.76, 25.77	**<.001**	28.42	25.91, 30.93	**<.001**
Days to Rehab Admission	-1.04	-1.21, -0.88	**<.001**	-0.45	-0.58, -0.33	**<.001**
FIM (at Rehab Admission)	1.07	0.99, 1.16	**<.001**	0.4	0.3, 0.49	**<.001**

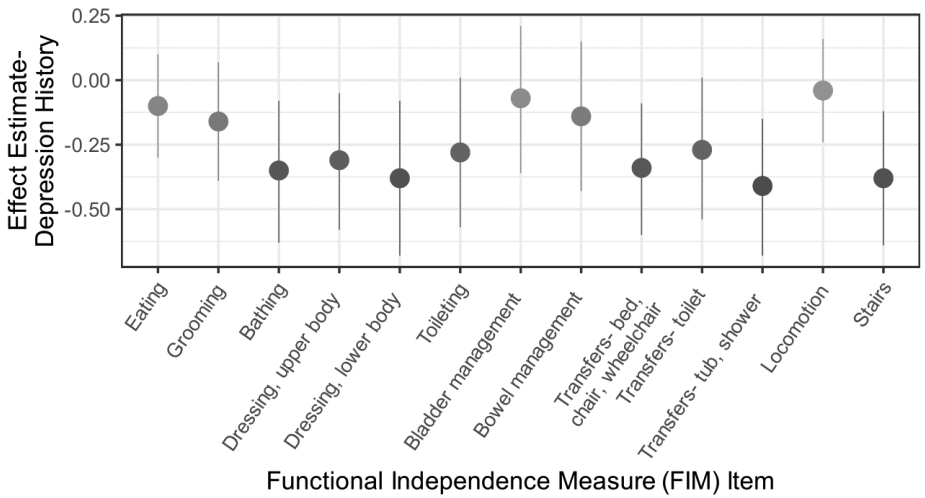

Figure 1: Regression coefficients for effect of depression history on FIM item scores in multivariable regression. 95% confidence intervals are shown.

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PAPER 25

Outcomes of Non-Union Type 2 Odontoid Fractures – A Multi-Institutional Study

Benjamin Johnston, MD, PhD[1], *Chady Omara, MD[2], Anna Lebouille-Veldman, MD[3], Alexander Yearley, MD[4], James Withers, MD[5], Helen Karimi, MD[6], Emma Steinbuchel, MD[6], Harshit Arora, MD[2], John Kilgallon, MD[2], Jakob V. E. Gerstl, MD[2], Jeroen Huybregts, MD[7], James Kryzanski, MD[6], Ron Riesenburger, MD, PhD[6], Timothy Smith, MD, PhD, MPH[2], Carmen Vleggeert-Lankamp, MD MSc PhD[7], Jeffrey Florman, MD[5], Chady Omara, MD[2]*

Brigham and Women's[1] Brigham & Women's Hospital[2] Leiden University[3] HMS[4] Maine Medical Center[5] Tufts Medical Center[6] Leiden University Medical Center[7]

Introduction: The treatment of type II odontoid fractures in the elderly population poses significant clinical challenges: surgical treatment can cause serious complications and conservative treatment carries the risk of non-successful union. Knowledge on the clinical effect of non osseous union is scarce, which makes the discussion on the appropriateness of conservative treatment even more challenging. This study aims to explore the safety of non osseous union after conservative treatment was applied by evaluating the clinical outcome of fibrous non-union and to identify risk factors for developing an unstable non-union.

Materials and Methods: A multi-institutional retrospective cohort study was conducted on patients with acute type 2 odontoid fractures treated conservatively between 2005 - 2022. Fracture healing outcomes (osseous union, fibrous non-union, unstable non-union) were evaluated post-collar removal via CT scans and dynamic X-rays. Incidence of neurologic deficits and eventual need for surgical fixation among groups was analyzed. Fracture stability was assessed post collar-removal using only dynamic X-rays. Risk factors for developing unstable fractures were analyzed through multivariate logistic regression.

Results: 315 patients with acute type 2 odontoid fractures were included (mean age: 76.3 ± 16.4 years, median follow-up: 24.0 months). Fibrous non-union occurred in 45.1% patients with a dynamic X-ray and CT-scan after a median collar wear of 3.5 months. Neurologic deficits after collar removal only occurred in unstable non-union cases (p=0.021), whereas no patients with fibrous non-union showed additional deficits post-collar removal, even after subsequent trauma. 81.6% of patients developed radiologically stable fractures. Risk factors for unstable fractures included male sex (OR 2.34; 95% CI: 1.17-4.68), osteoporosis/osteopenia (OR 2.17; 95% CI: 1.08-4.35), and baseline fracture displacement (OR 5.10; 95% CI: 2.60-10.01).

Conclusion: Fibrous non-union of type II odontoid fractures was identified as a safe outcome following conservative treatment, ruling out the need for surgical intervention. Factors such as male sex, osteoporosis or osteopenia, and baseline fracture displacement were associated with increased risk of unstable non-union after conservative fracture treatment and thus require prolonged immobilization, and an increased consideration for surgical stabilization to prevent spinal cord injury.

PAPER 26

Therapeutic Effects of Combined Therapy Involving Scar Resection, Decellularized Scaffold, and Human Induced Pluripotent Stem Cell-Derived-Neural Stem/Progenitor Cells Transplantation in Chronic Complete SCI

Keitaro Ito, MD[1], *Narihito Nagoshi, MD, PhD[1], Jun Kohyama, phD[1], Munehisa Shinozaki, MD,PhD[1], Hideyuki Okano, MD, PhD[1], Masaya Nakamura, MD, PhD[1]*
Keio university[1]

Introduction: Chronic complete spinal cord injury (SCI) presents a significant therapeutic challenge due to the scar formation and cavity lesions. Treatment with only human induced pluripotent stem cell-derived neural stem/progenitor cells (hiPSC-NS/PCs) transplantation is difficult, necessitating the use of scaffold materials to fill the cavities. In this study, we performed surgical removal of the scars and focused on Decellularized extracellular matrix (dECM) as a material for filling the cavities. Although dECM typically utilizes the extracellular matrix from the same organ, spinal cord–derived dECM hydrogel carries a risk of prion disease. Instead, we utilized a kidney-derived dECM hydrogel, anticipated for its high biocompatibility and potential to promote angiogenesis. This research aimed to evaluate the efficacy of a combined therapy involving scar resection, kidney-derived dECM hydrogel, and cell transplantation for chronic complete SCI.

Materials and Methods: We evaluated the efficacy of kidney gel concentrations (8 mg/ml, 16 mg/ml) using dorsal root ganglia (DRG), with collagen I serving as a control. A complete transection SCI was induced at the 10th thoracic vertebral level of the nude rat. We performed an initial treatment of scar resection and dECM hydrogel injection six weeks after SCI. Subsequently, the spinal cord microenvironment was assessed using immunostaining and RNA sequencing. In addition, one week after the initial treatment, hiPSC-NS/PCs were transplanted and their effects were evaluated.

Results: In vitro analysis showed cell viability of approximately 90% in all gel groups, and axonal elongation was observed at a kidney gel concentration of 8 mg/ml(Fig1). In vivo analysis revealed improvements in the microenvironment of the scar resection group one week after the initial treatment. These improvements included the emergence of neuroprotective microglia and macrophages (Arg1), and a decrease in axonal growth inhibitory factors(Fig2). The migration of vascular endothelial cells was also observed in the group receiving both scar resection and scaffold. Following such microenvironmental improvement and scaffold-induced angiogenesis, cell transplantation resulted in improved survival of the transplanted cells(Fig3) and regeneration of host axons. However, this combination therapy failed to achieve synapse formation between the rostral host axon and the transplanted cells at the center of the injury, nor did it achieve recovery of motor function.

Conclusion: This study demonstrated that dECM hydrogels can be applied to the injured spinal cord as a scaffold in chronic phase. The combination of scar resection and scaffold for chronic complete SCI contributed to improved microenvironment and angiogenesis, enhancing the survival rate of transplanted cells at the injury core, and facilitating the regeneration of host-derived axons. The therapeutic strategy, combining scar resection, dECM hydrogels, and cell transplantation, shows promise for clinical application in chronic complete SCI. Furthermore, combination therapy with rehabilitation and/or medications should be

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considered for practical success of this approach and to obtain functional recovery.

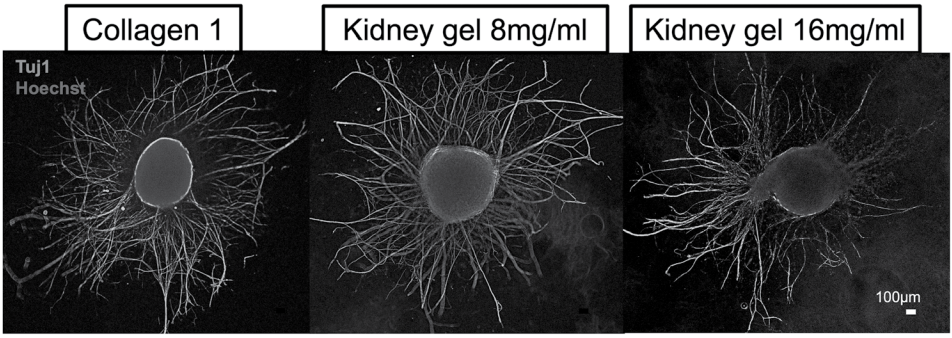

Fig2

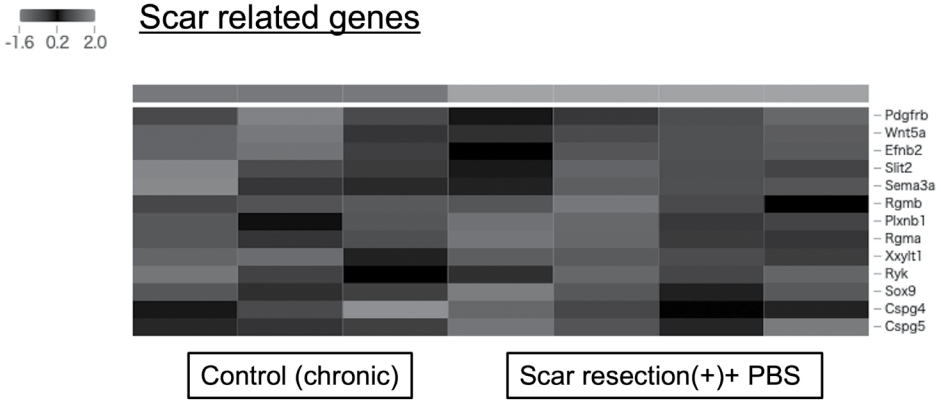

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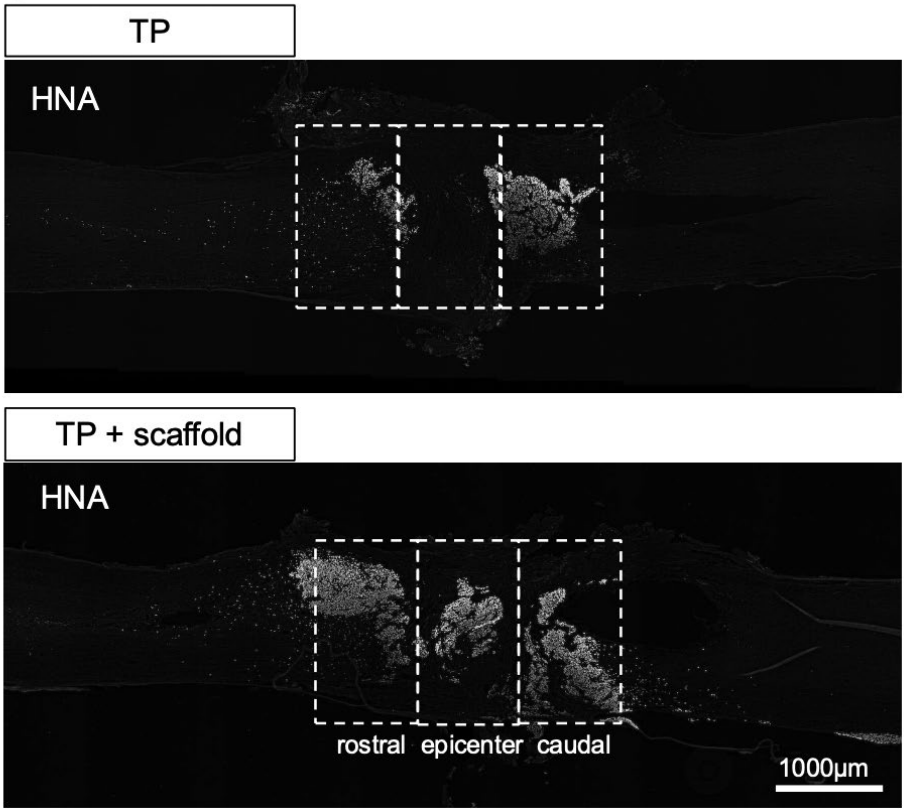
Fig.3



PAPER 27

Evaluating Incidence and Predictors of Postoperative Dysphagia Following Cervical Surgery Using EAT-10: A Multi-institutional Study

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Introduction: Dysphagia is a recognized complication following anterior cervical discectomy and fusion (ACDF), with reported incidence rates varying from 2% to 70% due to diverse assessment methods. The literature on dysphagia following posterior cervical surgeries is notably sparse, despite anecdotal reports of its occurrence. This study aims to address these gaps using the Eating Assessment Tool (EAT-10), known for its robust validation and ability to effectively capture the subjective nature of dysphagia.

Materials and Methods: We conducted a retrospective analysis of prospectively collected data from 1976 patients who underwent primary or revision cervical surgery for degenerative conditions at the University of Utah, Semmes-Murphy, and Goodman-Campbell from 2016-2023. Cases involving infections, trauma, or tumors were excluded, as were patients lacking baseline or follow-up EAT-10 scores. The study focused on identifying predictive factors and documenting the incidence and severity of dysphagia post-surgery. Additionally, associations between rates of dysphagia and multiple PROMs at 24 months were made.

Results: Dysphagia, defined as EAT-10 ≥ 3, was significantly more common and severe in anterior approaches, peaking at 61% two weeks post-operation. Posterior approaches showed a peak dysphagia rate of 32% at one month, with both surgical approaches returning to baseline levels by three months and maintaining stability up to two years. Rates of dysphagia varied with the number of levels operated on in anterior surgeries, reaching 100% in four-level operations and decreasing to 54% in one-level. Dysphagia rates also varied by specific disc spaces, with the highest at C2-C3 (100%) and decreasing towards C7-T1 (41%). Predictive factors for dysphagia included ASA grade (OR 1.6/grade; p<.0002), number of levels operated (OR 1.4/level; p=0.002), highest level (OR 1.4/level; p<.0002); presence of neck pain (OR 1.5; p=0.020), duration of symptoms > 3 months (OR 1.5; p=0.002), and baseline EAT-10 score (OR 1.1/point; p=<.0001). In posterior surgeries, only those in the upper cervical spine were found to have dysphagia at a peak rate of 47% at one month. The was a negative correlation between IV steroid use and severity of dysphagia in posterior surgery (B = -0.3, p=0.017). Lastly, dysphagia was associated with higher dissatisfaction rates (17% vs 13%, p=0.043) and increased rates of EQ-VAS decline compared to baseline (15% vs 11%, p=0.041).

Conclusion: This comprehensive study underscores the significant impact of dysphagia following cervical surgeries, particularly in anterior approaches. By documenting the varying rates and identifying predictive factors, the study provides valuable insights that can lead to improved surgical planning and patient management strategies. This research highlights the need for heightened awareness and preventive measures to mitigate the occurrence and impact of dysphagia in patients undergoing cervical spine surgeries, ultimately aiming to enhance patient outcomes.

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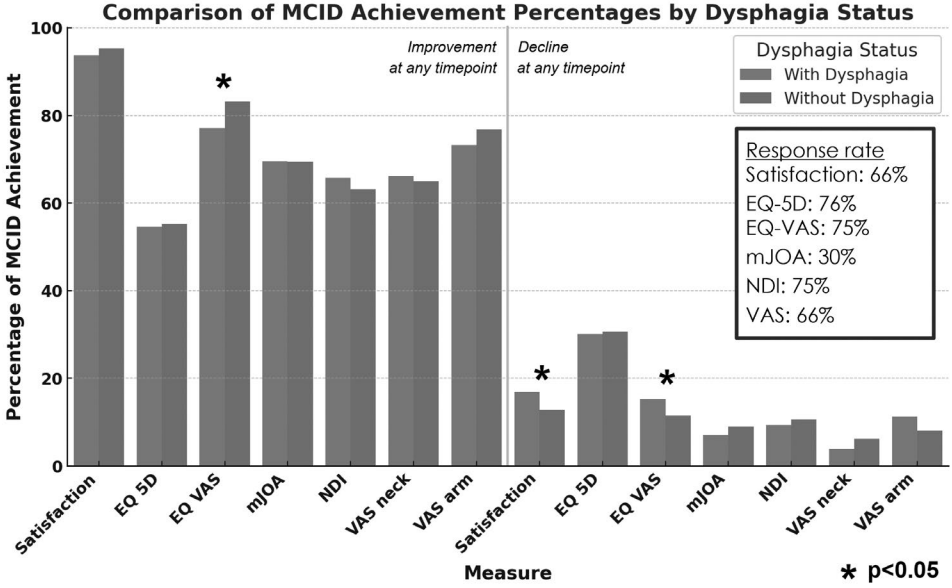

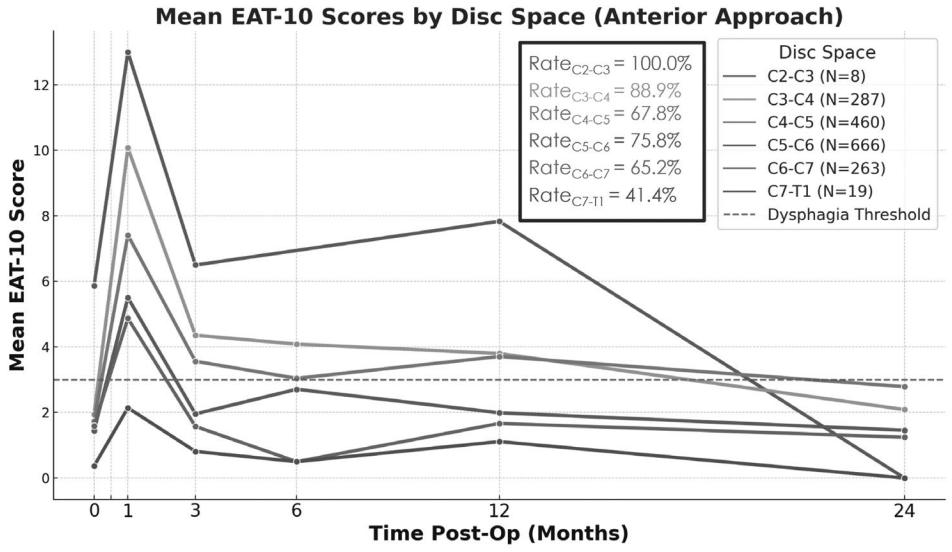

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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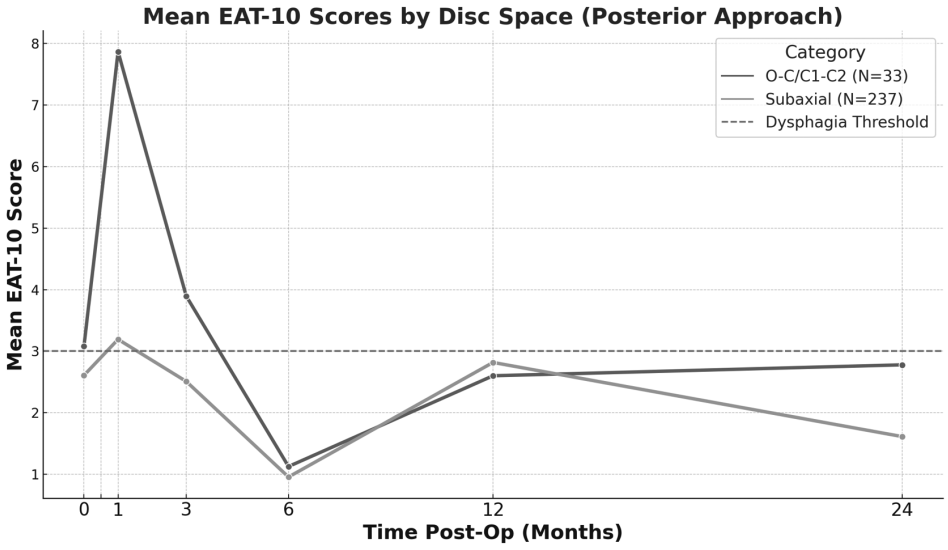

PAPER 28

Incidence, Risk Factors and Long-Term Consequence of Neurological Complication and Symptom Worsening After Surgery for Degenerative Cervical Myelopathy (DCM): Evidence for a Protective Effect of the Sodium-Glutamate Antagonist Rilusole

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Introduction: Degenerative cervical myelopathy (DCM) is the most common cause of nontraumatic spinal cord dysfunction among adults, significantly impacting patient's neurological and functional abilities. (1) Surgical intervention is recommended in moderate and severe DCM cases to decompress the spinal cord and stabilize the spine. (2) While surgery for DCM has demonstrated efficacy in improving outcomes and enhancing quality of life, it carries inherent risks, including the possibility of postoperative neurological complications. Despite advancements in surgical techniques, the incidence and risk factors associated with neurological worsening after surgery among DCM patients remains poorly understood. This study aims to investigate the occurrence and identify the clinical predictors of neurological complications following surgery, using data from a large multicenter, randomized trial.

Materials and Methods: Patients diagnosed with DCM and a modified Japanese Orthopaedic Association (mJOA) score of 8-14 were enrolled from sixteen North American centers as part of the prospective CSM-PROTECT trial between 2012 and 2017. (3) The primary outcome was postoperative neurological deterioration and symptom worsening, defined as the occurrence of postoperative C5 palsy, nerve root injury, worsening myelopathic symptoms, or the development of new numbness, neck, and shoulder pain. Patients were dichotomously categorized into groups with and without neurological complications. Functional and neurological outcomes were evaluated at one-year post-surgery and compared between groups using univariate paired statistics. Additionally, a multivariable logistic regression analysis adjusting for baseline differences was performed to determine significant predictors of postoperative neurological complications.

Results: Among the 290 patients enrolled in the CSM-PROTECT trial (mean age 57.95 years, 44.5% females, mean baseline mJOA =11.91), 117 patients (40.34%) experienced postoperative neurological complications following surgical decompression and/or fusion. Patients who did not experience neurological worsening were more likely to be non-frail (39.3% vs 23.1%, p=0.004), non-smokers (64.7% vs 52.1%, =0.032) and receiving riluzole therapy (54.9% vs 39.3%, p=0.009). The majority of patients who developed postoperative numbness, root injury, and pain fully recovered without residual symptoms at one year (60%, 38.10%, 47.17%, respectively). Long term functional and neurological outcomes did not significantly differ between patients with and without neurological deterioration (DmJOA p =0.235, DNurick p =0.643, DNeck pain NRS p =0.873, DArm pain NRS p =0.274, DSF-36 PCS p =0.639, DSF-36 MCS p =0.498). After adjusting for demographic variables, surgical approach, number of surgical level and symptom duration, significant predictors for neurological deterioration included the use of neuroprotective agent (OR: 0.58, CI 0.330-0.907, p=0.03), non-frailty (OR: 0.40, CI 0.210-0.733, p=0.004), and smoking (OR: 1.77, CI 1.033-2.851, p=0.026).

Conclusion: In this secondary analysis of a randomized DCM trial, the use of neuroprotective agent (i.e riluzole), non-frailty, and non-smoking status were associated with a reduced risk of

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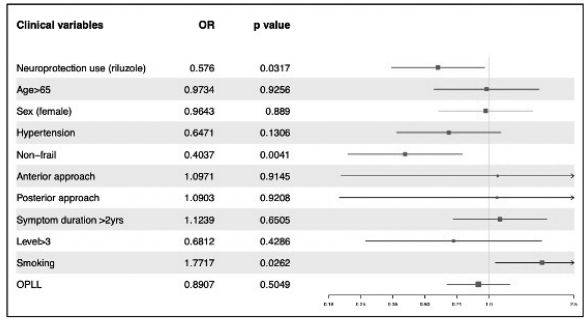
postoperative neurological deterioration and symptom worsening, independent of surgical approach. Addressing these modifiable risk factors preoperatively may have the potential to optimize outcomes in DCM patients undergoing surgical intervention.

Table 1. Incidence of neurological complications and symptom worsening with postoperative outcomes at one-year in the CSM-PROTECT trial cohort (n=290)

Neurological complication	Incidence		One-year outcome, n (%)		
	n	%	Complete recovery	Incomplete recovery	No recovery
Postoperative myelopathic symptoms	28	9.66%	8 (28.57%)	5 (17.86%)	10 (35.71%)
Numbness	15	5.17%	9 (60%)	1 (6.67%)	3 (20%)
Root injury	21	7.24%	8 (38.10%)	5 (23.81%)	6 (28.57%)
Postoperative pain	53	18.28%	25 (47.17%)	3 (5.66%)	21 (39.62%)
Total	117	40.34%	46 (39.32%)	14 (11.97%)	44 (37.61%)

Figure 1. Predictors of postoperative neurological complication and symptom worsening based on multivariable logistic regression



PAPER 29

Trends in Cervical Laminoplasty Incidence and Reimbursement in the United States from 2009-2019

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Emory University School of Medicine[1]

Introduction: With reported benefits of motion-preservation, lower revision rates [1], lower costs and lengths of stay [2], and overall potentially lower complication rates [3] than anterior or posterior cervical fusions, laminoplasty is an effective technique for cervical decompression. The purpose of this study was to leverage a large national database to explore more recent trends in laminoplasty utilization and reimbursement in the United States, in relation to several variables, including technique (i.e. with or without reconstruction/instrumentation), demographic, and geographic information.

Materials and Methods: This study utilized a large commercial insurance claims database (i.e. MarketScan) to estimate the total volume of laminoplasty procedures performed in the United States from 2009 to 2019. Current procedural terminology (CPT) codes were utilized to generate the sample, which was then analyzed by key variables including age, sex, geographic region, and technique (i.e. with or without reconstruction/instrumentation). Incidence rates were calculated to trend across years and assessed for change with the Cochran-Armitage trend test. Reimbursement data for laminoplasty adjusted for inflation was also generated from the database. Statistical analyses were conducted using R-Studio (PBC, Boston, MA). Statistical significance was set at $P<0.05$.

Results: The incidence of laminoplasty remained stable throughout the study period, ranging from 5.3 to 6.8 per 1,000,000 person-years (estimated total annual volume 944 to 1590 cases), with the Cochran-Armitage trend test demonstrating no significant change in volume over time (Figure 1). Laminoplasty volume was higher for older age groups: 15.4 per 1,000,000 person-years for 55-64 years of age and 20.9 per 1,000,000 person-years for 65+ years of age compared to 0.4 per 1,000,000 person-years for 0-17 years and 0.6 per 1,000,000 person-years for 18-34 years of age. The incidence values for laminoplasty without reconstruction were expectedly lower each year compared to those with instrumented reconstruction. Average (± standard deviation) reimbursements ranged from $1,843.89 (± $2,073.14) for Medicare with instrumentation to $2,310.35 (± $2,081.45) for commercial insurance with instrumentation. There was no statistically significant change in reimbursement for laminoplasty overall from 2009 to 2019 (Table 1).

Conclusion: Despite the purported benefits of motion-preservation, lower revision rates [1], lower costs and lengths of stay [2], and overall potentially lower complication rates [3] than its fusion counterparts, our study demonstrated that there was no significant change in laminoplasty incidence in the United States over the study period from 2009 to 2019. This supports similar findings by other studies of earlier time periods [4-7]. We discuss several factors that may be accounting for this trend, including including cultural inclinations, inconsistent surgical training in laminoplasty, or the perception that laminoplasty evidence is still evolving. Our study also found that this stagnation in laminoplasty usage coincided with no change in average annual reimbursement for laminoplasty from 2009 to 2019. Reimbursement incentive (i.e. higher payments) for fusion procedures in the United States may

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also be a contributing factor. Future studies should continue to track the nationwide trends in laminoplasty utilization, to explore the contributory financial, cultural, and educational factors, and to advocate appropriately.

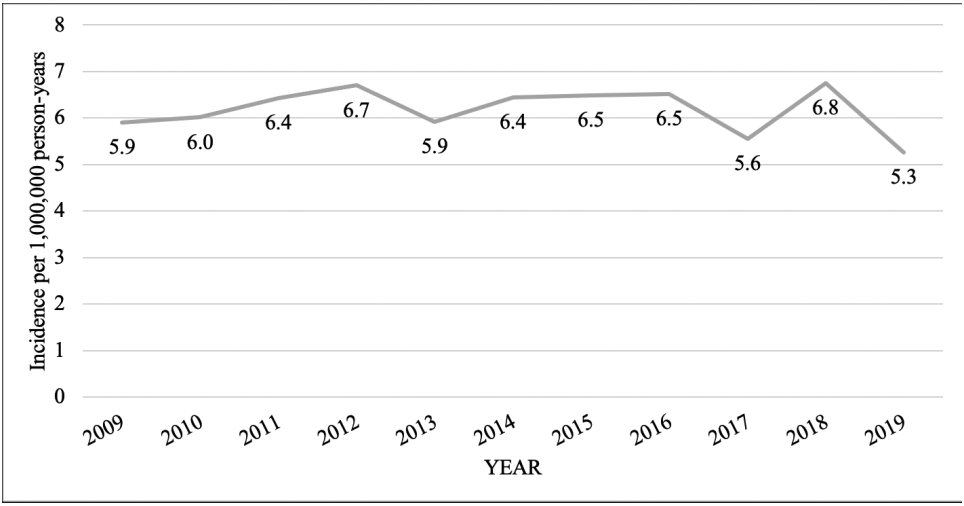

Table 1. Trends in Total Reimbursements for Cervical Laminoplasty from 2009 to 2019*

	2009			2019			
Procedure Category	**N**	**Average Reimbursement**	**SD****	**N**	**Average Reimbursement**	**SD**	**Percent (%) Change Reimbursement**
Cervical Laminoplasty w/o Reconstruction	37	$1,676.92	$1,606.52	11	$2,939.65	$2,619.66	75.30%
Cervical Laminoplasty with Reconstruction	236	$2,067.53	$1,598.26	86	$2,032.76	$2,250.37	-1.68%
Total	273	$2,014.59	$1,602.03	97	$2,135.6	$2,298.33	6.01%

*All Total Reimbursements adjusted for inflation to 2019 dollars
**SD = standard deviation
Using Student's t-tests, no statistical changes in reimbursement for cervical laminoplasty between 2009 and 2019

PAPER 30

Are Postoperative Neck Pain and Kyphotic Change After Laminoplasty Affected by Degree of Facet Joint Degeneration?

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Asan medical center, Orthopaedic surgery[1] Asan medical center[2] Inha University Hospital[3]

Introduction: Laminoplasty performed for cervical myelopathy inevitably injures neck musculature which increases possibility of neck pain and postoperative kyphosis. Previous studies have demonstrated association between laminoplasty and postoperative neck pain, and suggest preoperative severe neck pain as a relative contraindication for laminoplasty. Facet joint degeneration (FJD) could cause medial branch irritation which could lead to neck pain and is another factor that could contribute to postoperative neck pain. Furthermore, cervical lordosis is a prerequisite for laminoplasty since it achieves cord decompression by posterior shifting. However, relationship between postoperative neck pain or kyphosis after laminoplasty and FJD have not been clarified. Therefore, the present study was conducted to elucidate whether FJD affects postoperative neck pain or kyphotic change after laminoplasty.

Materials and Methods: One-hundred and twenty-six consecutive patients who underwent laminoplasty and were follow-up for more than 2-year were retrospectively reviewed. Degree of FJD was assessed on preoperative and postoperative 1-year CT images with 1-4 scale using previously reported grading system (Figure 1). Patients with moderate to severe neck pain at postoperative 2-year (neck pain visual analogue scale [VAS] ≥4, severe neck pain group) were compared with patients with mild or no neck pain (neck pain VAS<4, mild neck pain group). Furthermore, patients who experienced kyphotic change more 10 degrees of C2-C7 lordosis at postoperative 2-year (kyphotic change group) were compared with patients who did not suffer postoperative kyphotic change (non-kyphotic change group). Regression analyzes were performed to elucidate factors associated with postoperative neck pain and kyphotic change.

Results: Ninety-nine patients (78.6%) were included in the mild neck pain group, while remaining 27 patients (21.4%) were included in the severe neck pain group. Preoperative degree of FJD was significantly greater in the severe neck pain group (p=0.040), while cervical sagittal parameters and demographics did not demonstrate significant intergroup difference (Table 1). Correlation analysis demonstrated that preoperative FJD grade was significantly associated with neck pain VAS at postoperative 2-years (r=0.179, p=0.045). Furthermore, Multivariate logistic regression analysis showed that preoperative FJD grade associated with postoperative severe neck pain (p=0.046). Patient demographics, cervical sagittal parameter, and FJD grade did not demonstrate significant results when comparing non-kyphotic change group with kyphotic change group (Table 2). Moreover, FJD grade was not associated with postoperative cervical kyphosis in logistic regression analysis (p=0.769).

Conclusion: The present study showed that preoperative FJD is associated with postoperative neck pain after laminoplasty. Therefore, patients with pre-established FJD would be more likely to experience postoperative severe neck pain as demonstrated in this study. However, FJD was not associated with postoperative kyphosis after laminoplasty, and does not seem to affect cervical alignment aggravation. In conclusion, preoperative FJD was associated with postoperative neck pain after laminoplasty while it did not aggravate kyphotic change.

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Therefore, in cases when anterior approach and posterior approach could be both indicated, performing anterior approach would be preferred when preoperative severe FJD exists, since performing laminoplasty could aggravate postoperative neck pain.

Figure 1. Illustration of facet joint degeneration grade

Facet joint degeneration was categorized into four grades: Grade 1, representing a normal facet without degeneration; Grade 2, indicating degenerative changes such as joint space narrowing, cyst formation, and small osteophytes without joint hypertrophy; Grade 3, joint hypertrophy due to large osteophytes without fusion; Grade 4, bony fusion of the joint. Grading was conducted based on axial or sagittal slices of CT images. Measurements were taken from C2-3 to C7-T1 on both the right and left sides, and the average values were used.

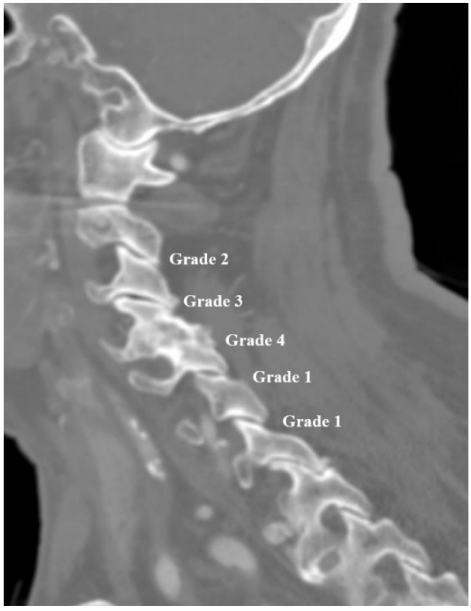

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Table 1. Comparisons between mild neck pain group and severe neck pain group

Variables	Mild neck pain group (VAS <4 , N=99)	Severe neck pain group (VAS ≥ 4 , N=27)	P-value
Patient characteristics			
Age	62.0±11.91	65.14±9.51	0.208
Sex (Male/Female)	77/22	20/7	0.685
Infection	4(4%)	0	0.288
Reoperation	0	1(4%)	0.055
Dural tear	0	0	
Neurologic deterioration	0	0	
Operated level	4.25	4.37	0.560
Preoperative clinical scores			
Neck pain (VAS)	2.54±2.39	2.91±2.12	0.346
Arm pain (VAS)	4.50±2.76	4.28±2.80	0.705
NDI score	24.13±16.95	28.37±16.91	0.405
JOA score	11.98±2.92	12.47±3.51	0.528
Preoperative radiologic parameters			
Anterolisthesis	15(15%)	3(11%)	0.595
K-line state(-)	2 (2%)	2 (7%)	0.157
C0-C2 lordosis	25.9 ± 8.73	27.59 ± 9.01	0.383
C2-C7 lordosis	16.29 ± 9.94	16.40 ± 13.51	0.961
C2 SVA	-20.39 ± 19.20	-18.37 ± 12.29	0.605
T1 Slope	24.37 ± 7.77	25.92 ± 10.63	0.399
K-line tilt	10.10 ± 7.62	10.00 ± 7.17	0.951
Cervical ROM	35.94 ± 14.49	32.03 ± 16.72	0.232
C2-C7 Extension capacity	9.76 ± 8.40	6.25 ± 8.73	0.059
C2-C7 flexion capacity	26.14 ± 12.77	25.77 ± 14.48	0.899
C7-SVA	-15.80 ± 41.68	-28.33 ± 42.57	0.171
Facet degeneration grade			
Pre-operative	1.63±0.46	1.85±0.50	0.040*
Post-operative 1-year	1.92±0.47	2.18±0.52	0.025*

VAS, visual analogue scale; FJD, facet joint degeneration; SVA, sagittal vertical axis; ROM, range of motion
*; statistically significant.

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Table 2. Comparison between non-kyphotic change group and kyphotic change group

Variables	Non-kyphotic change group (N=35)	Kyphotic change group (N=91)	P-value
Patient characteristics			
Age	62.34±8.04	62.80±12.58	0.841
Sex (Male/Female)	31/4	66/25	0.055
Infection	0	4(4.3%)	0.207
Reoperation	1(3%)	0	0.105
Dural tear	0	0	
Neurologic deterioration	0	0	
Operated level	4.25	4.28	0.882
Preoperative clinical scores			
Neck pain (VAS)	2.68±2.57	2.58±2.26	0.995
Arm pain (VAS)	4.34±2.78	4.50±2.77	0.820
NDI score	27.90±17.08	23.88±16.88	0.321
JOA score	12.38±3.08	12.00±3.07	0.571
Preoperative radiologic parameters			
Anterolisthesis	2(6%)	16(17%)	0.088
K-line state (-)	1(3%)	3(3%)	0.900
C0-C2 lordosis	25.11±8.89	26.72±8.75	0.359
C2-C7 lordosis	10.25±10.54	18.64±9.93	0.000*
C2 SVA	-21.8±13.69	-19.25±19.33	0.477
T1 Slope	22.57±7.70	25.52±8.60	0.078
K-line tilt	11.22±7.89	9.63±7.34	0.288
Cervical ROM	34.11±15.74	35.49±14.79	0.646
C2-C7 Extension capacity	13.57±9.57	7.26±7.49	0.000*
C2-C7 flexion capacity	20.54±14.45	28.18±11.96	0.003*
C7-SVA	-13.00±35.53	-20.60±44.26	0.365
Facet degeneration grade			
Pre-operative	1.72±0.476	1.66±0.488	0.578
Post-operative 1-year	1.85±0.39	2.02±0.51	0.076

VAS, visual analogue scale; FJD, facet joint degeneration; SVA, sagittal vertical axis; ROM, range of motion
*; statistically significant.

PAPER 31

Pre- and Intraoperative Factors Associated with Improvement of Neck Pain after Laminoplasty for the Treatment of Cervical Myelopathy

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Asan Medical Center[1]

Introduction: Laminoplasty offers advantages in treating cervical myelopathy, including suitability for long-segment cord compression, preserving neck motion, and low complication rates. However, it damages neck muscles and the cervical spine's posterior ligamentous complex, often worsening neck pain and lordosis loss. Preservation of muscle insertion at C2 and C7 prevents worsened neck pain, but factors predictive of neck pain improvement after laminoplasty remain unclear. This study aimed to elucidate factors associated with neck pain improvement post-laminoplasty.

Materials and Methods: We conducted a retrospective review of patients who underwent laminoplasty for degenerative cervical myelopathy. Patients with preoperative neck pain, as measured by the visual analogue scale (VAS) of ≥4, and those followed up for ≥1 year were included. Patients with a ≥50% improvement in neck pain VAS were classified as the improved group, while others were classified as the unimproved group. Radiographic factors including C2-C7 lordosis in neutral, flexion, and extension positions, C2-C7 range of motion (ROM), C2-C7 sagittal vertical axis, T1 slope, K-line tilt, and thoracic kyphosis were measured. Neck pain VAS, Neck Disability Index (NDI), and Japanese Orthopaedic Association (JOA) scores were assessed preoperatively and at the 1-year postoperative follow-up. Regression analysis was performed to identify factors associated with ≥50% neck pain improvement.

Results: A total of 88 patients were included, with 34 (38.6%) in the unimproved group and 54 (61.4%) in the improved group. Patients in the unimproved group more frequently underwent C3 laminectomy compared to the improved group (76.5% vs. 51.9%, p=0.026). C2-C7 lordosis in the extension position (improved, 28.2±7.6°; unimproved, 21.9±13.0°; p=0.006) and C2-C7 ROM (improved, 37.4±11.3°; unimproved, 31.0±17.9°; p=0.043) were significantly greater in the improved group than the unimproved group (Table 1). Multivariate logistic regression analysis demonstrated that C3 laminectomy decreased the likelihood of neck pain improvement (odds ratio, 0.285; p=0.018), while greater C2-C7 lordosis in the extension position increased the possibility of improvement (odds ratio, 1.057; p=0.048) (Table 2, table 3). Cut-off value of 20.5° was with sensitivity of 85.2% and specificity of 47.1% to predict improvement of neck pain after laminoplasty (Area under curve, 0.629; p=0.043).

Conclusion: In this study, 61.4% of patients with moderate preoperative neck pain (VAS ≥4) experienced more than a 50% improvement after laminoplasty, suggesting its feasibility for patients with neck pain. Additionally, two factors associated with neck pain improvement were identified: (1) undergoing C3 laminectomy; and (2) greater C2-C7 lordosis in the extension position. Injury to the semispinalis muscles is occasionally inevitable during C3 laminectomy procedures. Previous studies have suggested that preservation of semispinalis cervicis is not possible when the C2 interspinous angle is narrow. Therefore, careful consideration and potential modification of the surgical procedure are warranted when planning C3

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laminectomy. Furthermore, greater C2-C7 lordosis in the extension position may indicate better neck muscle power preoperatively, potentially providing greater capacity to resist exacerbation of neck pain after laminoplasty. Thus, patients with greater C2-C7 lordosis in extension, specifically >20.5°, may be considered good candidates for laminoplasty, even in the presence of preoperative neck pain.

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Table 1. Patient demographic, operative factors, and preoperative radiographic measurements

		Unimproved (n = 34)	Improved (n = 54)	P value
Patient demographic factors	Age	61.1±11.7	64.9±11.1	0.266
	Sex	28:6	36:18	0.142
	BMI	25.5±3.3	25.7±2.2	0.791
	HTN	22(64.7%)	26 (48.1%)	0.187
	DM	8 (23.5%)	14 (25.9%)	1.000
	Smoking	6 (17.6%)	8 (14.8%)	0.770
	Pathology			
	CSM	12 (35.3%)	26 (48.1%)	0.274
	OPLL	22 (64.7%)	28 (51.8%)	
	Follow-up period	18.7±2.4	20.4±3.2	0.341
Operative factors	Number of operated levels	4.5±1.0	4.3±0.9	0.291
	C2 dome laminectomy	8 (23.5%)	12 (22.2%)	1.000
	C3 laminectomy	26 (76.5%)	28 (51.9%)	0.026*
	C7 dome laminectomy	16 (47.1%)	24 (44.4%)	0.829
	Combined foraminotomy	24 (70.6%)	38 (64.8%)	1.000
Preoperative radiographic measurements	C2-C7 lordosis (neutral)	15.7±1.8	17.9±9.1	0.313
	C2-C7 lordosis (flexion)	-9.1±15.2	-9.2±9.7	0.951
	C2-C7 lordosis (extension)	21.9±13.0	28.2±7.6	0.006*
	C2-C7 range of motion	31.0±17.9	37.4±11.3	0.043*
	C2-C7 SVA	18.9±9.5	16.3±11.2	0.251
	T1 slope	25.0±10.0	23.5±5.6	0.362
	K-line tilt	10.1±6.0	9.7±6.3	0.795
	Thoracic kyphosis	-16.6±9.7	-9.2±18.4	0.046*

BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; CSM, cervical spondylotic myelopathy; OPLL, ossification of posterior longitudinal ligament; SVA, sagittal vertical axis

Continuous variables were analyzed using Student's t-test

Categorical variables were analyzed using chi-square test

* $P<0.005$

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Table 2. Patient reported outcome measures

		Unimproved	Improved	P value
Neck pain VAS	Preoperative	4.3±1.1	4.8±1.7	0.097
	Postoperative 1 year	4.5±1.9	0.7±0.6	<0.001*
	Improvement rate	-17.6±58.5	85.1±15.2	<0.001*
NDI	Preoperative	29.1±15.7	30.3±16.3	0.731
	Postoperative 1 year	20.7±11.3	14.1±15.0	0.041*
	Improvement rate	27.5±45.5	64.9±45.6	<0.001*
JOA	Preoperative	11.4±3.6	11.5±2.8	0.884
	Postoperative 1 year	12.5±3.4	13.5±2.8	0.157
	Recovery ratio	29.4±51.4	32.6±60.3	0.836

VAS, visual analogue scale; NDI, neck disability index; JOA, Japanese Orthopedic Association

All variables were analyzed using Student's t-test

* P<0.005

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Table 3. Logistic regression analysis demonstrating factors associated with neck pain improvement of ≥ 50%

	Univariate analysis			Multivariate analysis		
	Odds ratio	95% confidence interval	P value	Odds ratio	95% confidence interval	P value
Demographic factors						
Age	1.022	0.984 - 1.063	0.263			
Sex	2.333	0.818 - 6.652	0.113			
BMI	1.022	0.871 - 1.200	0.789			
HTN	0.506	0.209 - 1.225	0.131			
DM	1.137	0.419 - 3.090	0.800			
Smoking	0.812	0.255 - 2.584	0.724			
Pathology	0.587	0.243 - 1.420	0.238			
Operative factors						
Number of operated levels	0.766	0.468 - 1.254	0.289			
C2 dome laminectomy	0.929	0.335 - 2.574	0.887			
C3 laminectomy	0.331	0.127 - 0.861	0.023*	0.285	0.101 - 0.805	0.018*
C7 dome laminectomy	0.900	0.380 - 2.129	0.810			
Combined foraminotomy	0.990	0.386 - 2.536	0.983			
Radiographic factors						
C2-C7 lordosis (neutral)	1.024	0.978 - 1.071	0.310			
C2-C7 lordosis (flexion)	0.999	0.964 - 1.035	0.950			
C2-C7 lordosis (extension)	1.064	1.015 - 1.115	0.010*	1.057	1.003 - 1.117	0.048*
C2-C7 range of motion	1.032	1.000 - 1.064	0.048*	1.012	0.973 - 1.052	0.562
C2-C7 SVA	1.024	0.983 - 1.067	0.250			
T1 slope	0.974	0.920 - 1.031	0.361			
K-line tilt	0.991	0.924 - 1.062	0.792			
Thoracic kyphosis	1.035	0.999 - 1.072	0.056			
Patient reported outcome measures						
Neck pain VAS	1.297	0.951 - 1.767	0.100			
NDI	1.005	0.978 - 1.032	0.728			
JOA score	1.011	0.877 - 1.165	0.882			

BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; SVA, sagittal vertical axis; VAS, visual analogue scale; NDI, neck disability index; JOA, Japanese Orthopedic Association

* P<0.005

PAPER 32

Efficacy of Laminectomy and Fusion Versus Laminoplasty for the Treatment of K-line Negative Cervical Ossification of the Posterior Longitudinal Ligament

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Introduction: The K-line serves as an indicator for selecting surgical approach for treatment of cervical myelopathy, encompassing both cervical sagittal alignment and the canal-occupying ratio of the ossification of the posterior longitudinal ligament (OPLL). A preoperative K-line negative state is typically deemed unfavorable for posterior decompression. Nevertheless, procedures such as laminoplasty and laminectomy with fusion (LF) offer advantages for selected patients with extensive OPLL involvement. Yet, it remains unclear whether laminoplasty or LF yields superior outcomes. Therefore, this study aimed to compare outcomes between laminoplasty and LF for treating K-line negative OPLL cervical myelopathy.

Materials and Methods: This retrospective study reviewed 41 patients undergoing laminoplasty or LF for cervical myelopathy due to K-line negative OPLL, with follow-up exceeding one year. Radiographic measurements included C2–C7 lordosis, C2–C7 sagittal vertical axis (SVA), cervical range of motion, and modified K-line (mK-line) interval. Patient-reported outcome measures included neck pain visual analogue scale (VAS), arm pain VAS, neck disability index (NDI), and Japanese Orthopedic Association (JOA) scores. Results were compared between the laminoplasty group and LF group.

Results: Of the 41 patients, 18 (43.9%) underwent LF, and 23 (56.1%) underwent laminoplasty. The LF group had significantly more levels operated ($p<0.001$) and OPLL involvement ($p<0.001$) compared to the laminoplasty group. All patients were initially assessed as K-line negative preoperatively. Postoperative radiograph revealed that 61.1% of LF patients became K-line positive, compared to 21.7% of laminoplasty patients ($p=0.022$). The mK-line interval significantly improved in the LF group ($p<0.001$) but not in the laminoplasty group ($p=0.187$) after surgery. Although postoperative neck pain VAS, arm pain VAS, and NDI scores did not differ significantly between the two groups, the LF group exhibited a significantly higher JOA recovery rate at final follow-up (70.0±30.2%) compared to the laminoplasty group (29.7±50.5%, $p=0.011$).

Conclusion: This study suggests that LF is associated with a higher probability of converting a K-line negative state to positive one, improving the mK-line interval, and achieving a higher JOA recovery rate post-surgery compared to laminoplasty. While laminoplasty may reduce operation levels since it primarily focuses on decompression rather than altering cervical alignment, LF could aim to increase the mK-line interval and modify the K-line state through screw-rod constructs, albeit requiring a longer level operation. The choice of surgical method should carefully weigh the benefits of achieving an increased mK-line interval with LF for better neurological recovery against the costs of a more extensive operation. In summary, LF may convert K-line negative state into positive state, enabling better posterior cord shift, thereby facilitating improved neurological recovery. LF could be considered a preferable surgical option over laminoplasty for selected K-line negative OPLL patients, given these advantages.

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Table 1. Patient baseline characteristics

	LF (n = 18)	Laminoplasty (n = 23)	P value
Age	58.72±11.56	60.3±10.44	0.648
Sex (Female)	10 (56%)	7 (30%)	0.105
BMI	26.73±3.69	27.39±2.58	0.507
DM	5 (27.8%)	9 (39.1%)	0.447
Smoking	6 (33.3%)	10 (43.5%)	0.509
Number of OPLL levels involved	3.89±1.13	2.59±0.91	<0.001*
Number of levels operated	4.94±0.80	3.52±1.12	<0.001*
Follow-up period (m)	12.16±7.01	12.15±8.35	0.547

LF, laminectomy, and fusion; OPLL, ossification of the posterior longitudinal ligament

* $p<0.05$

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Table 2. Radiographic measurements

		LF (n = 18)	Laminoplasty (n = 23)	P value
C2–C7 lordosis	Preoperative	6.46±9.09	10.25±5.64	0.133
	Postop 3m	8.61±9.41	5.739±8.17	0.303
	Postop 1y	7.32±9.15	4.89±7.74	0.362
C2–C7 SVA	Preoperative	25.63±11.94	22.32±10.63	0.355
	Postop 3m	29.19±12.09	23.46±11.92	0.137
	Postop 1y	28.87±13.91	23.89±12.81	0.241
C2–C7 ROM	Preoperative	28.02±8.69	34.42±12.30	0.069
	Postop 3m	19.78±14.64	26.13±11.05	0.122
	Postop 1y	16.89±11.60	26.76±11.01	0.008
K-line conversion from (-) to (+)		11 (61.1%)	5 (21.7%)	0.022*
mK-line interval	Preoperative	0.978±1.615	0.037±1.576	0.068
	Postoperative	2.903±1.303	0.511±1.656	<0.001*

SVA, sagittal vertical axis; ROM, cervical range of motion; mK-line, modified K-line

* $p<0.05$

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Table 3. Patient reported outcome measures

		LF (n = 18)	Laminoplasty (n = 23)	P value
Neck pain VAS	Preoperative	5.50±2.68	3.65±2.59	0.031*
	Postop 3m	3.06±2.84	1.91±1.98	0.140
	Postop 1y	3.50±2.04	1.78±2.22	0.015*
Arm pain VAS	Preoperative	5.67±3.24	5.09±2.31	0.508
	Postop 3m	4.35±2.62	2.70±2.46	0.047
	Postop 1y	4.06±2.88	3.04±3.10	0.291
NDI	Preoperative	17.69±7.92	12.39±5.39	0.023
	Postop 3m	15.69±6.89	10.05±5.49	0.009
	Postop 1y	13.94±6.31	7.43±5.60	0.001*
JOA score	Preoperative	12.42±2.84	12.22±3.26	0.859
	Postop 3m	13.11±3.38	13.39±2.89	0.776
	Postop 1y	13.78±2.84	12.83±3.28	0.335
JOA recovery rate		70.05±30.18	29.73±50.50	0.011*

VAS, visual analogue scale; NDI, neck disability index; JOA, Japanese Orthopedic Association; JOA recovery rate, (postoperative JOA score – preoperative JOA score)/(17 – preoperative JOA score) x 100 (%)

* $p<0.05$

PAPER 33

Open-Door Cervical Laminoplasty with Skip-Fixation can be Considered as a Cost-Effective Procedure: 2-year Outcomes of 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 patients with DCM [(2, 3)]. However, it is imperative to investigate methods that curtail health expenses without decreasing surgical outcomes. We postulated that surgical outcomes of cervical open-door laminoplasty with every other expanded laminar fixation (skip-fixation, Figure 1A) might not be inferior to that with all expanded laminar fixation (all-fixation, Figure 1B). This study aimed to test the non-inferiority of laminoplasty with skip-fixation in myelopathy improvement at 2 years postoperatively than that with all-fixation. Additionally, we compared other radiographic and surgical 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 412 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 (Figure 2). The primary outcome was the difference in the two-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, two-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, 162 completed the trial after 2 years (skip-fixation, n=84; all-fixation, n=78; follow-up rate, 76.1 %). The difference in the JOA score after two years was -0.110 (95% confidence interval: -0.811-0.530), 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 ($p=0.032$, Mann-Whitney U test), better improvement in the VAS score for neck pain, NDI, and EQ-5D-5L score ($p=0.011$, $p=0.046$, $p=0.041$ respectively, mixed-effect model) than those with all-fixation. There were no significant differences in radiographic outcomes, including C2-7 angle and range of motion, between the surgical types.

Conclusion: 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 at 2-year postoperatively. Additionally, laminoplasty with skip-fixation can potentially improve neck pain and QOL more than that with all-fixation. Because skip fixation requires half the number of implants compared to all-fixation, laminoplasty with skip-fixation can reduce medical costs. 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.

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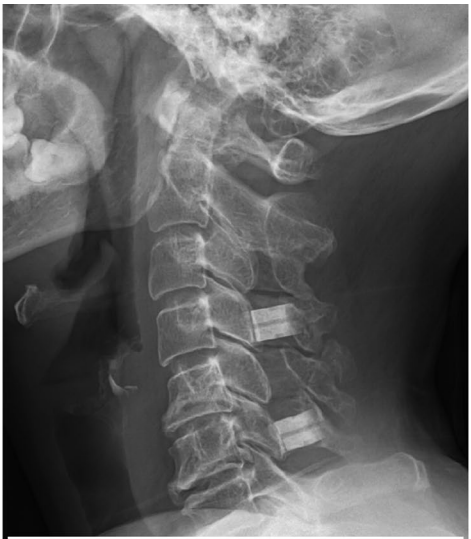
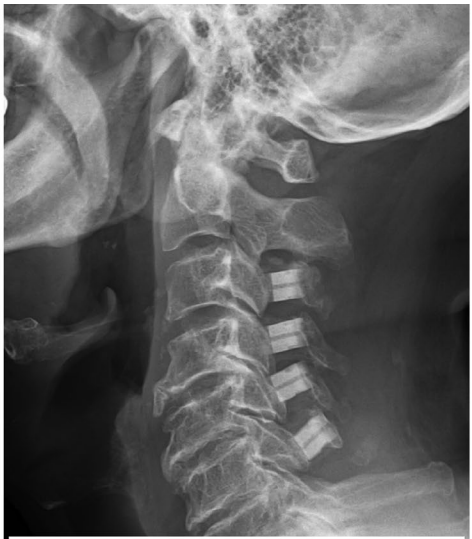


1A: C3-C6 open door laminoplsty with “skip fixation”



1B: C3-C6 open door laminoplsty with “all fixation”

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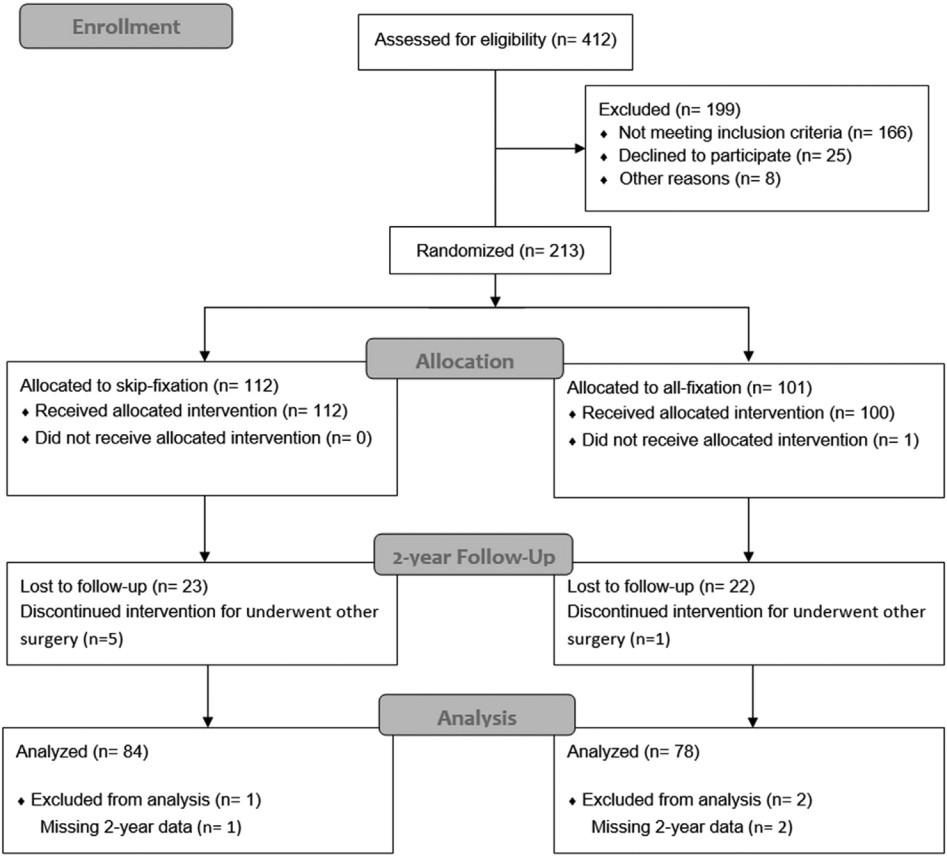

PAPER 34

Evaluation of Radiographically Relevant Heterotopic Ossification Following One-Level Cervical Disc Arthroplasty with a PEEK-on-Ceramic Artificial Disc

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Introduction: Cervical total disc replacement (TDR) has gained acceptance as a treatment for disc degeneration related to symptoms of radiculopathy with/without myelopathy. While favorable clinical outcomes of cervical TDR have consistently been reported, the development of heterotopic ossification (HO) at the index level has been reported. This study evaluated the impact of HO on 5-year clinical outcomes, as well as possible baseline characteristics that may potentially be associated with development of HO.

Materials and Methods: This study compared baseline characteristics and 5-year results of one-level PEEK-on-ceramic cervical TDR for patients with radiographically relevant HO to those without. Data were obtained from the prospective Food and Drug Administration (FDA) Investigational Device Exemption (IDE) trial for the Simplify cervical disc.

The study included 150 patients enrolled in the study and 121 with radiographic data available at 5-year follow-up. Of these 121 patients, 23 (19%) had radiographically relevant HO at 5 years. All patients were treated for one-level cervical disc degeneration with symptoms of radiculopathy and/or myelopathy.

Clinical outcome was based on the Neck Disability Index (NDI), visual analog scale (VAS) assessing neck and arm pain, neurologic status, adverse event (AE) rate, and reoperation rate.

Baseline variables and mean 60-month outcomes for patients who developed radiographically relevant HO (defined as grade 3 or 4 on the McAfee/Mehren[1,2] scale, which are considered motion-restricting) were compared to those who did not (grades 0, 1, 2). All radiographic assessments were evaluated by an independent lab specializing in image assessment.

Results: The group with radiographically relevant HO had a greater average disc height (3.5mm vs. 3.2mm; p=0.034), greater posterior disc height (3.3mm vs. 2.9mm; p=0.020), less global ROM (29.0° vs. 35.0°; p=0.020), and less spondylolisthesis (0.5mm vs. 1.1mm; p=0.003) at baseline. There were no statistically significant differences seen for the other baseline variables reviewed (age, sex, race, BMI, index level ROM, disc angle, and translation).

Of the 60-month clinical outcomes reviewed, no statistically significant differences were noted based on HO status, including mean NDI (p=0.240), mean VAS neck and arm pain (p=0.613), and reoperation rate (p=0.098). No statistically significant differences in neurologic status (p=0.257) or overall AE rate (p=0.705) were seen based on HO grade. All 23 patients with radiographically relevant HO at 60 months had either improved or stable neurologic status as compared to baseline.

Conclusion: This study found that patients treated with PEEK-on-ceramic TDR at one level, who developed radiographically relevant HO at 5-year follow-up, demonstrated clinical

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outcomes comparable to those of patients without radiographically relevant HO. Review of baseline variables revealed that patients who developed radiographically relevant HO at 5 years tended to have greater posterior and average disc heights, less global ROM, and less spondylolisthesis at baseline. These results provide additional information to clinicians regarding the clinical impact of HO and provides further support that HO is a radiographic finding and not a clinical finding.

PAPER 35

Impact of CDR and ACDF on the Global Spinal Alignment in Degenerative Spinal Disorder

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Introduction: Cervical disc replacement (CDR) has emerged as a viable alternative to anterior cervical discectomy and fusion (ACDF). While previous studies have detailed changes in cervical alignment, segmental motion, and biomechanical stress at the index level following ACDF and CDR, few have focused on its impact on global spinal alignment. [1-4] This study aims to compare global alignment changes between patients undergoing CDR and ACDF.

Materials and Methods: A total of 110 patients undergoing ACDF or CDR were assessed for preoperative global spine alignment using EOS imaging. Exclusions included patients with hybrid constructs, previous lumbar fusion surgery, and cervical deformity. Alignment parameters included C2-7 lordosis (CL), C2-7 sagittal vertical axis (cSVA), T1 slope (T1s), thoracic kyphosis (TK), pelvic tilt (PT), sacral slope (SS), pelvic incidence (PI), lumbar lordosis (LL), and the mismatch between PI and LL (PI-LL). Radiological assessments were repeated at 2, 6, 12, and 24 weeks postoperatively. Using inverse probability treatment weighting (IPTW) by propensity score, changes in global spinal alignment were compared via a linear mixed model. Additionally, correlation analysis examined alignment changes from preoperative to the 6-week postoperative timepoint.

Results: Of the 110 initially screened patients, 102 (56 ACDF, 46 CDR) were included. The CDR group was significantly younger (mean age: ACDF, 60.3 vs. CDR, 42.3 years), had a lower rate of comorbidities (CCI0: ACDF, 41.1% vs. CDR, 67.4%; P=0.014), and more single-level surgeries (ACDF, 37.5% vs. CDR, 73.9%; P=0.001). In terms of spinopelvic alignment, CDR patients showed significantly greater LL (56.3° vs. 50.0°; P=0.007) and smaller PI-LL mismatch (-6.8° vs. 0.6°; P=0.001). The IPTW-adjusted cohorts were well-matched, showing no significant differences in background including age, comorbidity, surgical levels, and preoperative initial spinal alignment. Linear mixed model analysis revealed no significant changes in cervical alignment in either group. However, significant differences were observed in changes over time in pelvic incidence (P=0.015) and lumbar lordosis (P=0.012). Final PI levels at 24 weeks were similar between groups (ACDF 47. 6° vs. CDR 48.0°; P=0.938), indicating that although the progression of PI differed, final PI measurements converged. Meanwhile, in the ACDF group, a decline in LL led to a notably lower final LL (42.1° vs. CDR 57.5°). Correlation analysis within the ACDF group showed moderate correlations with between ΔT1s and ΔTK (r=0.53), ΔTK and ΔLL (r=0.55), and ΔLL and ΔPI (r=0.41).

Conclusion: This matched cohort study highlights a significant postoperative decline in lumbar lordosis exclusively in the ACDF group, contrasting with stability in the CDR group. These findings underscore the impact of ACDF on global spinal alignment and illustrate CDR's capacity to mitigate unintended reciprocal changes in lumbar alignment, potentially driven

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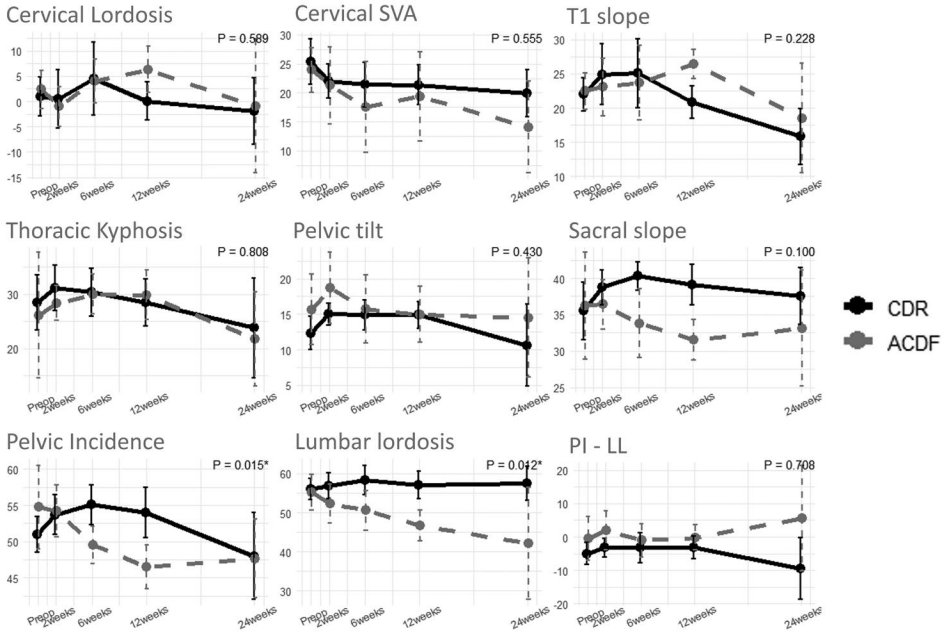
by alterations in T1 slope. CDR may be more beneficial in patients with normal global spinal alignment compared to ACDF which potentially affect normal spinal alignment.



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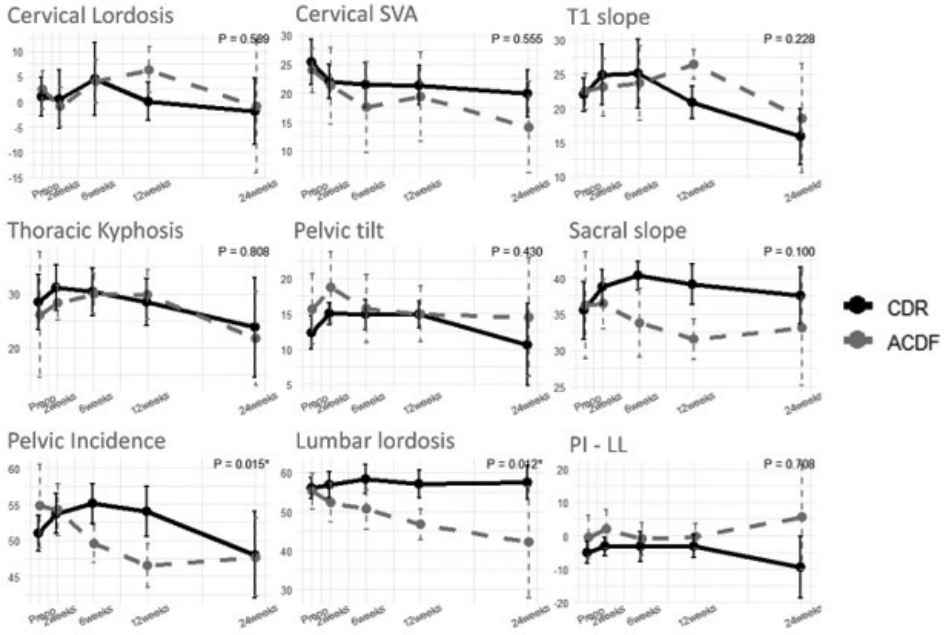

PAPER 36

Influence of Cervical Disc Prosthesis Design and 1- Versus 2-level Disc Replacements on ROM Outcomes 2-year Post Disc Arthroplasty in 835 Patients from 4 US IDE Clinical Trials

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Introduction: The functional goals of cervical disc arthroplasty (CDA) are to restore enough range of motion (ROM) to reduce the risk of accelerated adjacent segment degeneration but also limit excessive motion to obtain a biomechanically stable index segment. This motion range is termed "Physiological" and is defined as 5-16 degrees based on published scientific evidence. We analyzed prospectively-collected radiographic data from 1-level and 2-level US IDE clinical trials of CDA to investigate the influence of (a) the prosthesis design and (b) 1- versus 2-level implantations on the proportions of reconstructed segments that achieved physiological ROM (5-16 degrees), hypomobility (ROM: 0–4 degrees), and hypermobility (ROM≥17 degrees).

Materials and Methods: We analyzed 24-month post-CDA Flexion-Extension (FE) ROM data from IDE studies of artificial disc prostheses approved for both one-and two-level use. Of these, only the Prestige and Mobi-C trials had published histograms presenting how many implanted levels in a clinical trial yielded postoperative ROM of a given degree, rounded to the nearest degree. In total, 835 patients participated in the one- and 2-level US FDA-IDE clinical trials: 416 patients participated in 2-level trials and 419 patients participated in the 1-level clinical trials of the same 2 prostheses (Table 1). These data allowed calculation of the proportion of implanted levels with postoperative FE-ROM in the following motion-ranges: Hypomobile [0–4 degrees], Physiological [5–16 degrees], and Hypermobile [≥17 degrees]. The 5-degree lower bound of the physiological range was based on clinical data showing significantly reduced incidence of progressive radiographic adjacent-level degeneration in patients with 5 degrees or greater ROM after CDA. The 16-degree upper bound was based on laboratory data from 102 cervical spines with mild-to-moderate degeneration. The upper ROM bound was derived from the sum of the standard deviation and average range of motion of 133 segments.

Results: 1-Level Implantation: On average, 65.0% of the 419 patients in the 1-level clinical trials yielded FE-ROM in the physiological range (Table 1). 25% of the implanted levels yielded hypomobility, while 11% yielded hypermobility.

2-Level Implantation: 67% of 830 implanted levels from 416 patients in the 2-level clinical trials yielded physiological ROM (Table 1). 26% of the implanted levels yielded hypomobility, whereas 7% yielded hypermobility. Two-level arthroplasty did not significantly increase or decrease the likelihood of achieving post-CDA motion in the physiological range when compared to 1-level CDA.

Average ROM at 2 years post-CDA (Table 2): 25% of the implanted segments moved on average 2.4 degrees (hypomobility), two-thirds moved on average 9.5 degrees (physiological mobility), and about 10% had an average ROM of nearly 20 degrees (hypermobility).

Conclusion: On average, two-thirds of the patients demonstrated a return to physiological ROM at 2 years following both one- and 2-level constructs. Prestige disc had significantly fewer patients exhibiting hypermobility at 24 months in both single-level and two-level cases than

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the Mobi-C disc (P<.05). In 2-level Mobi-C constructs, it was the superior level of the construct where most of that hypermobility occurred. Prosthesis design influenced the motion outcome in both 1- and 2-level constructs.

Motion Range 24-month Postop	Mobi-C : 2-level		Mobi-C 1-level	Prestige : 2-level		Prestige 1-level	All Prostheses	
	Superior n (%)	Inferior n (%)	n (%)	Superior n (%)	Inferior n (%)	n (%)	N	Proportion
0 - 4 deg	41 (19%)	61 (28%)	26 (17%)	55 (28%)	57 (29%)	77 (29%)	317	25% ± 5.7%
5 - 16 deg	142 (65%)	140 (64%)	96 (62%)	138 (70%)	134 (68%)	175 (66%)	825	66% ± 3.1%
≥ 17 deg	37 (17%)	17 (8%)	33 (21%)	3 (2%)	5 (3%)	12 (5%)	107	9% ± 8.1%
Sub Total	**220 (100%)**	**218 (100%)**	**155 (100%)**	**196 (100%)**	**196 (100%)**	**264 (100%)**	**1249**	**100.0%**

Table 2. Average ROM of implanted segments falling into the 3 motion ranges: hypomobile (0-4 deg), physiological (5-16 deg), hypermobile (17 & higher).

Motion Range 24-month Postop	Mobi-C: 2-level		Mobi-C 1-level	Prestige: 2-level		Prestige 1-level	All Prostheses	
	Superior Mean ± SD	Inferior Mean ± SD	Mean ± SD	Superior Mean ± SD	Inferior Mean ± SD	Mean ± SD	N	Proportion
0 - 4 deg	2.3±1.5	2.2±1.3	2±1.6	2.6±0.9	2.7±1.1	2.5±1	317	25.4%
5 - 16 deg	9.9±3.2	9.5±3.1	9.8±3.3	9.1±2.8	8.9±3	9.7±3.2	825	66.1%
≥ 17 deg	19.8±2.9	19.3±2.1	20.4±3.4	18.3±1.2	19.4±1.8	19.2±2.7	107	8.6%
Sub Total	10.1±5.9	8.2±5.3	10.7±6.5	7.4±4	7.4±4.3	8±4.9	1249	100.0%

PAPER 37

Surgeons' Views on Cervical Disc Arthroplasty for Elite Athletes: A Survey of Cervical Spine Research Society Members

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Introduction: Cervical disc arthroplasty (CDA) is increasingly offered to elite athletes as a surgical treatment option for degenerative cervical conditions. The purpose of this study was to characterize spine surgeons' opinions regarding treating elite athletes with CDA and assess current recommendations regarding time to return to training and competition.

Materials and Methods: Surveys were designed to obtain spine surgeons' opinions regarding treating elite athletes with CDA, including sport-specific considerations and current recommendations regarding time to return to training and competition. The surveys were administered to members of the Cervical Spine Research Society (CSRS) via their membership listserv. Survey data was analyzed to identify patterns in recommendations for the use of CDA as a treatment option for elite athletes.

Results: Sixty surgeons responded to the CSRS survey (Table 1). Surgeons generally agreed that elite athletes include NCAA Division I, Olympic, and professional athletes, although some surgeons also indicated these results should extend to other athletic levels. Surgeons generally agreed (93.3%) that being an elite athlete was not a contraindication to a single-level disc arthroplasty. Some surgeons (73.3%) did report at least one absolute contraindication for CDA in elite athletes: cord signal changes, congenital stenosis, prior bilateral posterior cervical foraminotomy with ≥ 50% of joint remaining, prior unilateral posterior cervical foraminotomy with ≥ 50% of joint remaining, and adjacent level degeneration above or below a healed, single-level ACDF. Surgeons were no more likely to consider two-level CDA compared to hybrid CDA and ACDF procedures (p=0.192), with 53.3% and 66.7% surgeons, respectively, reporting they would consider two-level CDA or hybrid procedures for elite athletes.

All surgeons were of the opinion that there were sports to which elite athletes could safely return after a one-level CDA. Most (≥95.0%) agreed golf, cycling, and tennis were safe, whereas only 35.0 – 36.7% surgeons thought boxing/MMA, Greco-Roman/freestyle wrestling, and professional wrestling would be safe (Figure 1). There were some differences in opinions regarding the safety of returning to specific sports based on how many CDAs surgeons perform per year – compared against surgeons who perform 1-10 or 11-20 CDAs per year, significantly more surgeons who perform ≥21 CDAs per year reported that athletes could safely return to ice hockey (p=0.009), lacrosse (p=0.013), Formula 1 (F1) and NASCAR (p=0.049), and American football (p=0.049) after a one-level CDA. Surgeons provided time to clearance for different levels of training, and the most frequent recommendations were two weeks for light cardio training, six weeks for full cardio training and strength training, and twelve weeks for sport-specific training and full competition (Figure 2).

Most surgeons (85.0%) thought the perception of CDAs in elite athletes is changing, with top reasons including increased surgeon adoption and comfort with CDA and the growing number of athletes receiving CDA and returning to competition. That being said, 46.7% surgeons were

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still concerned about either litigation or criticism in offering CDA to elite athletes.

Conclusion: CDA as a treatment option for elite athletes has increased in recent years, and many surgeons feel quite comfortable with allowing return to most sports after a one-level CDA.

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Descriptive Variable	n	% of sample
Specialty		
... Orthopedic Surgery	51	85%
... Neurosurgery	9	15%
Practice Type		
... Academic	36	60%
... Private	19	32%
... Employed	5	8%
Board Certified		
... Yes	53	88%
... No	7	12%
Completed Fellowship		
... Yes	57	95%
... No	3	5%
Years in Practice		
... 0 - 3	14	23%
... 4 - 10	9	23%
... 11 - 20	15	25%
... > 20	22	37%
Number of CDAs performed per year		
... 0	6	10%
... 1-10	24	40%
... 11-20	16	27%
... 21-50	12	20%
... 51-100	2	3%

Table 1: Descriptive variables of the sample of surgeons who completed the survey regarding opinions on use of CDA as a treatment option for elite athletes. All surgeons who were not yet board certified were within 0-3 years in practice.

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

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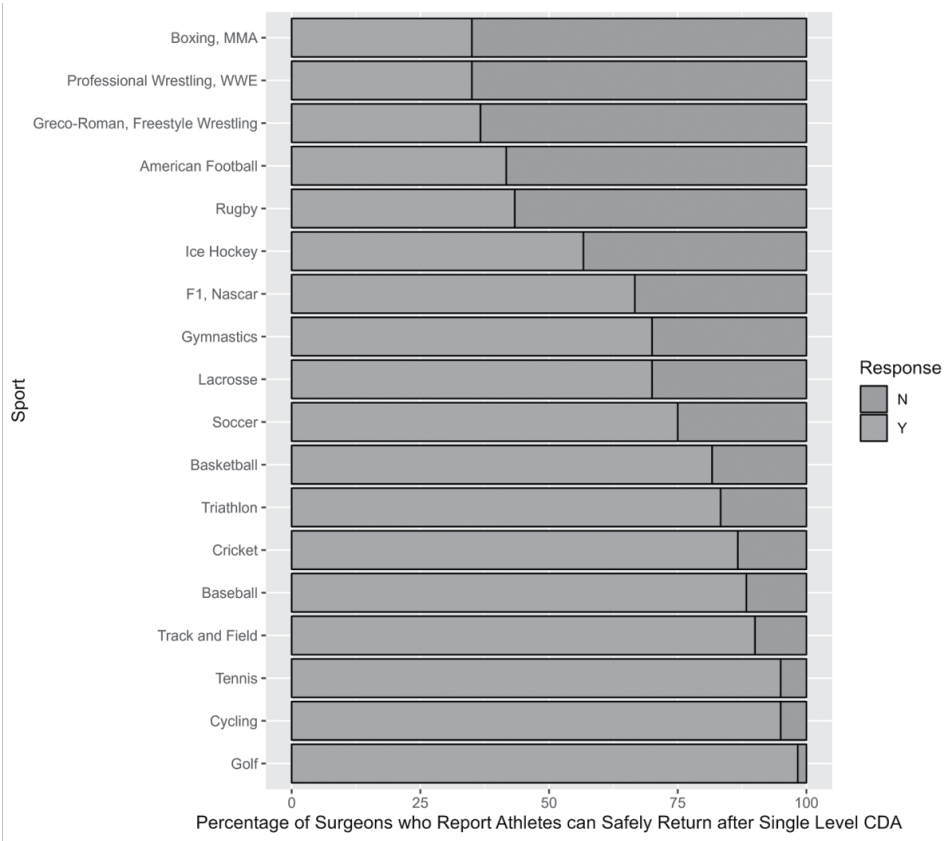

Figure 1: Surgeons reported if athletes could safely could return to various sports after single level cervical disc arthroplasty (CDA), and the percentage of surgeons who responded yes (Y, blue) and no (N, red) for each sport is displayed here. There was more concern with returning to high contact sports like wrestling and fighting sports, American football, and rugby. Lower contact sports like track and field, tennis, cycling, and golf had much higher support for return to play. Most sports had >50% support for potential safe return to play after a single level CDA.

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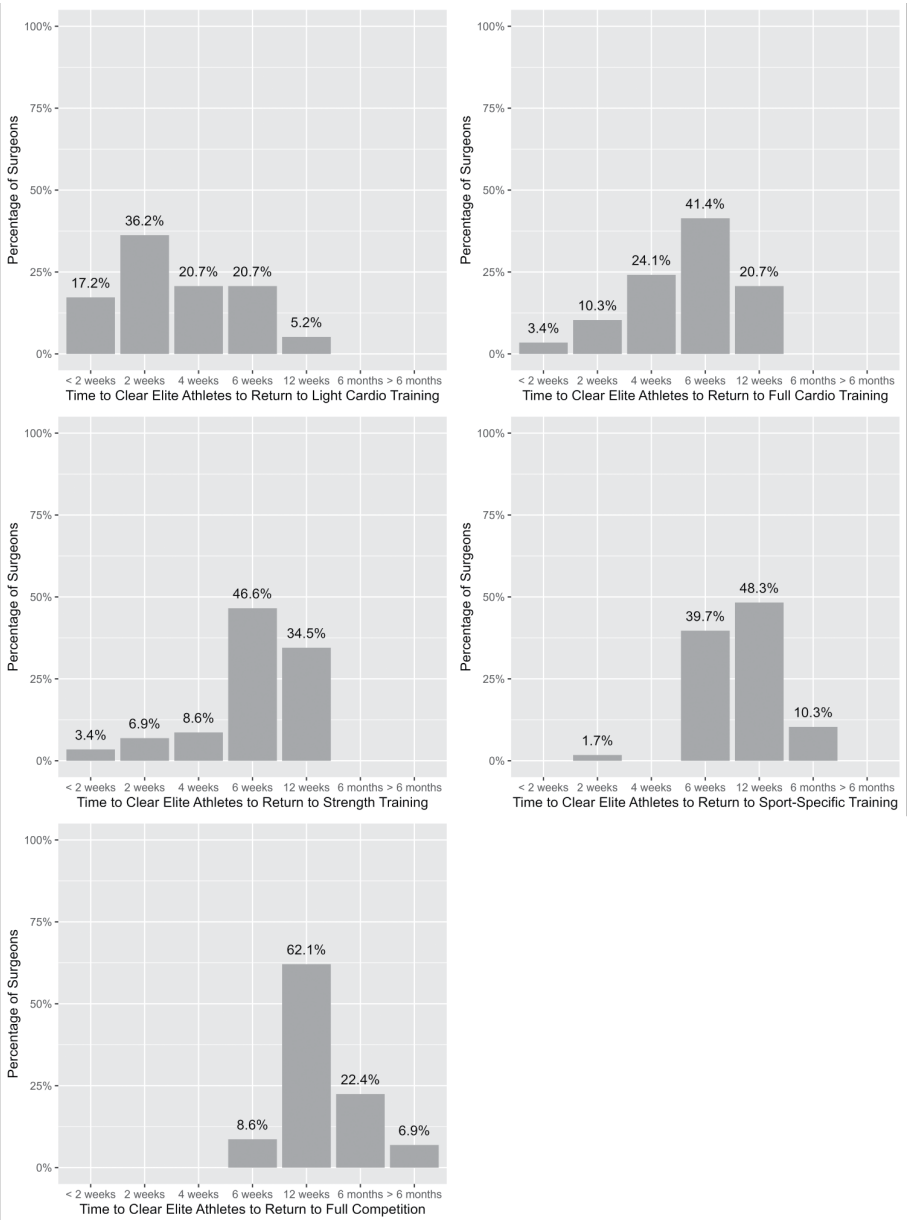

Figure 2: Overall recommendations regarding time to clearance for light and full training for elite athletes after single level cervical disc arthroplasty (CDA). Most surgeons recommended 2 weeks for light cardio training, 6 weeks for full cardio training, 6 weeks for strength training, 12 weeks for sport-specific training, and 12 weeks for full competition.

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

PAPER 38

Does Baseline Severity of Arm Pain Affect PROMIS Scores Following Cervical Disc Replacement?

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Introduction: Severe baseline arm pain secondary to cervical radiculopathy may be associated with worse postoperative patient-reported outcomes. However, the influence of preoperative arm pain on Patient-Reported Outcome Measurement Information System (PROMIS) outcomes following cervical disc replacement (CDR) has not been evaluated. The purpose of this study is to investigate the influence of baseline arm pain severity in PROMIS outcomes following CDR.

Materials and Methods: Patients undergoing elective CDR for herniated nucleus pulposus with Visual Analog Scale (VAS)-Arm and PROMIS scores were included. Cohorts were created based on an established cut-off for severe pain (VAS-Arm ≥7.5—Severe Arm Pain; VAS-Arm <7.5—Milder Arm Pain). PROMIS scores included Physical Function (PF), Anxiety, (A), Sleep Disturbance (SD), and Pain Interference (PI). Legacy measures included VAS-Neck, Neck Disability Index (NDI), and 9-Item Patient Health Questionnaire (PHQ-9). Outcome scores were collected at baseline and up to two years postoperatively, with an average follow-up period of 9.9±7.0 months. Improvements in scores by six weeks and final follow-up and rates of minimum clinically important difference (MCID) were calculated. Multivariate linear and logistic regression were employed to determine differences in scores and MCID achievement rates between groups.

Results: Thirty-two patients were in the Severe Arm Pain group, and 92 were in the Milder Pain group. There were more females in the Severe Arm Pain group (p=0.011). Controlling for differences in gender between groups, at baseline, the Severe Arm Pain group reported worse NDI, VAS-N, PHQ-9, PROMIS-PF, and PROMIS-SD (p≤0.023, all). However, there were no differences in any reported scores at six weeks postoperatively (p≥0.054, all). At final follow-up, VAS-N, PROMIS-PI, and PROMIS-A were significantly worse in the Severe Arm Pain group (p≤0.047, all). VAS-N, VAS-A, NDI, and PHQ-9 improved by greater magnitudes for the Severe Arm Pain group by six weeks and final follow-up (p≤0.046, all). MCID achievement was higher for VAS-A and PHQ-9 for the Severe Arm Pain group.

Conclusion: While patient-reported sleep disturbance and physical function were worse at baseline for patients with worse preoperative arm pain, these differences did not persist by six weeks postoperatively. By final follow-up, anxiety and pain interference were worse in patients with worse arm pain. However, there were no differences in the amount of improvement in PROMIS outcomes postoperatively, or in rates of clinically meaningful change in any PROMIS domain we studied.

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Table 1. Patient Demographics

Characteristic	Total (n=124)	Milder Arm Pain (n=92)	Severe Arm Pain (n=32)	*p-value
Age (mean±SD, years)	47.4±10.3	47.6±10.9	46.8±8.4	0.709
Female Gender	40.3% (50)	33.7% (31)	59.4% (19)	**0.011**
BMI (mean ± SD, kg/m^2)	29.0±5.3	29.2±5.1	28.5±5.7	0.510
Ethnicity				0.695
Asian	3.3% (4)	3.3% (3)	3.2% (1)	
Black	5.8% (7)	4.4% (4)	9.7% (3)	
Hispanic	9.1% (11)	7.8% (7)	12.9% (4)	
White	79.3% (96)	82.2% (74)	71.0% (22)	
Other	2.5% (3)	2.2% (2)	3.2% (1)	
Comorbidities				
Smoker	8.9% (11)	9.9% (9)	6.3% (2)	0.535
Hypertension	16.3% (20)	14.3% (13)	21.9% (7)	0.317
Diabetes	4.8% (6)	5.4% (5)	3.1% (1)	0.600
ASA Classification				0.656
ASA<2	86.7% (104)	87.5% (77)	84.4% (27)	
ASA≥2	13.3% (16)	12.5% (11)	15.6% (5)	
Insurance Type				0.922
Medicare/Medicaid	2.4% (3)	2.2% (2)	3.1% (1)	
Worker's Comp	20.3% (25)	19.8% (18)	21.9% (7)	
Private	77.2% (95)	78.0% (71)	75.0% (24)	

BMI = Body Mass Index; ASA = American Society of Anesthesiologists; SD = Standard Deviations; Workers' Comp = workers' compensation

*p-value calculated using chi-square tests for categorical variables or independent samples t-test for continuous variables

Boldface indicates significance

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Table 2. Patient-reported outcomes measures

	Total (n=124)	Milder Arm Pain (n=92)	Severe Arm Pain (n=32)	*p-value
Pre-Op				
NDI	34.9±17.8	30.8±16.1	47.1±17.4	**<0.001**
VAS-N	6.1±2.3	5.3±2.1	8.3±1.2	**<0.001**
VAS-A	5.5±2.6	4.5±2.2	8.4±0.8	—
PHQ-9	6.3±5.6	5.5±5.3	8.5±5.8	**0.023**
PROMIS-PF	40.3±7.2	41.2±7.2	37.6±6.3	**0.023**
PROMIS-PI	61.3±8.6	60.6±8.3	63.6±9.8	0.265
PROMIS-SD	59.9±9.5	58.7±9.7	64.2±7.5	**0.018**
PROMIS-A	54.4±10.1	54.0±10.4	55.7±9.4	0.633
6-week Post-Op				
NDI	21.5±17.5	19.4±15.7	27.1±20.9	0.078
VAS-N	2.6±2.4	2.3±1.9	3.5±3.2	0.054
VAS-A	2.0±2.5	1.8±2.3	2.6±3.0	0.208
PHQ-9	4.2±4.9	4.1±4.5	4.7±6.1	0.589
PROMIS-PF	45.3±8.2	45.7±8.4	44.1±7.7	0.382
PROMIS-PI	54.9±9.7	53.9±9.0	58.6±11.6	0.166
PROMIS-SD	51.3±12.4	50.5±11.3	53.9±16.3	0.444
PROMIS-A	49.3±11.5	49.6±11.4	48.2±12.2	0.718
Final Post-Op				
NDI	15.9±16.4	14.6±15.4	19.5±18.7	0.192
VAS-N	2.2±2.4	1.9±2.0	3.2±3.0	**0.011**
VAS-A	2.0±2.7	1.9±2.6	2.4±2.9	0.354
PHQ-9	3.6±4.7	3.3±4.4	4.3±5.6	0.471
PROMIS-PF	49.7±9.7	50.6±9.5	47.1±10.0	0.099
PROMIS-PI	47.9±9.6	46.5±8.9	51.8±10.6	**0.017**
PROMIS-SD	49.0±12.8	47.7±11.7	53.1±15.5	0.176
PROMIS-A	45.7±10.5	44.2±10.4	49.8±10.5	**0.047**

*p-value calculated using multivariable linear regression and logistic regression accounting for gender

VAS-N=Visual Analog Scale-Neck Pain; VAS-A=VAS-Arm Pain; NDI=Neck Disability Index (ODI); PHQ-9=9-Item Patient Health Questionnaire; PROMIS=Patient-Reported Outcome Measure Information System; PI=Pain Interference; PF=Physical Function; SD=Sleep Disturbance; A=Anxiety; MCID=Minimal Clinically Important Difference

Bolding denotes statistical significance ($p < 0.05$)

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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Table 3. Changes in patient-reported outcomes and minimum clinically important difference

	Total (n=124)	Milder Arm Pain (n=92)	Severe Arm Pain (n=32)	*p-value
Δ Pre-Op to 6-week Post-Op				
NDI	11.9±15.0	9.2±14.8	19.1±12.9	**0.003**
VAS-N	3.1±2.7	2.5±2.3	4.9±3.1	**<0.001**
VAS-A	3.3±3.2	2.4±2.9	5.8±3.0	**<0.001**
PHQ-9	1.6±4.7	1.0±4.1	3.7±5.9	**<0.046**
PROMIS-PF	4.6±8.2	4.1±8.9	6.2±8.2	0.395
PROMIS-PI	6.0±10.2	6.9±9.3	2.8±13.0	0.267
PROMIS-SD	8.1±11.8	7.3±11.4	11.2±12.6	0.352
PROMIS-A	5.8±8.7	5.4±9.3	7.3±6.3	0.527
Δ Pre-Op to Final Post-Op				
NDI	19.1±17.0	15.9±15.2	28.0±18.6	**0.001**
VAS-N	3.7±3.0	3.2±2.7	5.0±3.1	**0.004**
VAS-A	3.3±3.5	2.3±3.3	6.0±2.7	**<0.001**
PHQ-9	2.6±4.5	2.0±3.9	4.2±5.7	**0.034**
PROMIS-PF	4.6±8.2	4.1±8.9	6.2±5.2	0.395
PROMIS-PI	11.4±12.4	12.4±12.0	7.9±13.9	0.246
PROMIS-SD	11.6±12.9	11.1±13.1	13.5±12.5	0.456
PROMIS-A	7.9±12.1	9.2±12.3	3.4±12.1	0.147
MCID Achievement				
NDI	76.9% (83)	72.2% (57)	89.7% (26)	0.066
VAS-N	73.4% (80)	68.4% (54)	86.7% (26)	0.056
VAS-A	45.4% (49)	32.1% (25)	80.0% (24)	**<0.001**
PHQ-9	42.1% (45)	33.8% (26)	63.3% (19)	**0.018**
PROMIS-PI	69.4% (43)	68.8% (33)	71.4% (10)	0.875
PROMIS-PF	78.2% (86)	75.6% (62)	85.7% (24)	0.363
PROMIS-SD	82.8% (48)	82.2% (37)	84.6% (11)	0.941
PROMIS-A	61.7% (37)	58.7% (27)	71.4% (10)	0.359

*p-value calculated using multivariable linear regression and logistic regression accounting for gender

VAS-N=Visual Analog Scale-Neck Pain; VAS-A=VAS-Arm Pain; NDI=Neck Disability Index (ODI); PHQ-9=9-Item Patient Health Questionnaire; PROMIS=Patient-Reported Outcome Measure Information System; PI=Pain Interference; PF=Physical Function; SD=Sleep Disturbance; A=Anxiety; MCID=Minimal Clinically Important Difference

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 medical device he or she wishes to use in clinical practice.

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Cervical Disc Replacement Can Improve Neck Pain Similarly to Anterior Cervical Discectomy and Fusion in Patients with Prominent Neck Pain: Propensity Score Matching Analysis with Overlap Weighting

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Introduction: Anterior cervical discectomy and fusion (ACDF) has been considered as a preferred treatment for neck pain, yet recent studies suggest cervical disc replacement (CDR) may offer favorable outcomes. [1, 2] Despite this, direct comparisons of ACDF and CDR focusing on patients predominantly suffering from neck pain remain debatable due to different patient backgrounds between the two surgical methods and the relative contraindications for CDR. [3] This study aims to delineate the clinical outcomes between ACDF and CDR in a cohort of patients with neck pain more severe than arm pain, matched for background characteristics.

Materials and Methods: This retrospective study included patients with prominent neck pain (VAS neck ≥ VAS arm) undergoing ACDF or CDR. Patient-reported outcome and measures (PROMs) were collected at preoperative, ≤ 3 months postoperative, and ≥1-year postoperative timepoint. Achievement rate of Minimal Clinically Important Differences (MCID) for each PROM, including Neck Disability Index (NDI), VAS neck, VAS arm, Short Form-12 physical component (SF-12PC), and mental component (SF-12MC). Standard mean differences (SMD) were utilized to evaluate background variations between the groups, categorizing small, moderate, and large differences as 0.2, 0.5, and 0.8, respectively. Propensity score matching with overlap weighting was applied to ensure comparable baseline characteristics, followed by univariate analysis to compare the outcomes between the matched groups.

Results: The study encompassed 295 patients with marked preoperative neck pain undergoing either 1- or 2-level CDR or ACDF (CDR: 107; ACDF: 188). Initially, the ACDF group was older and had higher BMI, greater comorbidity, and a higher prevalence of disc degenerative disease (DDD) compared to the CDR group (SMD: age, 1.27; BMI, 0.31; CCI, 0.87; DDD, 0.42; all P<0.05). Preoperative NDI and VAS neck were lower in the ACDF group (NDI, 35.7 vs. 39.8, SMD=0.21; VAS neck, 5.4 vs 6.2, SMD=0.29). Using overlap weighting by propensity scores derived from variables including age, BMI, comorbidity, DDD, T1 slope, and preoperative NDI, a well-balanced cohort were achieved (Figure; all SMD<0.10). Between the matched cohort with a mean age of 47.6 years, NDI at ≤3months time point was lower in the CDR group (ACDF, 34.6 vs. CDR, 29.0, P=0.037), although other PROMs were similar between the groups (ACDF vs. CDR: VAS neck, 3.8 vs. 3.4, P=0.28; VAS arm, 2.1 vs. 2.0, P=0.78; SF-12PC, 36.4 vs. 37.3, P=0.34; SF-12MC, 48.4 vs. 50.2, P=0.26). PROMs at ≥1-year timepoint and MCID comparisons across all PROMs were similar between the groups.

Conclusion: In a well-matched cohort, CDR and ACDF demonstrated similar clinical outcomes with the exception of early postoperative disability, where CDR showed a more rapid improvement in neck pain-related disability up to three months postoperatively. Thus, CDR might be a viable alternative to ACDF for patients with predominant neck pain, offering faster

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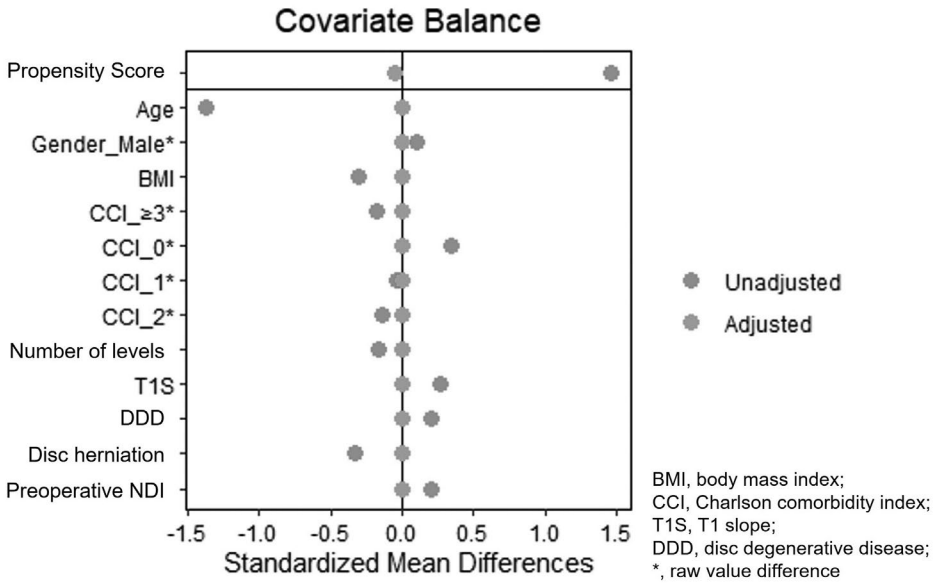
initial recovery and motion preservation in this specific population.



BMI, body mass index;
CCI, Charlson comorbidity index;
T1S, T1 slope;
DDD, disc degenerative disease;
*, raw value difference

PAPER 40

Disc to Disc: Early Results of the Multi-center, Prospective, Randomized Clinical Investigational Device Exemption Trial comparing a novel Total Disc Replacement (TDR) to an approved TDR control at two contiguous levels of the Cervical Spine.

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Introduction: Previous Investigational Device Exemption (IDE) clinical trials for the treatment of Symptomatic Cervical Disc Disease (SCDD) at two contiguous levels have compared Total Disc Replacement (cTDR) to Anterior Cervical Discectomy and Fusion (ACDF). These trials have shown superiority of cTDR to ACDF with regards to lower reoperation rates, improvement in Neck Disability Index (NDI), and lower incidence of Adjacent Segment Degeneration (ASD). As cTDR becomes a more established surgical option, the focus has shifted to understanding the performance of different motion sparing technology mechanisms of action (MOA).

Materials and Methods: As part of a prospective, randomized, multi-center, controlled IDE clinical trial, 35 sites enrolled 433 patients that met the inclusion/exclusion criteria. Under Institutional Review Board approval, patients were consented and randomized in a 2:1 (investigational: control) ratio. If randomized to investigational, surgeons were permitted to intra-operatively choose the endplate configuration based on patient anatomy. All patients were seen for follow-up at 6 weeks, 3 months, 6 months, 12 months, 18 months (phone call only), and 24 months. Patient-reported outcome measures and radiographs were collected at each in-office follow up. The study design was a non-inferiority design. Based on an adaptive Bayesian model, the first analysis of the data can be reported at 50% of subjects reaching 24 month follow-up. The primary endpoint was composite clinical success (CCS) at 24 months where a patient must be a success in all 4 criteria, defined as: ≥ 15 point improvement in Neck Disability Index (NDI) Score (out of 100) in subjects at 24 months compared with baseline, maintenance or improvement in neurological status at 24 months compared to baseline, no secondary surgical interventions at the index levels, and absence of major device-related adverse events. Secondary endpoints such as Visual Analog Score (VAS) neck pain, VAS arm pain, VAS Hoarseness, Nurick Scale, and Short-Form-12 (SF-12) and Dysphagia Handicap Index (DHI) were collected at each in-office time point.

Results: At 24 months, the CCS was achieved in 88.2% of the investigational compared to 86.8% of the control group (95% confidence interval: -7.5% to 11.1%; $p = 0.994$) confirming non-inferiority. There was no major device-related adverse events in the investigational group and 1 event in the control group. There was a higher incidence of secondary surgical interventions in the control compared to investigational, however not statistically different. NDI showed statistically significant improvement from pre-operative (investigational: 58.8±15.8: control 57.2±15.9) to 24 month (investigational: 14.2±16.7: control 14.5±15.9) in both groups but no difference between treatments. NDI success was achieved in 95.3% of the investigational patients and 94.2% of the control patients and was not statistically different between groups ($p > 0.99$). All secondary endpoints consistently showed similar improvement from baseline for both groups but none of the measures showed a statistically significant difference between treatments.

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Conclusion: This is the first randomized study comparing two cervical disc designs with different MOA. At 24 months, both designs were found safe and effective at two levels. Further, cTDR is consistently a successful surgical option for the treatment of SCDD.

PAPER 41

Reason for Revision Surgery after Cervical Disc Arthroplasty Based on Medical Device Reports Maintained by the United States Food and Drug Administration

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Introduction: Cervical disc arthroplasty (CDA) was established in the last two decades as a motion-sparing alternative to anterior cervical discectomy and fusion (ACDF) for degenerative cervical disease, achieving comparable patient-reported and clinical outcomes. Many unique CDA device designs are available, with distinct outcomes and complications identified. Despite these differences in device design and performance, there is a paucity of data on distinct modes of failure of CDA implants. A previous report identified a range of complications based on reports from the Drug Administration's Manufacturer and User Facility Device Experience (MAUDE) database until 2020, showing variability for each device. However, to date, there has been little data regarding the reason CDA devices have been reported to require revision surgery. To date, literature on complications associated with revision surgery for CDA is limited, mainly comparing CDA to fusion instead of comparing different CDA models.

Materials and Methods: The MAUDE database was queried for data from January 2005 to September 2023. All the reported complication entries for the nine FDA-approved CDA devices were analyzed. The full-text entries of all complications were individually analyzed, reported, and grouped depending on the revision surgery performed. For each revision case, the device used, the associated complication, the time until revision, and the type of revision surgery were collected.

Results: In summary, 1,347 entries were analyzed from the MAUDE database, with the highest number of reports made to the database in 2018 (218). A total of 678 cases reported revision surgery for nine different CDA models: Mobi-C (239), M6 (167), Prodisc-C (88), Prestige (60), PCM (44), Bryan (35), Secure (23), Simplify (21) and Discover (1). The top three complications associated with CDA revision were implant migration (23.5%), neck pain (15.5%), and heterotopic ossification (6.6%). The top complication per device was migration for Mobi-C (26.4%), Prodisc-C (21.3%), Prestige (24.6%), PCM (84.1%), Bryan (48.6%), Secure (30.4%) and Discover (100%). For M6 the most common complications associated with revision surgery were osteolysis (18.6%) and neck pain (18.6%). Neck pain (23.8%) was the most common for the Simplify device.

Conclusion: The MAUDE database highlights complications related to revision cases for CDA, which may not receive sufficient emphasis in existing published studies and can vary depending on the device. Nevertheless, the primary complications linked to CDA revision consistently include implant migration, neck pain, and heterotopic ossification.

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Table 1 Grouping different CDA designs based on implant material combination.

MATERIAL CONCEPT	Metal-on-Metal (MoM)	Metal-on-Polyethylene (MoP)	Metal-on-Ceramic (MoC)	Viscoelastic (VC)
	Prestige	ProDisc-C	Simplify	Bryan
		Mobi-C		M6
		Secure-C		
		PCM		
		Discover		
Total= 478	**N=45**	**N=309**	**N=10**	**N=114**

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

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Table 2 Complications associated with revision surgery for non-constrained devices.

NON-CONSTRAINED (n=296)	Complications associated with revision surgery	Nr. (% of revision cases for non-constrained models)
	Migration	84 (28.4%)
	Osteolysis	39 (13.2%)
	Implant breakage over time	32 (10.8%)
	Heterotopic ossification	28 (9.5%)
	Segmental Instability	25 (8.4%)
	Subsidence	20 (6.8%)
	Malpositioning	19 (6.4%)
	Severe patient injury during insertion	13 (4.4%)
	Traumatic dislocation	12 (4.1%)
	Device malfunction	9 (3.0%)
	Wrong size	7 (2.4%)
	Allergy	5 (1.7%)
	ASD	3 (1.0%)

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Table 3 Complications associated with revision surgery for semi-constrained devices.

SEMI-CONSTRAINED (n=140)	Complications associated with revision surgery	Nr. (% of revision cases for semi-constrained models)
	Migration	43 (30.7%)
	Subsidence	21 (15.0%)
	Heterotopic ossification	18 (12.9%)
	ASD	15 (10.7%)
	Malpositioning	14 (10.0 %)
	Osteolysis	6 (4.3%)
	Segmental instability	6 (4.3%)
	Implant breakage over time	4 (2.9%)
	Traumatic dislocation	4 (2.9%)
	Allergy	4 (2.9%)
	Wrong size	3 (2.1%)
	Severe patient injury during insertion	2 (1.4%)
	Device malfunction	0 (0.0%)

PAPER 42

Preoperative Selective Nerve Root Injections Do Not Increase Risk of Postoperative Infection After Anterior Cervical Decompression and Fusion

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Introduction: Although postoperative infection is uncommon following anterior cervical decompression and fusion (ACDF), previous studies have reported that patients who received a cervical epidural steroid injection (CESI) within 3 months before ACDF had significantly increased odds of developing a postoperative infection.[1] However, there is a lack of evidence regarding the effect of preoperative selective nerve root injections (SNRIs) on risk of postoperative infection following ACDF.

Materials and Methods: 3,116 patients who underwent ACDF at a single institution from 2018 to 2023 were identified. Patients undergoing surgery for trauma, tumor, or infection were excluded, as were patients undergoing revision surgery or surgery via combined anterior-posterior approach. Demographic and operative data were collected via retrospective chart review. Patients who received an SNRI preoperatively were identified using appropriate CPT codes. Postoperative surgical site infections were identified using appropriate ICD-10 codes and CPT codes for irrigation and debridement. Patients were grouped based on timing of SNRI prior to surgery: <30 days, 30-90 days, 90-180 days, and >180 days. Categorical data were compared using Fisher's exact and Chi-squared tests and quantitative data were compared using unpaired t-tests. Significance was defined as $p<0.05$.

Results: Of 3,116 patients who met inclusion criteria, 714 patients (23%) received an SNRI preoperatively. There were no significant differences in demographics including sex, race, age at surgery, or smoking status between patients who received an SNRI preoperatively and those who did not. Patients who received an SNRI preoperatively underwent surgery on significantly fewer levels ($p<0.01$) and had shorter operative duration (85 minutes vs 92 minutes respectively, $p<0.01$) compared to those who did not receive an SNRI preoperatively. 205 patients (29%) received an SNRI <30 days prior to surgery, 339 (47%) between 30-90 days, 106 (15%) between 90-180 days, and 64 (9%) >180 days. Two patients developed postoperative infections, one who received an SNRI preoperatively (27 days prior to surgery) and one who did not. Overall rate of postoperative infection following ACDF was 0.064%, which is in line with published literature. [2] There was no significant difference in rate of postoperative infection between patients who received an SNRI preoperatively and those who did not (0.14% and 0.042% respectively, $p=0.41$).

Conclusion: Preoperative SNRIs have been shown to be predictive of surgical outcomes for both cervical and lumbar radiculopathy, even in patients with equivocal or multilevel MRI findings.[3,4] There is currently no evidence regarding the effect of preoperative SNRIs on risk of postoperative infection following ACDF. While previous studies have reported increased risk of postoperative infection in patients who received a CESI within 3 months before ACDF, our results demonstrate no increased risk of postoperative infection in patients who receive an SNRI prior to ACDF. With literature supporting the utility of preoperative SNRIs and a significant portion of patients undergoing ACDF receiving an SNRI preoperatively, this finding may guide decision making and patient counseling regarding SNRIs in patients with cervical radiculopathy who may be candidates for ACDF.

PAPER 43

Prognostic Value of Onodera's Prognostic Nutritional Index (OPNI) in Predicting Postoperative Complications in Cervical Spine Surgery

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Introduction: The prevalence of readmissions after cervical spinal surgeries has been reported to be between 5.4% and 10%, with complication rates of up to 19%. Onodera's Prognostic Nutritional Index (OPNI) is a measure of preoperative nutritional status and has been previously used to predict postoperative complications in patients undergoing gastrointestinal surgery. Subsequent studies have confirmed its prognostic value across other surgical subspecialties. To date, there is no consensus on the optimal nutritional marker in cervical spine patients and the relationship between OPNI and postoperative complications following cervical spine surgery is unclear. This study aims to explore the utility of preoperative OPNI as a predictor of postoperative complications.

Materials and Methods: Retrospective review was conducted of spine surgical cases performed by multiple surgeons at a Level 1 Trauma Center. All cases were identified by CPT codes for procedures performed on the cervical spine at the center from January 2017 to March 2023. Patients were excluded if they did not have the required lab values, serum albumin and total lymphocyte count, for OPNI calculation within 90 days preoperatively. Patient demographics, surgical characteristics, and clinical outcomes within the window were collected and compared between the groups. The data was then sorted by spinal region and a subset of the database including only cervical spine surgeries was analyzed. Multivariate regression modeling measured the effect of OPNI or the likelihood of a complication occurring within the 90-day postoperative period. Alpha was set to $p<0.05$.

Results: A total of 1964 patients and 2122 cases were identified. Of the 626 patients that met inclusion criteria noted above, a subset of 295 patients was identified for surgery involving the cervical spine. 233 patients underwent spine surgery for non-traumatic indications (52.2% degenerative, 6.78% tumor, 6.44% infection, 2.03% scoliosis) and 62 patients underwent surgery for traumatic indications. A stepwise multivariate regression analysis demonstrated that an increase in OPNI score has significantly lower odds of requiring return to OR for an all-cause complication (OR 0.92, P=0.001). No differences were noted for surgical approach utilized, revision status, traumatic etiology, or any concomitant medical comorbidities. Interestingly, a degenerative diagnosis was associated with lower odds of requiring return to OR for any complication (OR 0.30, P=0.043).

Conclusion: Patients with a higher OPNI score had significantly lower odds of returning to the operating room regardless of complication type. This study confirms that nutritional status is an independent risk factor for acute postoperative complications in cervical spine surgery patients. OPNI may serve as a valuable tool in preoperative risk stratification and identification of potential modifiable risk factors in patients undergoing cervical spine operations.

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Stepwise Multivariate Regression: All Cause Complications Requiring RTOR

	Estimate (b)	Odds Ratio	95% CI	*P*-value
Age (yrs)	-0.035	0.97	0.93-1.00	0.050
Indication: Degenerative	-1.207	0.30	0.08-0.89	**0.043***
OPNI	-0.082	0.92	0.87-0.97	**0.001***

PAPER 44

Graft Migration and Subsidence in ACDF Surgery

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Introduction: Migration and subsidence represent significant complications following anterior cervical discectomy and fusion (ACDF). Migration compromises fusion integrity, leading to instability, and recurrent symptoms. Conversely, subsidence is known to jeopardize fusion success and predispose patients to adjacent segment disease, foraminal stenosis, and neurologic compromise. Both complications may lead to potential revision surgery. While graft characteristics have been investigated as a risk factor for migration and subsidence in the lumbar spine, there is a relative paucity of data within the cervical spine literature. Among a cohort of patients undergoing ACDF, we sought to determine the impact of graft length and positioning on: a) migration, b) subsidence and c) pseudarthrosis.

Materials and Methods: Patients from a single institution undergoing ACDF for degenerative pathology from 2010-22 were identified. The primary independent variables were graft length and anterior-posterior positioning. Graft length was dichotomized between grafts less than or equal to and greater than 80% of the endplate length. Positioning was categorized into anteriorly, centrally and posteriorly placed grafts. Primary outcomes of interest were migration and subsidence at first and final x-ray imaging, respectively. A subanalysis of patients with single-level ACDF were analyzed for pseudarthrosis at 12months.

Results: Among 196 patients undergoing ACDF for degenerative cervical pathology, the mean age was 51.5±10.8; 88 (44.9%) were male. Of these, 92 (46.9%) had single-level, 79 (40.3%) two-level, and 25 (12.8%) three-level ACDF. Among 329 grafts, there were 58 (17.6%) autograft, 145 (44.1%) polyetheretherketone (PEEK), 62 (18.8%) titanium and 64 (19.5%) allografts. 236 (71.7%) had a graft/endplate ratio ≤0.8. Grafts ≤80% endplate length had greater incidence of migration (54.2% vs. 26.9%, p<.001) than grafts >80% endplate length, with no difference in migration distance (1.4±0.5 vs. 1.3±0.6mm, p=.582), migration direction (anterior: 47.7% vs. 64.0%, p=.117), subsidence incidence (27.5% vs. 20.4%, p=.183), distance (2.0±1.3 vs 2.5±1.5mm), or grade distribution (1: 23.7% vs. 16.1%; 2: 3.4% vs. 3.2%; 3: 0.4% vs. 1.1%, p=.439). Among grafts ≤80% endplate length, 178 (75.4%) were positioned anteriorly, 50 (21.2%) centrally, and 8 (3.4%) posteriorly. There was no difference in migration incidence (56.7% vs. 48.0% vs. 37.5%, p=.334) or distance (1.3±0.6 vs. 1.3±0.6 vs. 1.3±0.6mm, p=.996) between anteriorly, centrally and posteriorly positioned grafts. More anteriorly placed grafts migrated posteriorly (60.4% vs. 25.0%, p=.003) than centrally placed grafts. There was no difference in subsidence incidence (28.1% vs. 28.0% vs. 12.5%, p=.625), distance (2.0±1.2 vs. 2.0±1.4 vs. 1mm, p=.731) or grade distribution (1: 84.0% vs. 92.9% vs. 100.0%, p=.439) between anteriorly, centrally and posteriorly positioned grafts. On sub-analysis, there was no difference in pseudarthrosis rates between grafts ≤80% endplate length and >80% endplate length (30.0% vs. 32.1%, p=.839), between grafts placed anteriorly, centrally and posteriorly (32.5%; 27.8%; 0.0%, p=.601).

Conclusion: In our cohort of patients undergoing ACDF, grafts ≤80% endplate length

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had greater incidence of migration than grafts >80% endplate length, with no difference in subsidence or pseudarthrosis. Graft anterior-posterior positioning had no influence on migration, subsidence or pseudarthrosis.

PAPER 45

All-Cause Revision Surgery After Single Level Anterior Cervical Discectomy and Fusion with Plate vs. Stand-Alone Cage

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Introduction: Anterior cervical discectomy and fusion (ACDF) surgeries are commonly performed operations for the treatment of degenerative cervical pathologies. Previous studies have examined differences in revision rates by the presence of allograft vs. synthetic interbody.[1] The aim of this study was to investigate the incidence of all-cause revision surgery between plated vs. stand-alone cage constructs for single level ACDF.

Materials and Methods: We retrospectively analyzed a commercial insurance claims database. Patients 18 – 65 years-old were included if they underwent single-level inpatient ACDF (defined with CPT codes) from 2010 – 2018, with a minimum of 2-years continuous insurance enrollment. The primary independent variable was the use of anterior plating versus zero profile device or stand-alone cage. Synthetic (i.e., metal, PEEK, etc.) vs. allograft interbody was a secondary independent variable used in subanalysis. The primary outcome variable was revision cervical arthrodesis after the index operation.

Results: In total, 21,092 patients undergoing single-level inpatient ACDF were included. 10.0% received a stand-alone cage during the index operation. The mean follow-up duration was 4.5 years. Revision arthrodesis occurred in 8.2% of patients overall, at a mean of 2.4 years after the index surgery. Patients with anterior plating had a lower rate of all-cause revision surgery in unadjusted (overall rate 8.1% vs. 9.6%, p=0.0185) and adjusted analysis (OR 0.78, p=0.0016) vs. stand-alone cages. Patients with stand-alone cages had higher rates of revision with a posterior approach and patients with plates had higher rates of revision with an anterior approach. In multi-variable sub-analysis, the combination of a stand-alone interbody device with an allograft had significantly higher odds of revision than other combinations of devices (i.e., plated constructs with allograft or synthetic interbodies, as well as stand-alone synthetic interbodies) (p=0.0113).

Conclusion: Among commercially insured patients ≤65 years-old undergoing single-level inpatient ACDF, anterior plating was associated with a reduced incidence of revision surgery compared to stand alone cages. Patients with a stand-alone cage and an allograft interbody were particularly at risk for revision surgery. Further studies are warranted to assess specific clinical reasons for revision, and whether differences in risk of revision surgery exist between specific stand-alone cage designs, particularly those with allograft interbody devices.

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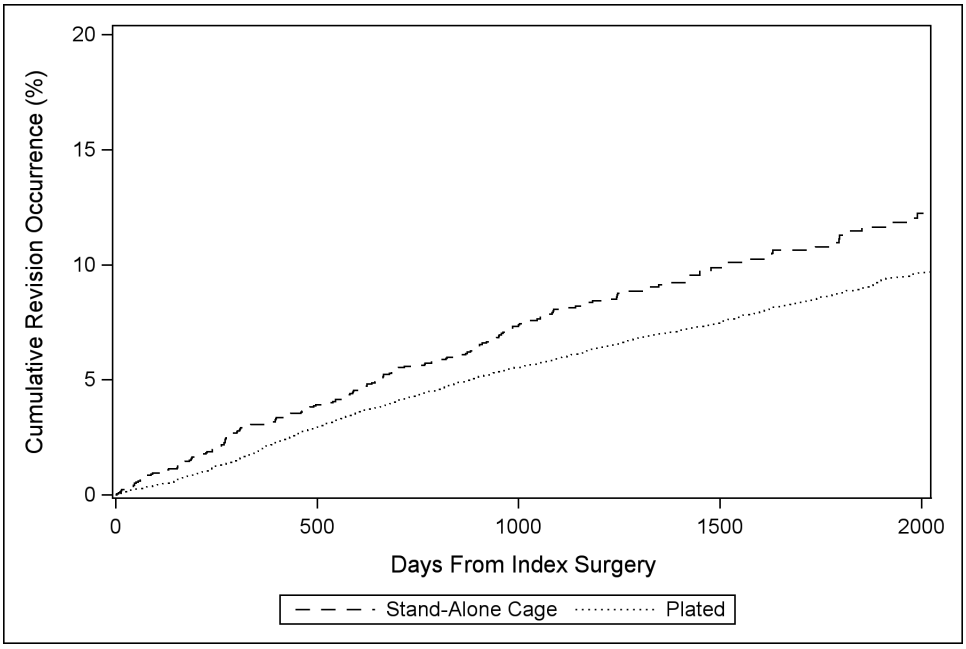

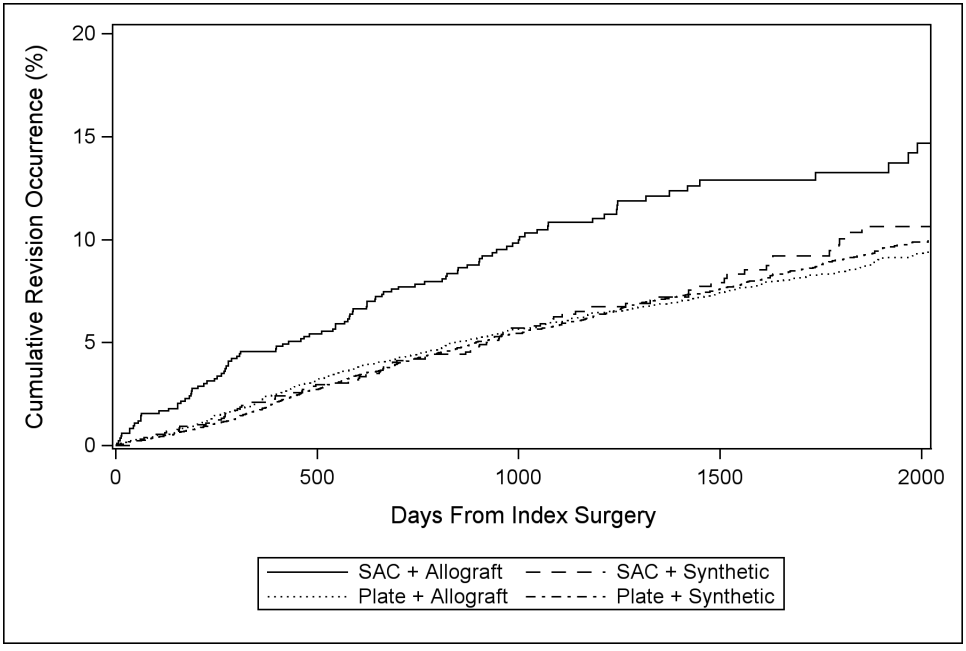

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

PAPER 46

Primary Repair of Delayed Esophageal Perforation Following Anterior Cervical Discectomy and Fusion

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Introduction: Delayed esophageal perforation after anterior cervical discectomy and fusion (ACDF) is a rare but significant complication. The objective of this study is to analyze a series of patients with delayed esophageal perforations following ACDF and to describe their presentation, causes, and the efficacy of primary esophageal repair.

Materials and Methods: A retrospective chart review of all patients >18 years of age with esophageal perforations presenting to a single otolaryngologist from 1998 to 2023 was performed. Patients were included if they had a delayed esophageal perforation with a prior history of an ACDF. Demographic information, comorbidities, operative information for both ACDF and esophageal perforation correction, intrahospital, and discharge data were collected.

Results: Seven patients met final inclusion and exclusion criteria. The average age was 63.6±10.0 years, and 4 (57%) were female. The average body mass index (BMI) was 24.8±1.8 kg/m^2, and the average Charlson Comorbidity Index (CCI) was 3.1±2.0. The average time between ACDF and esophageal perforation repair was 6.8±9.0 years. Patients presented with symptoms such as dysphagia, dysphonia, neck abscesses, cutaneous fistula, and neck pain. Proposed reasons for esophageal perforation consisted of exposed instrumentation on endoscopy (N = 2), anterior displacement of instrumentation (N = 2), mispositioned instrumentation (N = 1), failure and infection of instrumentation (N = 1), and adherence of plate to pharyngoesophageal segments causing perforation upon mobilization (N = 1). All patients were successfully treated with instrumentation removal followed by primary closure of the esophageal defect. Methods of primary closure of the esophageal perforations varied between patients but included 3-0 Vicryl sutures, 3-0 Monocryl sutures, 3-0 PDS sutures, interrupted horizontal mattress sutures, and ACell application, as well as combinations of these types of closure. After primary closure, patients spent an average of 7.4±3.3 days in the hospital. One patient experienced an intrahospital complication of wound drainage and two patients experienced fistulas post-discharge. Patients spent an average of 35.6±9.6 days NPO, with no further complications after restarting PO. The average length of follow-up from esophageal repair surgery was 464.4±443.4 days, while the average length of follow-up from prior ACDF was 8.1±8.3 years.

Conclusion: This study demonstrates that delayed esophageal perforation is a significant postoperative complication of ACDFs but can be effectively treated through instrumentation removal and primary closure. Past literature has described the use of both free flaps and pedicled flaps in repair of esophageal perforations. Though effective, reconstruction with free flaps or pedicled flaps can be laborious and can often cause additional complications and prolonged recovery. This case series demonstrates the effectiveness of primary closure. Careful observation of symptoms post-ACDF and immediate evaluation upon present symptoms is paramount to managing esophageal perforations.

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Table 1. Demographics of entire cohort (N=7).

	Mean ± SD
Age (years)	63.6 ± 10.0
Body Mass Index (kg/m^2)	24.8 ± 1.8
Charlson Comorbidity Index	3.14 ± 2.0
	N (%)
Sex	
Female	4 (57)
Male	3 (43)
Cardiovascular Disease	4 (57)
Hypertension	2 (29)
Diabetes Mellitus	2 (29)
Smoke	
Yes	1 (14)
No	3 (43)
Former	3 (43)
ASA Class	
1	4 (57)
2	3 (43)

ASA: American Society of Anesthesiologists

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Table 2. Surgical characteristics of entire cohort (N=7).

	Mean ± SD
ACDF Hospital LOS (days)	3.7 ± 4.7
Perforation LOS (days)	7.4 ± 3.3
Time Between ACDF and Esophageal Repair (years)	6.8 ± 9.0
Length of Follow-up from Esophageal Repair (days)	464.4 ± 443.4
Length of Follow-up from Prior ACDF (years)	8.1 ± 8.3
	N (%)
Reasons for Esophageal Perforation	
Exposed Instrumentation on Endoscopy	2 (29)
Anterior Displacement of Instrumentation	2 (29)
Mispositioned Instrumentation	1 (14)
Failure and Infection of Instrumentation	1 (14)
Adherence of Plate to Pharyngoesophageal Segments	1 (14)

ACDF: Anterior Cervical Discectomy and Fusion, LOS: Length of Stay

PAPER 47

Impact of Added Morbidity When Performing Cervical Circumferential Cervical Fusion (CCF) Compared to ACDF Alone: Results from 227 Prospectively Randomized Enrolled Subjects Treated with 3-Level Fusion

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Introduction: Anterior discectomy and fusion (ACDF) is the most common treatment for radicular and/or myelopathic pain resulting from degeneration of the cervical discs[1]. In patients with multi-level disease, a surgeon may opt to include supplemental posterior fixation to improve the rate of arthrodesis (circumferential cervical fusion, CCF), however this adjunct potentially introduces added risk for complications and hospital readmission[2]. This analysis attempted to understand how the added morbidity of tissue-sparing supplemental posterior fusion (PCF) impacted post-operative complication rates compared to an anterior only approach when treating 3 levels.

Materials and Methods: Subjects were prospectively recruited and randomized from 18 sites with enrollment beginning in May 2020 and concluding in June 2023. All subjects had myeloradicular symptoms from degenerated discs at 3 contiguous levels between C3 and C7 and were randomized 1:1 to ACDF or CCF. Morbidity of ACDF and PCF procedures were reported through operative duration, estimated blood loss, and hospital length of stay. Adverse events (AEs) were documented at each study with relationship to treatment (device or procedure) adjudicated by a 3-member independent clinical events committee comprised of board-certified spine surgeons.

Results: A total 227 subjects were treated as part of the study (113 ACDF, 114 CCF, 58±10 years, 57% female) with 116 followed through study conclusion as of this interim analysis. The ACDF procedure required a median 129 minutes and resulted in a median estimated blood loss of 50mL. Subjects in the CCF arm had an additional median 48 minutes of procedure time and median 10ccs of estimated blood loss due to the supplemental PCF procedure. Median length of stay was one night and was similar between the two cohorts (p=0.293). Through the first 6 weeks following treatment, 7 ACDF subjects (6%, 3x respiratory, 1x psychiatric, 2x neurological, 1x trauma) and 5 CCF subjects (4%, 3x cardiac, 1x neuro, 1x renal) required extended or re-hospitalization due to treatment or device related complications. When followed through study completion, the CCF arm had a lower number of related events when compared to the ACDF arm (CCF=45.5%, ACDF=65.0%, p=0.005). Of the subjects followed through study conclusion, there was one CCF subject requiring subsequent surgical treatment at index levels (1.7%, C5 palsy) compared to 13 in the ACDF arm (23%, 11x pseudarthrosis, 1x anterior plate replacement for ASD treatment, 1x kyphosis & additional posterior decompression).

Conclusion: Our study demonstrated that supplemental PCF did not increase risk of extended or re-hospitalization and resulted in subjects having a lower long-term incidence of treatment related complications and re-intervention when compared to subjects treated with ACDF only.

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Results from this prospective randomized controlled trial suggest that the rates of symptomatic pseudarthrosis in long-segment ACDF patients is higher than previously reported. When performed with this tissue-sparing approach, the added morbidity of supplemental PCF did not introduce any additional risk of post-operative complications and significantly reduced the risk of subsequent surgical intervention in the following months and years.

PAPER 48

Complications, Morbidity, and Mortality Following Corrective Surgery for Cervical Deformity Among Geriatric Cohorts

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Introduction: Corrective surgery for cervical deformity (CD) is challenging due to high risk of complications and morbidity as well as technical difficulties. With the increase of an aging population and utility of cervical spine fusions, there is a concomitant increase in the number of CD patients requesting corrective surgery. To our knowledge, this is the first study to analyze complication rates among different geriatric cohorts.

Materials and Methods: This is a retrospective review of a prospective, multicenter CD database. Operative CD patients with clinical and health-related quality of life (HRQL) data at 6-week follow-up were included in the study. CD patients were divided into 3 cohorts, >75 vs. <75 years of age, >70 vs. <70 years of age, and >65 vs. <65 years of age. Patient demographics, HRQLs, surgical characteristics, and complications were compared using Welch's t-test and chi-square analysis. Logistic regression was performed to assess the impact of patient demographics on complication and revision surgery rates.

Results: A total of 278 CD patients were analyzed. Mean age was 62.60±11.32 years, with 57.19% (159/278) females. Number of levels fused, estimated blood loss, operative time, and length of showed no difference within the >65, >70, and >75 years of age cohorts ($p > 0.05$). Baseline neck disability index (NDI) and numeric pain rating scale (NRS) neck were higher in <65, <70, and <75 years of age groups within their respective cohorts ($p<0.05$). The number of patients with complication were 82:71(53.6:56.8%) in the <65: >65 years group, 113:40 (56.2:52%) in the <70: >70 years group, and 131:22 (54.1:61.1%) in the <75: >75 years group. Among complication types, patients >65 years of age had higher rates of instrumentation complications ($p=0.049$), and patients >75 years had higher rates of dysphonia ($p=0.026$) and musculoskeletal complications ($p<0.001$). Logistic regression revealed age had no impact on complication or revision surgery rates ($p>0.05$). History of osteoporosis was found to be a significant predictor of revision surgery, with odds of revision surgery increasing by 3.56 times (OR = 3.56, 95% CI [1.17, 10.89], $p=0.026$).

Conclusion: The present study demonstrates high complication rates following corrective surgery for CD, more than 50% regardless of age criteria. There are no differences in surgical

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characteristics, major complication rates, revision surgery and mortality when comparing patients among geriatric cohorts with different criteria including 65, 70 and 75 years old. Understanding high complication and morbidity risks associated with different ages will be important when discussing corrective surgery for CD in geriatric patients.

	Analysis 1			Analysis 2			Analysis 3		
	<65 years (n = 153)	>65 years (n = 125)	p value	<70 years (n = 201)	>70 years (n = 77)	p value	<75 years (n = 242)	>75 years (n = 36)	p value
Patient Characteristics									
Age, years	54.59 ± 8.29	72.41 ± 5.10	**<0.001**	57.72 ± 9.17	75.34 ± 4.30	**<0.001**	60.18 ± 9.99	78.93 ± 3.54	**<0.001**
Female Sex	99 (64.71%)	60 (48.00%)	**0.005**	126 (62.69%)	33 (42.86%)	**0.003**	146 (60.33%)	13 (36.11%)	**<0.001**
History of Osteoporosis	19 (12.75%)	34 (29.06%)	**0.001**	30 (15.38%)	23 (32.39%)	**0.002**	41 (17.75%)	12 (34.29%)	**0.022**
Surgical Characteristics									
Number of Levels Fused	9.71 ± 4.16	10.95 ± 4.67	0.102	10.01 ± 4.28	10.94 ± 4.79	0.302	10.09 ± 4.36	11.58 ± 4.74	0.260
EBL, cc	678.29 ± 777.56	946.12 ± 1,524.02	0.098	746.41 ± 1,225.94	924.92 ± 927.72	0.224	787.13 ± 1,203.49	825.86 ± 738.39	0.809
Operative Time, mins	369.25 ± 195.41	381.08 ± 199.46	0.639	371.18 ± 205.08	383.34 ± 171.31	0.642	378.52 ± 202.46	341.31 ± 144.70	0.223
Length of stay, days	5.85 ± 4.13	16.00 ± 57.37	0.278	12.58 ± 49.69	7.50 ± 7.25	0.473	11.27 ± 43.78	8.38 ± 10.09	0.634
No. of Patients with a Complication	82 (53.59%)	71 (56.80%)	0.593	113 (56.22%)	40 (51.95%)	0.522	131 (54.13%)	22 (61.11%)	0.432
Total Complications	155	143		215	83		245	53	
Cardiopulmonary	22	19	0.849	28	13	0.894	30	11	0.073
Dysphagia	9	12	0.350	17	4	0.591	18	3	0.627
Dysphonia	2	3	0.224	3	2	0.315	3	2	**0.026**
Infection/Wound	17	12	0.775	20	9	0.713	23	6	0.106
Instrumentation	6	12	**0.049**	12	6	0.367	16	2	0.956
Intraoperative	7	7	0.930	10	4	0.800	13	1	0.563
Musculoskeletal	3	4	0.512	3	4	0.078	3	4	**<0.001**
Neurologic	30	30	0.196	44	16	0.937	51	9	0.400
Radiographic	12	14	0.477	18	8	0.679	22	4	0.627
Revision Surgery	23 (15.03%)	20 (16.00%)	0.824	30 (14.93%)	13 (16.88%)	0.163	38(15.70%)	5 (13.89%)	0.779
Mortality	0 (0.00%)	1 (0.80%)	0.450	1 (0.50%)	0 (0.00%)	0.723	1 (0.41%)	0 (0.00%)	0.871
HRQLs									
NRS Back (Baseline)	5.96 ± 2.93	5.09 ± 3.09	**0.022**	5.79 ± 2.98	5.01 ± 3.11	0.071	5.82 ± 2.92	3.97 ± 3.25	**0.003**
NRS Back (6-Week)	5.36 ± 2.98	4.34 ± 3.51	0.175	4.78 ± 3.13	5.04 ± 3.65	0.762	4.91 ± 3.22	4.50 ± 3.75	0.749
NRS Neck (Baseline)	7.43 ± 2.35	6.08 ± 2.80	**<0.001**	7.24 ± 2.41	5.75 ± 2.93	**<0.001**	7.08 ± 2.50	5.23 ± 3.02	**0.001**
NRS Neck (6-Week)	5.73 ± 3.20	4.84 ± 3.18	0.226	5.29 ± 3.24	5.30 ± 3.20	0.987	5.43 ± 3.19	4.45 ± 3.33	0.380
NDI (Baseline)	54.64 ± 17.36	41.21 ± 17.57	**<0.001**	52.33 ± 18.03	38.89 ± 16.78	**<0.001**	50.43 ± 18.21	37.24 ± 17.75	**<0.001**
NDI (6-Week)	47.71 ± 2.82	44.17 ± 3.68	0.449	47.71 ± 20.95	44.17 ± 17.65	0.449	47.97 ± 19.99	37.80 ± 18.51	0.134
mJOA (Baseline)	13.62 ± 2.86	14.01 ± 2.57	0.298	13.62 ± 2.86	14.01 ± 2.57	0.298	13.71 ± 2.85	13.82 ± 2.42	0.810
mJOA(6-Week)	14.48 ± 2.48	14.33 ± 2.72	0.811	14.48 ± 2.48	14.33 ± 2.72	0.811	14.31 ± 2.57	15.08 ± 2.40	0.312

*Values presented as mean ± standard deviation or count (percent of total); *EBL* = estimated blood loss; *HRQL* = health-related quality of life; *NRS* = numeric pain rating scale; *NDI* = neck disability index; *mJOA* = modified Japanese Orthopaedic Association score

Table 1. Comparing patient characteristics, surgical characteristics, complication rates, and HRQLs by age group

	Odds Ratio	Standard Error	p value	95% Confidence Interval	
Any Complication	1.006	0.011	0.601	0.985	1.027
Cardiopulmonary	1.016	0.018	0.378	0.981	1.052
Dysphagia	1.014	0.023	0.528	0.971	1.069
Dysphonia	1.083	0.060	0.152	0.971	1.208
Infection/Wound	1.006	0.019	0.753	0.970	1.043
Instrumentation	1.044	0.027	0.092	0.993	1.098
Intraoperative	1.017	0.027	0.527	0.966	1.070
Musculoskeletal	1.032	0.038	0.388	0.960	1.110
Neurologic	1.016	0.014	0.242	0.989	1.044
Radiographic	1.023	0.022	0.286	0.981	1.067
Revision Surgery	1.014	0.015	0.358	0.984	1.045
Mortality	1.068	0.114	0.536	0.867	1.316

Table 2. Logistic regression assessing the impact of age on postoperative complications

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Preoperative Chronic Steroid Use Predicts Increased Infections and Readmissions After Anterior Cervical Discectomy and Fusion

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Introduction: Corticosteroids are commonly used to treat a variety of inflammatory and rheumatologic conditions, but they have been associated with adverse outcomes. These effects have been studied in lumbar spinal surgery, however studies specifically exploring the influence of steroid use on anterior cervical discectomy and fusion (ACDF) are limited. The purpose of this study is to evaluate the impact of preoperative chronic steroid use on 30-day perioperative outcomes in patients undergoing ACDF.

Materials and Methods: The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried between 2011 and 2016 to identify patients receiving elective ACDF (CPT: 22551, 22554, 63075) for degenerative cervical spine conditions. Patients were isolated into two groups based on preoperative chronic corticosteroid use, defined by the database as regular administration of oral or parenteral corticosteroid within 30 days of surgery. Univariate analyses were used to compare demographics, comorbidities, and hospital metrics between the groups. Univariate and multivariate analyses adjusted for demographics, comorbidities, and American Society of Anesthesiologists (ASA) class were used to determine if preoperative steroid use was an independent risk factor for 30-day complications, readmissions, reoperations, and mortality.

Results: 38,452 patients that underwent ACDF were identified from the ACS-NSQIP database, of them 1,275 (3.31%) with chronic steroid use and 37,177 (96.69%) without. Demographics and comorbidities that were significantly associated with steroid use included older age ($p < 0.001$), female sex ($p < 0.001$), American Society of Anesthesiologists class >2 ($p < 0.001$), diabetes ($p < 0.001$), smoking ($p < 0.001$), chronic obstructive pulmonary disease ($p < 0.001$), congestive heart failure ($p < 0.001$), hypertension ($p < 0.001$), dialysis-dependence ($p < 0.001$), cancer ($p = 0.009$), open wounds ($p < 0.001$), unintentional weight loss ($p = 0.019$), bleeding disorders ($p < 0.001$), and preoperative anemia ($p < 0.001$). Chronic steroid use was also associated with longer hospital length of stays (2.06 days vs 1.68 days; $p < 0.001$) and operative times (133.54 minutes vs 127.72 minutes; $p = 0.007$). On multivariate analysis, chronic preoperative steroid use was found to be an independent risk factor for organ/space infections (OR 3.972; 95% CI 1.361-11.592; p=0.012) and readmissions (OR 1.336; 95% CI 1.024-1.743; p=0.033) in the 30-day postoperative period.

Conclusion: Chronic preoperative steroid use was found to be an independent risk factor for 30-day organ/space surgical site infections and readmissions in patients following elective ACDF. It is important to be aware of this risk to further optimize and mitigate potential postoperative adverse events.

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Table 1. Demographics, comorbidities, and hospital metrics between patients undergoing ACDF with and without chronic steroid use.

Variables	No Steroid	Yes Steroid	P-value
Sex (N, %)			**<0.001**
Male	18273 (49.2%)	546 (42.8%)	
Female	18904 (50.8%)	729 (57.2%)	
Race (N, %)			0.506
White	32094 (86.3%)	1089 (85.4%)	
African American or Black	3954 (10.6%)	152 (11.9%)	
Asian	713 (1.9%)	23 (1.8%)	
Native American or Alaska Native	274 (0.7%)	6 (0.5%)	
Hawaiian Native or Pacific Islander	142 (0.4%)	5 (0.4%)	
Age (mean ± SD; years)	54.15 ± 11.31	57.52 ± 11.18	**<0.001**
BMI (mean ± SD; kg/m2)	30.37 ± 6.60	30.66 ± 6.81	0.136
ASA Score (N, %)			**<0.001**
≤2	22274 (59.9%)	481 (37.7%)	
>2	14903 (40.1%)	794 (62.3%)	
Comorbidity (N, %)			
Diabetes	5748 (15.5%)	257 (20.2%)	**<0.001**
Smoking	10574 (28.4%)	288 (22.6%)	**<0.001**
COPD	1556 (4.2%)	104 (8.2%)	**<0.001**
CHF	67 (0.2%)	10 (0.8%)	**<0.001**
Hypertension requiring medication	16805 (45.2%)	708 (55.5%)	**<0.001**
Dialysis-dependent	72 (0.2%)	9 (0.7%)	**<0.001**
Disseminated Cancer	21 (0.1%)	4 (0.3%)	**0.009**
Open wound with or without infection	83 (0.2%)	12 (0.9%)	**<0.001**
Weight loss (>10% in 6 months)	58 (0.2%)	6 (0.5%)	**0.019**
Bleeding disorder	361 (1.0%)	33 (2.6%)	**<0.001**
Preoperative anemia	5442 (14.6%)	275 (21.6%)	**<0.001**
Multilevel (N, %)	14652 (39.4%)	488 (38.3%)	0.414
Total Length of Hospital Stay (mean ± SD; days)	1.68 ± 4.92	2.06 ± 3.56	**<0.001**
Operative Time (mean ± SD; minutes)	127.72 ± 70.89	133.54 ± 76.01	**0.007**

BMI: body mass index; ASA: American Society of Anesthesiologists; COPD: chronic obstructive pulmonary disease; CHF: congestive heart failure; SD: standard deviation

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Table 2. 30-day postoperative outcomes between patients undergoing ACDF with and without chronic steroid use.

Postoperative Outcomes	No Steroid	Yes Steroid	P-value
Any Medical Complication (N, %)	970 (2.6%)	59 (4.6%)	**<0.001**
Wound Complications (N, %)	201 (0.5%)	12 (0.9%)	0.079
Superficial SSI	108 (0.3%)	6 (0.5%)	0.283
Deep SSI	51 (0.1%)	1 (0.1%)	0.730
Organ/Space SSI	26 (0.1%)	4 (0.3%)	**0.017**
Wound dehiscence	24 (0.1%)	1 (0.1%)	1.000
Pulmonary Complications (N, %)	417 (1.1%)	21 (1.6%)	0.105
Pneumonia	215 (0.6%)	11 (0.9%)	0.189
Pulmonary Embolism	67 (0.2%)	2 (0.2%)	1.000
Failure to wean from ventilator > 48 hours	122 (0.3%)	9 (0.7%)	**0.031**
Unplanned Intubation	181 (0.5%)	6 (0.5%)	1.000
Renal Complications (N, %)	176 (0.5%)	12 (0.9%)	**0.025**
Progressive Renal Insufficiency	10 (0.0%)	2 (0.2%)	0.058
Acute renal failure	9 (0.0%)	0 (0.0%)	1.000
Urinary tract infection	162 (0.4%)	10 (0.8%)	0.082
Neuro Complications (Stroke) (N, %)	34 (0.1%)	2 (0.2%)	0.633
Cardiac Complications (N, %)	165 (0.4%)	7 (0.5%)	0.667
Cardiac arrest	45 (0.1%)	2 (0.2%)	1.000
Myocardial Infarction	43 (0.1%)	0 (0.0%)	0.405
DVT/Thrombophlebitis	83 (0.2%)	5 (0.4%)	0.219
Sepsis-Related Complications (N, %)	94 (0.3%)	7 (0.5%)	0.051
Sepsis	70 (0.2%)	5 (0.4%)	0.103
Septic Shock	24 (0.1%)	3 (0.2%)	0.059
Bleeding require transfusion (N, %)	141 (0.4%)	14 (1.1%)	**<0.001**
Readmission (N, %)	1068 (2.9%)	63 (4.9%)	**<0.001**
Reoperation (N, %)	497 (1.3%)	20 (1.6%)	0.535
Mortality (N, %)	45 (0.1%)	4 (0.3%)	0.079

SSI: surgical site infection; DVT: Deep venous thrombosis

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Table 3. Adjusted multivariate logistic regression to demographics, comorbidities and American Society of Anesthesiologists score comparing 30-day postoperative outcomes between patients with chronic steroid use to those without.

Postoperative Outcomes	OR (95% CI)	P-value
Any Medical Complication	1.266 (0.959-1.671)	0.096
Wound Complications	1.512 (0.838-2.728)	0.170
Superficial SSI	1.481 (0.645-3.400)	0.355
Deep SSI	0.468 (0.064-3.406)	0.453
Organ/Space SSI	3.972 (1.361-11.592)	**0.012**
Wound dehiscence	1.010 (0.135-7.560)	0.992
Pulmonary Complications	0.941 (0.594-1.490)	0.795
Pneumonia	0.919 (0.493-1.714)	0.791
Pulmonary Embolism	0.732 (0.178-3.015)	0.666
Failure to wean from ventilator > 48 hours	1.251 (0.614-2.551)	0.537
Unplanned Intubation	0.565 (0.243-1.316)	0.186
Renal Complications	1.210 (0.656-2.235)	0.542
Progressive Renal Insufficiency	3.287 (0.680-15.894)	0.139
Acute renal failure	NE	NE
Urinary tract infection	1.110 (0.569-2.165)	0.760
Neuro Complications (Stroke)	1.181 (0.278-5.025)	0.822
Cardiac Complications	0.932 (0.429-2.023)	0.858
Cardiac arrest	0.738 (0.171-3.195)	0.685
Myocardial Infarction	NE	NE
DVT/Thrombophlebitis	1.694 (0.681-4.215)	0.257
Sepsis-Related Complications	1.222 (0.556-2.683)	0.618
Sepsis	1.144 (0.453-2.889)	0.775
Septic Shock	2.327 (0.682-7.938)	0.177
Bleeding requiring transfusion	1.569 (0.874-2.816)	0.132
Readmission	1.336 (1.024-1.743)	**0.033**
Reoperation	0.916 (0.580-1.444)	0.704
Mortality	1.189 (0.393-3.600)	0.759

OR: Odds ratio; CI: Confidence Interval; NE: Not evaluable due to low incidence of variable; SSI: Surgical site infection; DVT: Deep venous thrombosis

PAPER 50

Malnutrition as a Risk Factor for Anterior Cervical Discectomy and Fusion Complications: A Large Propensity-Matched Retrospective Cohort Study

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Introduction: Malnutrition, defined as albumin <3.5 g/dL, is a preoperative risk factor linked to postoperative complications and increased length of stay in surgical procedures. However, outcomes in anterior cervical discectomy and fusion (ACDF) patients have yet to be fully explored, with small cohorts and limited outcomes variables without long-term results. As ACDF is a commonly utilized surgical procedure for treating various pathologies in the cervical spine it has become increasingly widespread, with Medicare data demonstrating a 25.25% increase between 2011 to 2014 and a study with the Nationwide Inpatient Sample projecting a 13.3% increase by 2040.[1,2] As such, evaluating the role of hypoalbuminemia and malnutrition to predict complications following ACDF may reduce complications and decrease health care costs in the elective setting where preoperative optimization is possible. In this work, we present the largest retrospective study elucidating the relationship between malnutrition and early and long-term ACDF outcomes.

Materials and Methods: 33,340 ACDF patients were identified over the last 20 years from the TrinetX database (60 US healthcare organizations) with serum albumin obtained within four months of surgery. 4554 patients were classified as malnourished and were propensity-matched, using baseline demographic variables including race, age, and sex to 4554 patients in the nourished (albumin≥3.5g/dL) cohort. Outcome differences between cohorts were compared using T-tests for risk differences at 1 month and 3 months.

Results: Malnourished patients experienced a greater risk of 1-month (39.7% vs. 19.2%, p<0.001) and 3-month readmission (12.8% vs. 3.9%, p<0.001) compared to those who were not. Malnourished patients experienced a greater rate of postoperative complications at 1 month. These included ED visits (12.3% vs. 9.7%, p<0.001), sepsis (12.1% vs 2.4%, p<0.001), pneumonia (10.2% vs. 2.9%, p<0.001), ventilator use (11.1% vs. 3.3%, p<0.001), neurological deficit (4.3% vs. 2.7%, p<0.001) and wound infection (3.3% vs. 1.0%, p<0.001). Mortality in malnourished patients was higher at 4.1% versus 0.09% (p<0.001). Kaplan-Meier survival analysis demonstrated a lower rate of survival in the malnourished cohort for readmission (59.95% vs. 80.73%, p=0.008), ED visit (87.29% vs. 90.11%, p<0.001), and pneumonia (89.62% vs 97.03%, p=0.008). Survival rates were not significantly different for sepsis, ventilator use, neurological deficit, and wound infection.

Conclusion: Nutritional status can be used as a predictor of negative outcomes in ACDF, with malnutrition being associated with increased rates of postoperative complications, readmission, and mortality. These data suggest that malnutritional is a modifiable risk factor for poor outcomes in ACDF. In an elective setting, evaluation of a patients' nutritional status and preoperative nutritional optimization may decrease postoperative complications in ACDF. Further retrospective research is required to identify the ideal timepoint to identify malnutrition and additional prospective studies are required to evaluate the optimal nutritional optimization regimen in ACDF.

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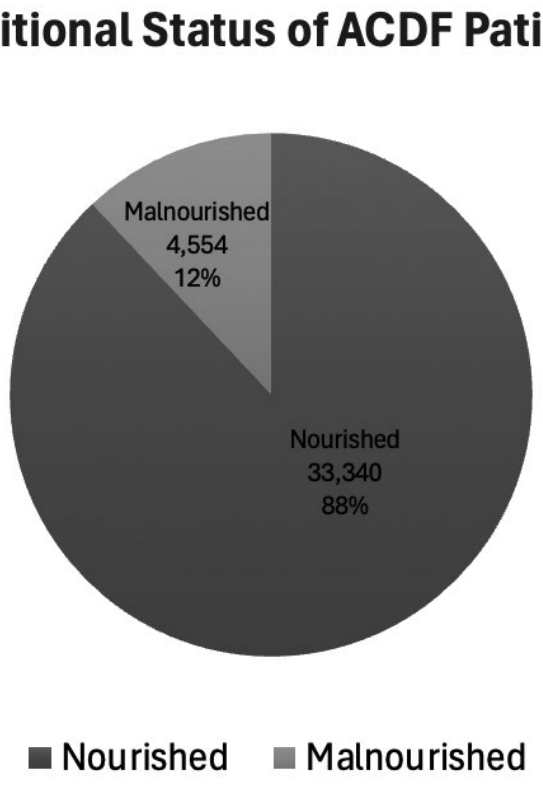

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or medical device he or she wishes to use in clinical practice.

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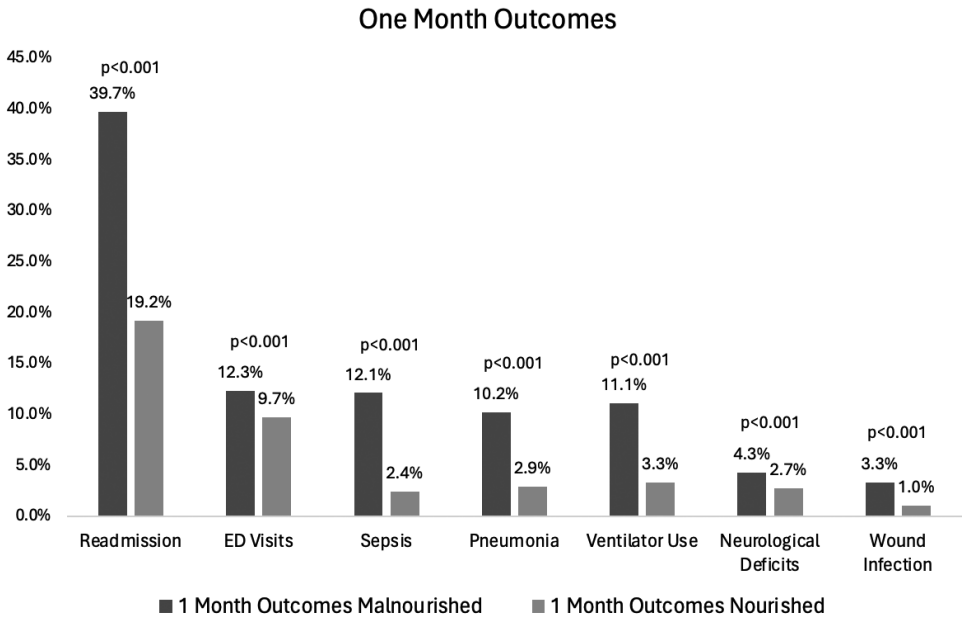

PAPER 51

So Close Yet So Far: The Impact of cSVA Undercorrection during Adult Cervical Deformity Surgery - An Incremental Correction Analysis

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Introduction: Surgeons have long acknowledged that a one-fit-all approach to re-alignment goals for adult cervical deformity is not sufficient. There is a fine balance to meeting alignment targets for the various cervical parameters, and while overcorrection has been identified as a source of potential complications, undercorrection may hinder long-term outcomes. We aim to to compare degrees of cSVA correction and to theorize possible minimum and maximum thresholds of cSVA correction for patients to benefit clinically.

Materials and Methods: In a retrospective cohort review of a prospectively enrolled database, operative ACD patients with complete baseline (BL) and two year (2Y) radiographic measurements and HRQL data were analyzed via descriptive statistics and means comparison testing. Patients were grouped into a corrected cohort (cSVA<4cm) and an undercorrected cohort (cSVA) based on postoperative radiographs. Chi-squared testing and regression analyses were run to identify differences in cohort composition and outcomes.

Results: 265 patients met inclusion criteria (mean age 58.2±11.4 years, mean BMI 28.9±7.5, mean CCI 0.9±1.3) Surgically, mean operative time was 348.0±194.9 minutes, mean EBL 834.4±1180.3, mean LOS 4.9±5.6 mean anterior levels fused: 3.3±1.4, and mean posterior levels fused 5.1±1.4. BL radiographic measurements were T1S: 21.7±24.4° ,C2S: 30.9±20.2° C2-C7 -7.3±18.4°, TS-CL: 28.2±19.6°, BL cSVA: 19.6±32.2 mm. 11.2% of patients were undercorrected, while 88.8% of patients were appropriately corrected. The undercorrected cohort contained a significantly higher proportion of moderately to severely frail patients than the corrected cohort (91.3% v. 71.4%, p=0.041). Amongst the undercorrected cohort, there was a significantly greater occurrence of radiographic complications (47.8% v. 27.6%,p<0.046). Those who were undercorrected demonstrated a significantly greater rate of severe 6M DJK (p<.001) and Y1 DJK (54.5% v. 45.5%, p<.001). On a clinical level, undercorrected patients showed lesser rates of improvement in key symptoms such as hand clumsiness (C:80% v. UC: 22%, p=0.33) and bladder/bowel continence (C: 66.7% v. UC: 33.%, p=0.029). Furthermore, the C patients reported a significantly greater rate of resolution of persistent symptoms as opposed to the UC cohort (95.5% v. 4.5%, p=0.026). In terms of HRQLs, the corrected cohort demonstrated significantly greater Y2 EQ5D-Health values (76.9 v. 46.7, p=0.012). Being undercorrected was a significant predictor of moderate-high Y1 mJOA score (OR 3.0, CI 95% 1.2-7.3, p=0.015) Still, in terms of CIT, the threshold for DJF risk increased significantly (p=0.026) when the cSVA were corrected greater than 5 cm, demonstrating the risk also posed by overcorrection and the narrow range of correction.

Conclusion: Undercorrection of cSVA yielded worse clinical outcomes and posed a significant risk for mechanical complications. Although undercorrection does not seem to be efficacious, certain thresholds for overcorrection should still be respected as there is a risk for DJK on either end of the spectrum.

PAPER 52

Analysis of Success Versus Poor Realignment in Patients with Cervical Deformity: In-Construct Angles Provide Novel Targets for Correction

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Introduction: Correction of cervical deformity (CD) has the potential to improve patient function significantly. However, previously described radiographic parameters cannot be measured intraoperatively. The present study investigates in-construct measurements, sagittal angles (SA) within the fusion from C2 to various thoracic vertebrae, which can be used as targets for CD correction.

Materials and Methods: Patients with adult cervical deformity with either cervical kyphosis more than 10°, cSVA of more than 4 cm, CBVA more than 25°, and a LIV at T1 or caudal were included. Patients were categorized into the failed outcome group if they had a cSVA of more than 4 cm postoperatively. The in-construct measurements were based on patients' LIV. All patients had a C2-T1 SA. C2-T4 SA were compared between groups with LIV below T4, and C2-T10 SA between groups with LIV below T10. Change in C2-LIV SA described the sagittal correction within the fusion for each patient. Analyses between failed and success realigned groups for clinical and radiographic characteristics were performed using t-test, X^2 analysis, and multivariate regression. Linear regression analysis was used to determine the C2-T1, C2-T4, C2-10 SA measures that correspond to a cSVA=4 cm and DJK =10°. HRQL analysis was done in patients with 1 year follow up.

Results: A total of 143 patients with CD (mean age 63 yr, 60% female) were included with 73 having failed radiographic outcomes by high cSVA (51% Failed). Failure to correct cSVA was associated with worse baseline deformity including cSVA, T1S, C2S, TS-CL, with greater change in DJKA, and larger postop C2-T1 SA within the fusion (all $p<0.05$). Multivariate regression for variables with $p<0.05$ revealed that the postop C2-T1 in-construct angle independently predicted failed realignment outcome (OR= 1.25, CI 1.11-1.41; $p<0.001$). Using linear regression, a cSVA measurement of 4.0cm corresponded to a C2-T1-SA of -9.55°, C2-T4 SA of -0.37°, C2-T10-SA of 14.67°(all $r>0.38$, $p<0.05$). Linear regression revealed that postoperative C2-T10 SA was able to predict change in DJKA, where a change of 10° yielded a C2-T10 SA of 20.67°($r>0.57$,

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p=0.02). While no difference in postop HRQL was observed between groups, improvement in C2-LIV SA was associated with improvement in NRS neck scores at 1 year (r>0.42, p=0.036).

Conclusion: Failure to restore cSVA patients was independently associated with undercorrection, as evidenced by significantly larger postoperative in-construct angles. In-construct measures can be used as alignment targets to optimize radiographic outcomes and prevent DJK thereby improving patient reported outcomes

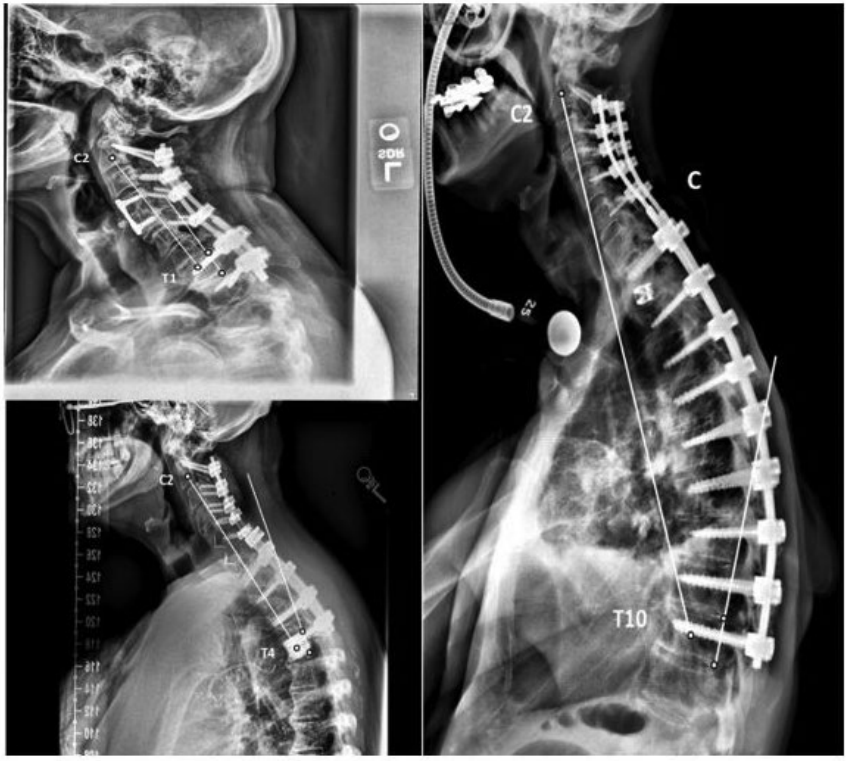

Figure 1: The novel, in-construct angles are measures of sagittal alignment within the fused construct. The dots depict the centroids of C2 and lower thoracic vertebra as well as the superior and inferior edges of the posterior cortex of the lower thoracic vertebra. (A) C2-T1 SA is defined as the angle of a line from the centroid of C2 to the centroid of T1, and a line parallel to the posterior vertebral body of T1. (B) C2-T4 SA is the angle formed by a line from the centroid of C2 to the centroid of T4, and a line parallel to the posterior vertebral body of T4. (C) C2-T10 SA is defined as the angle of a line from the centroid of C2 to the centroid of T10, and a line parallel to the posterior vertebral body of T10.

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In Construct Measurements at 3 Month Follow Up and Targets For Optimal Realignment						
		N	Mean	p-value	In-Construct Target Goal at cSVA=4 cm	Mean Offset from Target
C2-T1 SA°	Success	72	-12.84±9.97	<0.001	-9.55°	-3.29±8.88
	Failed	70	-5.23± 9.33			4.32±9.33
C2-T4 SA°	Success	28	1.01± 7.56	0.004	-0.37°	1.38±7.56
	Failed	41	7.38±9.51			7.75±9.51
C2-T10 SA°	Success	6	21.38± 3.53	0.096	14.67°	6.71±3.53
	Failed	19	30.98± 13.22			16.31±13.22

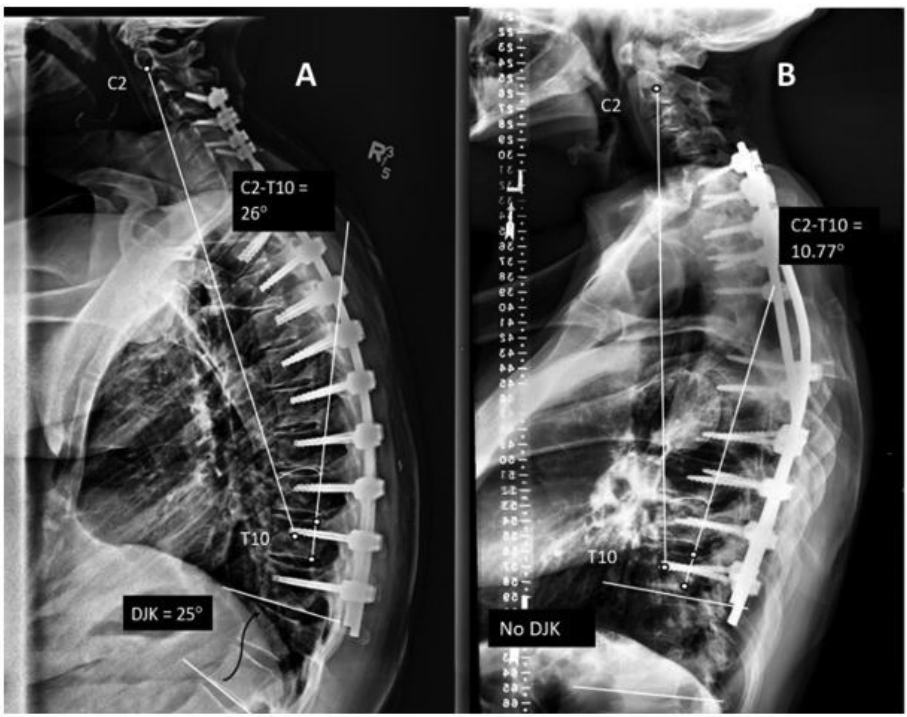

Figure 2: (A) Postoperative x-ray of under-corrected patient as evidenced by a larger C2-T10 SA of 26° who developed severe DJK. (B) Postoperative x-ray of patient with good correction with a C2-T10 SA of 10.77° with no DJK present.

PAPER 53

Quantifying the Importance of Upper Cervical Extension Reserve in Adult Cervical Deformity Surgery and its Impact on Baseline Presentation and Outcomes

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Introduction: Hyperextension of the upper cervical spine is a prominent compensatory mechanism to maintain horizontal gaze and balance in adult cervical deformity (ACD). However, the relaxation of upper cervical (C0-C2) extension reserve (ER) and its impact on postoperative outcomes is not well understood.

Materials and Methods: ACD patients undergoing subaxial cervical fusion with 2Y data were included. Upper cervical extension reserve (ER) was defined as: ΔC0-C2 sagittal Cobb angle between neutral and extension. Relaxation of ER was defined as the ER mean in those that met the ideal ACD modifiers. ANCOVA and multivariable logistic regressions were utilized, with conditional inference tree (CIT) determining thresholds.

Results: 108 ACD patients met inclusion. Preoperative C0-C2 ER was 8.7°±9.0°, and last follow-up was 10.3°±11.1°. ER in those meeting all ideal CD modifiers at 2Y was 12.9°±9.0°. Preoperatively 29% had adequate ER, 60% had improved ER postoperatively, with 50% achieving adequate ER at 2Y. Lower ER correlated with greater cervical deformity ($p<.05$). Preoperatively, greater ER had lower disability in NDI ($p<.001$). Controlled analysis found improved ER to have a 7x higher likelihood of NDI MCID (OR 6.94, $p=.019$). Isolating those with inadequate preoperative ER, found postoperative resolution having 5x odds of good clinical outcomes ($p<.05$). In those with inadequate ER at baseline, the preoperative C2-C7 of <-18° and TS-CL of >59° for TS-CL was predictive of ER resolution. In those with preoperative C2-C7 >-18°, a T1PA of >13° was predictive of postoperative return of ER (all $p<.05$). Surgical correction of C2-C7 by >16° from baseline was found to be predictive of ER return, highlighting its compensatory role in cervical deformity.

Conclusion: Increased preoperative utilization of the extension reserve in the upper cervical spine in cervical deformity was associated with worse baseline regional and global alignment while impacting health-related measures. The majority of patients had relaxation of extension reserve postoperatively, however, in those who didn't, there was a decreased likelihood of achieving good outcomes.

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Table 1. Alignment

	Baseline	Postop	2Y
T1S	33.9°±19.3°	36.1°±15.0°	36.2°±15.4°
C2S	38.9°±21.3°	26.5°±10.8°	24.8°±12.7°
MGS	4.3°±13.9°	-4.5°±5.8°	-4.9°±8.9°
cSVA	47.2mm±24.8mm	38.0mm±22.3mm	39.5mm±17.3mm
C2-C7 Apex	C4	C5	C5
C2PA	18.6°±11.9°	19.9°±18.3°	21.5°±13.9°
C0-C2	32.6°±12.1°	30.1°±9.7°	27.5°±11.2°
C2-C7	-6.9°±22.1°	8.4°±18.8°	8.7°±13.8°
Flex C0-C2	18.9°±10.4°		14.1°±10.0°
Ext C0-C2	40.9°±9.5°		37.6°±10.3°
Flex C2-C7	-21.2°±20.5°		2.7°±14.9°
Ext C2-C7	3.5°±21.4°		10.6°±14.2°

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Table 2. HRQLs Association

		Beta	R^2	p-value
BL NDI				
	ROE Pre	-0.623	0.104	**<.001**
	ROE Post	-0.025	0	0.944
	ROE Last	0.163	0.083	0.853
	ROE Dif (Last - Pre)	0.064	0.002	0.678
Last NDI				
	ROE Pre	-0.428	0.028	0.097
	ROE Post	-0.73	0.12	**0.01**
	ROE Last	-0.434	0.036	0.057
	ROE Dif (Last - Pre)	-0.364	0.059	**0.044**
NDI DIF (Last - Pre)				
	ROE Pre	0.275	0.018	0.216
	ROE Post	-0.651	0.157	**0.004**
	ROE Last	-0.6	0.094	**0.002**
	ROE Dif (Last - Pre)	-0.412	0.095	**0.012**

PAPER 54

Limited Improvement Following Anterior Cervical Discectomy and Fusion in Patients with Age-adjusted Spinopelvic Malalignment: A Propensity Score and Inverse Probability Weighted Cohort Study

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Introduction: Recent focus on sagittal alignment in spinal surgery outcomes has underscored its relevance, particularly in cervical deformity surgeries. However, the implications of global sagittal spinopelvic alignment on outcomes following cervical degenerative surgeries like anterior cervical discectomy and fusion (ACDF) are less understood.

Materials and Methods: This retrospective study included patients who underwent anterior cervical discectomy and fusion (ACDF) with preoperative whole spinal alignment assessment by EOS imaging. We examined demographic data, sagittal spinopelvic parameters (Lumbar lordosis, LL; pelvic tilt, PT; pelvic incidence, PI; sacral slope, SS), and Patient Reported Outcomes and Measures (PROMs) including NDI, VAS neck, and VAS arm. By age-adjusted optimal spinal alignment[1], patients were categorized into PI minus LL (PI-LL) ≥0 (PILL+ group) and PI-LL <0 (PILL- group). After creating background matched groups by inverse probability of treatment weighting (IPTW) using propensity score, PROMs at 12-weeks and 1 year postoperatively were analyzed for its change and minimal clinically important differences (MCID) achievement.

Results: Of 90 patients with preoperative EOS imaging, 29 were in the PILL+ group. Before matching, the PILL+ group had a higher percentage of males (PILL+, 72.4% vs PILL-, 52.5%) and significantly higher BMI (29.4 vs. 26.2). Post-IPTW matching comparison ensured no significant differences between groups in demographics, including age, sex, BMI, modified frailty index-5, smoking status, cerlordosis, 6.1 vs 7.9°, P=0.526; T1 slope: 25.5 vs 23.1, P=0.252), and preoperative PROMs (NDI, 31.6 vs. 31.7; VAS neck, 4.5 vs. 5.0; VAS arm, 4.5 vs. 4.2). The PILL+ group showed a PI-LL of 14.5 compared to -6.2 in the PILL- group (P<0.001). At 12-weeks and 1-year postoperatively, the PILL+ group experienced significantly less improvement in VAS neck scores compared to the PILL- group (12-week, 0.4 vs 2.0 points, P=0.018; 1-year, 1.5 vs. 3.8, P<0.001) (Fig. b). However, improvement in NDI and VAS neck were similar at 1-year (NDI, 13.9 vs. 18.6, P=0.21; VAS arm, 2.9 vs. 3.3, P=0.71) (Fig. a and c). As a result, MCID achievement in VAS neck were significantly lower in the PILL+ group (15.9% vs. 65.5%, P<0.001), whereas no significant difference were observed in MCID of NDI (58.8% vs. 75.5%, P=0.18) and VAS arm (36.0% vs. 37.0%, P=0.95).

Conclusion: Our study demonstrated poorer improvement of neck pain in patients with age-adjusted global sagittal malalignment following ACDF, using IPTW groups by propensity score, although improvement in functional disability was not different. This study emphasizes the necessity of a comprehensive preoperative evaluation of whole spinal alignment prior to cervical surgery, though it does not advocate for preoperative spinopelvic corrective surgery. Understanding these nuances can aid in managing patient expectations and potentially

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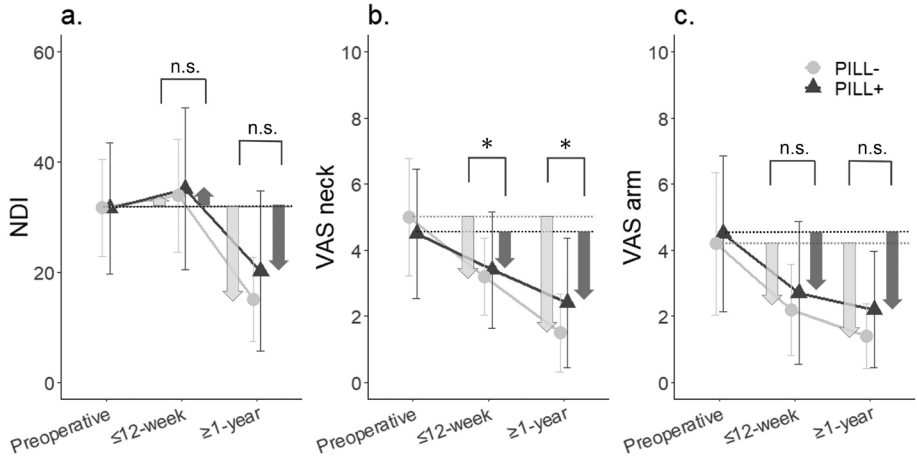
enhance postoperative satisfaction. Furthermore, these findings warrant additional research to determine the optimal approach for patients with mild global sagittal malalignment.



*, P<0.05 in comparison of improvement between matched cohort
Error bar indicates standard deviations
Arrows in the figures presents improvement from the baseline

PAPER 55

Sex, Age and Ethnicity Affect Cervical Spine Sagittal Alignment: Results of a Systematic Review and Meta-Analysis of >35,000 Asymptomatic Participants

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Introduction: Understanding normal sagittal parameters of the spine is important for treating cervical spine pathologies, especially when treating cervical deformity and avoiding creation of iatrogenic deformity. The objective of this study is to conduct a review and meta-analysis of regional and global sagittal parameters of the cervical spine in asymptomatic adults. To our knowledge, there exists no study aggregating these results into a metanalysis.

Materials and Methods: We searched PubMed for "(spine or spinal or spinopelvic or pelvic cervical) AND (alignment or reference or balance or "reciprocal angulation" or sagittal) AND (asymptomatic or volunteer or healthy or fundamental)." We included only primary observational studies on asymptomatic patients with normal spinal anatomy and no prior spinal intervention. Abstracts were reviewed for relevancy and full papers were used to collect age range, gender percentage, study inclusion and exclusion criteria, level of evidence were recorded, and the following cervical and global parameters: occiput to C2 (O-C2), cervical lordosis (CL), C2-C7 sagittal vertical axis (C2 SVA), T1 vertebral slope (T1S), C7 SVA, T1 pelvic angle (TPA), and spinosacral angle (SSA). Spinal measurements must have been performed using x-ray imaging. Data was analyzed according to sex, age (20-40 vs 40-60 vs >60 years), ethnic group (Asian, Caucasian, Hispanic, Middle Eastern), and Asian subgroup (Chinese, Japanese, Korean).

Results: Our PubMed search resulted in 5,453 citations for review. 5,069 were excluded based on relevance and 193 papers were excluded as they were not primary research. The full papers of the remaining 191 citations were assessed. They came from 27 countries and included 35,913 participants: 16,125 men (44.9%), 18,222 women (50.7%), weighted average age: 45.9 years, age range: 18-93 years. Significant findings included: [Male/Female] C2 SVA: (Overall) 2.04±0.11cm, (Male) 2.39±0.15cm, (Female)1.69±0.12cm ($p<0.001$). [Age] O-C2: (20-40) -15.67±0.4, (40-60) -13.77±0.98, (>60) -12.14±0.45 ($p=0.001$). CL: -7.61±1.29, -13.32±1.25, -15.96±0.82 ($p<0.001$). C7 SVA: 0.07±0.31cm, 0.84±0.34cm, 3.07±0.03cm ($p<0.001$). SSA: 130.91±0.44, 130.45±1.16, 126.7±1.13 ($p=0.022$). [Ethnic group] CL: Asians (-12.2±0.61) and Caucasians (-21.14±1.41) both > Middle Easterners (the reference, -0.53±4.85, $p<0.001$). [Asian subgroup] C2 SVA: Chinese (1.61±0.12cm) < Japanese (the reference, 2.2±0.15cm, $p=0.008$). T1S: Japanese (26.56±0.8) > Koreans (the reference, 21.9±1.05, $p=0.009$).

Conclusion: Ideal spinal parameter targets are used in preoperative planning, but these targets do not always take sex, age or ethnic background into account. We found that C2 SVA was greater in men than in women and that O-C2 and SSA decreased with age, while CL, C7 SVA, and TPA increased. CL, C2 SVA, T1S, and C7 SVA all showed ethnicity-dependent differences, but global alignment was largely equivalent across broad ethnic groups. The differences identified here should be incorporated into presurgical planning to ensure that

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target operative alignment is best suited to a patient's demographics.

Table 1: Mean normative overall, male and female cervical and global spinal parameters

Angle	Overall	Male	Female	P value (M vs F)	N participants (Overall)
O-C2	-14.4 (0.39)	-14.18 (0.39)	-14.68 (0.67)	0.491	2,458
CL	-12.7 (0.63)	-13.83 (0.7)	-11.57 (1.01)	0.059	8,115
C2 SVA (cm)	2.04 (0.11)	2.39 (0.15) *	1.69 (0.12) *	**<0.001**	4,670
T1S	25.4 (0.62)	26.36 (0.79)	24.27 (0.95)	0.088	5,445
C7 SVA (cm)	1.61 (0.23)	1.65 (0.29)	1.57 (0.36)	0.850	10,711
TPA	11.37 (0.79)	10.19 (0.88)	12.62 (1.28)	0.117	3,543
SSA	128.83 (0.78)	127.77 (1.09)	129.9 (1.06)	0.163	2,373

Table 1: Values in parenthesis represent Std. Error. P values are for the overall regression effect from the regression analysis. N participants is the aggregate number of male and female measurements that were reported for that parameter across all studies. * indicates statistical significance ($p<0.05$). All values are in degrees except for C2 and C7 SVA (cm).

Table 2: Mean normative cervical and global spinal parameters in different age groups

Angle	Overall	20-40	40-60	>60	P value
N Participants	23,891	10,514	3,622	9,755	n/a
O-C2	-14.51 (0.55)	-15.67 (0.4) *	-13.77 (0.98)	-12.14 (0.45) ^{R}	**0.001**
CL	-12.83 (0.73)	-7.61 (1.29) *	-13.32 (1.25)	-15.96 (0.82) ^{R}	**<0.001**
C2 SVA (cm)	2.2 (0.,12)	2.07 (0.25)	2.09 (0.13)	2.29 (0.19) ^{R}	0.726
T1S	25.96 (0.7)	24.49 (1.04)	24.71 (1.1)	27.38 (1.12) ^{R}	0.141
C7 SVA (cm)	1.85 (0.25)	0.07 (0.31) *	0.84 (0.34) *	3.07 (0.3) ^{R}	**<0.001**
TPA	11.87 (0.83)	7.58 (0.61) *	9.08 (0.54) *	14.28 (0.96) ^{R}	**<0.001**
SSA	130.41 (0.48)	130.91 (0.44) *	130.45 (1.16) *	126.7 (1.13) ^{R}	**0.022**

Table 2: Age groups are given in years. Values in parenthesis represent Std. Error. P values are the pooled p value across subgroups from the regression analysis. N participants is the aggregate number of male and female measurements that were reported for that parameter across all studies. (*) indicates statistical significance ($p<0.05$) for the individual subgroup compared to the reference group (^{R}) for the overall regression. All values are in degrees except for C2 and C7 SVA (cm).

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Table 3: Mean normative cervical and global spinal parameters in different ethnic groups						
Angle	Overall	Asian	Caucasian	Hispanic	Middle Eastern	P value
N participants	34,080	22,585	7,941	1,421	803	n/a
O-C2		-14.4 (0.4)	-	-	-	n/a
CL	-12.7 (0.63)	-12.2 (0.61) *	-21.14 (1.41) *	-	-0.53 (4.85) ^{R}	**<0.001**
C2 SVA (cm)	2.04 (0.11)	2.0 (0.11)	-	-	2.79 (0.33) ^{R}	0.086
T1S	25.4 (0.62)	25.35 (0.67)	-	25.14 (0.61) ^{R}	-	0.932
C7 SVA (cm)	1.61 (0.23)	1.71 (0.23)	2.64 (0.54)	-0.53 (0.34) ^{R}	-1.4 (0.93)	0.07
TPA	11.37 (0.79)	11.37 (0.87)	14.67 (0.6)	7.93 (0.42) ^{R}	-	0.217
SSA	128.83 (0.78)	127.48 (1.46)	130.13 (0.62) ^{R}	-	-	0.108

Table 3: Age groups are given in years. Values in parenthesis represent Std. Error. P values are the pooled p value across subgroups from the regression analysis. N participants is the aggregate number of male and female measurements that were reported for that parameter across all studies. (*) indicates statistical significance ($p<0.05$) for the individual subgroup compared to the reference group (^{R}) for the overall regression. All values are in degrees except for C2 and C7 SVA (cm). Only the Asian group had data for O-C2, so no reference group was designated. Some groups had no data for a given parameter and were left blank.

PAPER 56

Fusion Outcomes of GLP-1 Agonist Therapy in Multi-Level Cervical Spinal Fusion: A Propensity-Matched Analysis

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Introduction: The rising prevalence of obesity and diabetes mellitus has rendered the usage of glucagon-like peptide-1 receptor (GLP-1) agonists increasingly commonplace since their introduction in 2005. However, there is a dearth of evidence to suggest whether outcomes of multi-level cervical spinal fusion differ in patients treated with GLP-1 agonists. This study assesses rates of pseudarthrosis in patients who underwent multi-level cervical spine fusion with and without concurrent GLP-1 agonist therapy.

Materials and Methods: The TriNetX, LLC Diamond Network database was queried utilizing CPT codes for patients undergoing both anterior and posterior multi-level cervical spinal fusion from 2005 to 2024. Patients prescribed liraglutide, pramlintide, tirzepatide, semaglutide, lixisenatide, or dulaglutide within one year of surgery were propensity matched to patients without GLP-1 agonist prescriptions. Cohort balancing was achieved categorically according to age at procedure, race, sex, and nicotine dependence. Cohort balancing was performed continuously to account for body mass index, hemoglobin A1C, and estimated glomerular filtration rate at the time of procedure. Diagnosis codes for pseudarthrosis after attempted fusion were concomitantly utilized to assess pseudarthrosis rates at 6-months, 1-year, and 2-years postoperatively using Fisher's exact test. Statistical significance was set at $p<0.05$.

Results: In consideration of anterior multi-level cervical fusion, 1204 patients utilized GLP-1 agonist therapy, while 1204 patients did not use GLP-1 agonists. With respect to posterior multi-level cervical fusion, 1378 patients utilized GLP-1 agonist therapy, and 1378 patients did not have a GLP-1 agonist prescription. Anterior postoperative pseudarthrosis rates were significantly decreased in the GLP-1 agonist cohort versus the non-GLP-1 agonist cohort at 6-months (10.71% vs. 17.61%; $p<0.001$), 1-year (12.04% vs. 18.52%; $p<0.001$), and 2-years (12.87% vs. 19.19%; $p<0.001$). Posterior postoperative pseudarthrosis rates were also significantly decreased in the GLP-1 agonist cohort versus the non-GLP-1 agonist cohort at 6-months (13.21% vs. 22.28%; $p<0.001$), 1-year (14.37% vs. 24.45%; $p<0.001$), and 2-years (16.87% vs. 24.43%; $p<0.001$).

Conclusion: Our findings demonstrate a statistically significant lower incidence of pseudarthrosis among patients treated with GLP-1 agonist therapy at all timepoints within this study – from 6-months to 2-years postoperatively, suggesting a potentially beneficial effect of GLP-1 agonist therapy in promoting fusion success in multi-level cervical spine surgery. Fundamentally, this aligns with the pharmacodynamic nature of GLP-1 agonists: as compounds that enhance osteoblastic activity and suppress osteoclastic activity, thereby facilitating bone formation and attenuating bone resorption. Further investigation into the mechanistic underpinnings of GLP-1 agonists' effects on bone metabolism may pave the way for enhancing the success of cervical spine surgery.

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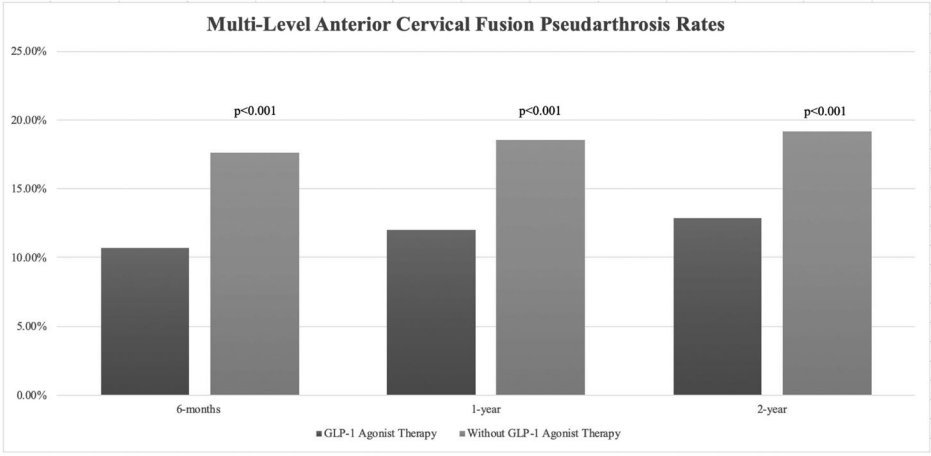

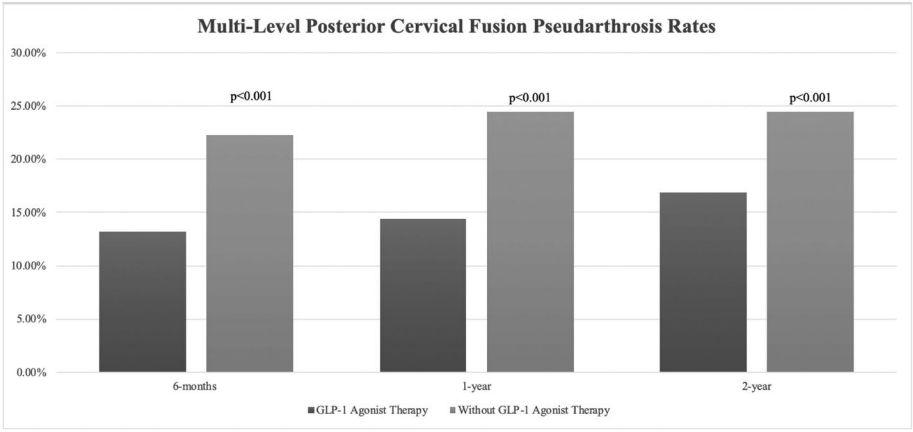

PAPER 57

Should We Re-Instrument the Originally Fused Level in Adjacent-Segment ACDF?: A Quality Outcomes Database Study

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Introduction: Adjacent-segment disease continues to be a clinically significant issue for patients undergoing anterior cervical discectomy and fusion (ACDF) surgery. Re-instrumenting the originally fused segment provides greater biomechanical stability of the construct. However, there remains a relative paucity of research investigating the differences in outcomes between patients undergoing re-instrumentation of the originally fused level vs only the adjacent-segment level. In a cohort of patients undergoing revision ACDF, we sought to determine the difference between multi-level vs single level instrumentation on: 1) perioperative variables, 2) patient-reported outcome measures (PROMs), and 3) reoperation.

Materials and Methods: A retrospective cohort study using the Quality Outcome Database was conducted for patients who underwent single level, adjacent-segment revision ACDF. The primary exposure variable was re-instrumentation of the original segment. Patient characteristics and perioperative variables were compared. Outcomes of interest were 12-month reoperation and 3-, 12-, and 24-month PROMs, including numeric rating scale for neck and arm pain, neck disability index, quality of life (QALY) and modified Japanese Orthopaedic Association scores (when applicable). Multivariable regression models were fitted for each outcome, controlling for age, sex, body mass index, race, smoking status, medical comorbidities, primary diagnosis, and baseline PROMs.

Results: Of 1,255 patients (age 57.1±10.4; 47.0% male) undergoing revision ACDF, 364 (29.0%) had re-instrumentation of the originally fused level. On bivariate and regression analysis controlling for age, sex, body mass index, race, smoking status, medical comorbidities, primary diagnosis, and baseline PROMs, patients with re-instrumentation of the originally fused level had greater blood loss (56.7±65.1 vs. 37.1±43.8mL, $p<.001$; $\beta=18.9$, 95%CI=12.4-25.5, $p<.001$), operative time (120.3±49.6 vs. 90.3±36.9mins, $p<.001$; $\beta=29.8$, 95%CI=24.6-35.0, $p<.001$) and length of hospital stay (1.3±1.0 vs. 1.1±1.0days, $p=.003$; IRR=1.18, 95%CI=1.1-1.3, $p=.005$) than patients without re-instrumentation of the originally fused level. There was no difference in PROMs at 3-, 12- and 24- months between patients with two-level and single-level revision ($p>0.05$). Further, there was no difference in reoperation rates between the groups at 3 (5.1% vs. 3.1%, $p=.154$) and 12-months (6.7% vs. 4.0%, $p=.194$) postoperatively.

Conclusion: Among a cohort of patients undergoing revision ACDF, patients who underwent re-instrumentation of the originally fused level had significantly greater blood loss, operative time, and length of hospital stay compared to single-level revision patients. However, there were no significant differences in PROMs at 3-, 12-, and 24-month follow-ups or reoperation rates at both 3- and 12-months postoperatively between the two groups. Given the comparable long-term outcomes, when clinically feasible, surgeons may consider avoiding re-instrumentation of the original ACDF fusion, opting for a single-level revision to minimize the risk of complications associated with increased perioperative blood loss, and operative time.

PAPER 58

Differences in European and North American Results in Secondary Surgery Following Cervical Disc Arthroplasty vs. Anterior Cervical Discectomy and Fusion: Systematic Review and Meta-analysis of Randomized Controlled Trials

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Introduction: Cervical disc arthroplasty (CDA) and anterior cervical discectomy and fusion (ACDF) are both treatment options for patients with cervical degenerative disc disease. Prior studies have demonstrated lower rates of adjacent segment degeneration (ASD) and secondary surgery after CDA compared to ACDF, yet the geographic differences in prior randomized controlled trial (RCT) data are unclear.

Materials and Methods: Two independent reviewers searched PubMed, Embase, and the Cochrane Library for RCTs comparing CDA and ACDF for cervical degenerative disc disease with at least 60 months of follow-up. We then grouped study results based on European or North American study location. The risk ratio or standardized mean difference (and 95% CIs) were calculated for dichotomous or continuous variables, respectively.

Results: A total of 5 RCTs were included for analysis published between 2014-2023. Two studies were performed in Europe and 3 were performed in North America. The North American RCTs were more likely to be industry sponsored. The pooled North American RCT analysis showed a significant benefit of CDA over ACDF for ASD requiring secondary surgery (combined OR 0.47, 95% CI 0.32 – 0.70, p = 0.0002), whereas no difference was seen in the pooled analysis of European RCTs (OR 0.46, 95% CI 0.07 – 2.89, p = 0.40). No differences in NDI or VAS neck or arm scores were observed between regions. When the RCTs with at least 60 months follow-up were combined, European RCTs had statistically higher rates of postoperative follow up in ACDF patients vs. North American RCTs (p = 0.03).

Conclusion: The results of this meta analysis of RCT data from North America and Europe comparing CDA vs. ACDF suggest that North American RCTs were more likely to demonstrate a positive benefit of CDA over ACDF for ASD requiring secondary surgery, were more likely to be industry sponsored, and more likely to have lower postoperative follow up rates.

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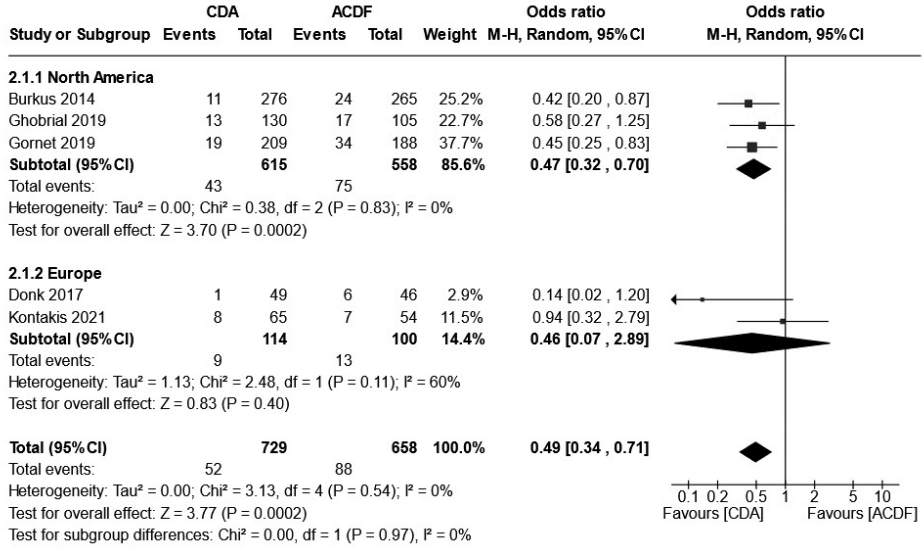
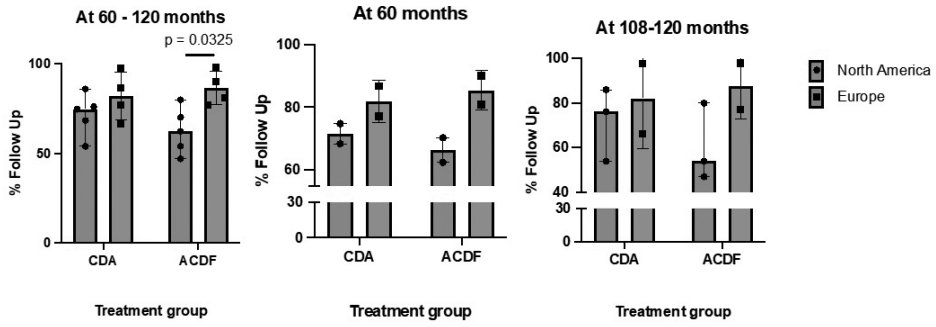
FIGURE 1. Symptomatic Adjacent Level Degeneration Requiring Surgery @108-120 mos Follow Up





When the studies with at least 60 months follow-up are combined, randomized clinical trials in Europe had statistically higher rates of follow up with patients who have undergone ACDF than in North America (P = 0.0325).

PAPER 59

An Economic Analysis of the Cervical Spondylotic Myelopathy Surgical (CSM-S) Trial: Cost-Effectiveness of Anterior and Posterior Approaches

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Introduction: Surgery for cervical spondylotic myelopathy (CSM) improves quality of life but surgical approaches might differ by cost. A formal cost-effectiveness study of anterior and posterior approaches for cervical myelopathy has not been performed in the past. We aimed to evaluate the cost-effectiveness of anterior cervical discectomy and fusion (ACDF), posterior laminectomy/ fusion (PCDF), and laminoplasty (LP) for treating cervical spondylotic myelopathy.

Materials and Methods: We conducted a cost-effectiveness analysis of a prospective randomized trial comparing surgical approaches for CSM across 15 sites in North America. Patients were randomized (2:3) to either anterior surgery (ACDF) or posterior surgery (LP or PCDF, at surgeon's discretion). A cost analysis was performed from a societal perspective with a one-year time horizon, including only patients from the United States. Direct costs were estimated using 2022 Medicare reimbursement rates for professional fees and cost-to-charge ratios. Indirect costs were estimated using a human capital approach based on patient surveys. Effectiveness was measured in quality-adjusted life-years (QALYs) using the Euro-Qol-5-Dimensions (EQ-5D) at one year.

Results: 153 patients were included as-treated in a three-way cost analysis by surgical approach. Index hospitalization costs were higher after PCDF than ACDF and LP ($32,507 vs. $24,991 vs. $24,574, p<0.001). 34 patients (22.2%) had complications. Complication costs and lost wages did not differ between groups. One-year total costs were higher after PCDF than ACDF and LP ($49,590 vs. $39,678 vs. $40,716; p=0.007). For 71 patients with one-year costs and EQ-5D outcomes available, PCDF was associated with lower QALY gains than ACDF (0.687 vs. 0.786, p=0.029) and LP (0.687 vs. 0.791, p=0.062).

Conclusion: Among patients in the CSM-S Trial, LP and ACDF had similar cost-utility. PCDF was less cost-effective, yielding worse outcomes with higher costs, driven by index hospitalization.

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Cost Measures	Laminoplasty	Posterior Cervical Decompression/ Fusion	Anterior Cervical Decompression/ Fusion	P-value
	n=28	n=64	n=61	
Index Hospitalization (USD), mean (SD)	n=28 24,574 (9,123)	n=64 32,507 (12,263)	n=60 24,991 (13,345)	**<0.0001***
1-year Follow-Up (USD), mean (SD)	n=28 4,278 (7,946)	n=64 2,813 (5,582)	n=60 4,348 (11,213)	0.516
1-year Total Direct Costs (USD), mean (SD)	n=28 28,852 (13,868)	n=64 35,320 (13,714)	n=60 28,852 (18,421)	**0.0014***
Lost Wages (USD), mean (SD)	n=17 19,542 (20,553)	n=34 26,861 (22,108)	n=35 18,856 (18,825)	0.4551
1-year Total (Direct and Indirect) Costs (USD), mean (SD)	n=28 40,716 (23,495)	n=64 49,590 (24,275)	n=60 39,678 (27,983)	**0.0072***

Table 1: Cost measures by assigned as-treated surgical groups in the CSM-S Trial. Follow-up costs indicate resource utilization within one year after index hospitalization. Lost wages were calculated using a human capital approach, based on lost productivity reported in patient surveys and national median weekly wages for 2022 reported by the Bureau of Labor Statistics.

Abbreviations: SD, standard deviation. USD, U.S. dollars.

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		LP	PCDF	ACDF	Estimated Between-Group Mean Differences (95% CI)	P-value
		n=15	n=27	n=29		
One-year total costs, predicted mean (SE)		48,867 (6,595)	60,100 (6,045)	49,853 (4,839)	ACDF vs. PCDF: -10,246 (-25,423 – 4,930) ACDF vs. LP: 986 (-15,045 – 17,017) PCDF vs. LP: 11,232 (-6,301 – 28,767)	0.186 0.904 0.209
One-year QALY gained, mean (SD)		0.791 (0.047)	0.687 (0.030)	0.786 (0.034)	ACDF vs. PCDF: 0.099 (0.01 – 0.18) ACDF vs. LP: -0.005 (-0.12 – 0.11) PCDF vs. LP: -0.104 (-0.21 – 0.01)	**0.029*** 0.927 0.062
ICER		60,100 > 48,867 0.687 < 0.791		-	LP dominates PCDF	
		-	60,100 > 49,853 0.687 < 0.786		ACDF dominates PCDF	

Table 2: Incremental cost-effectiveness ratio analysis by as-treated surgical groups in the CSM-S Trial, calculated as the difference between treatment groups in mean cost divided by the difference between groups in mean QALYs. QALYs were calculated from patient responses to the EQ-5D instrument, to measure utility preference scores at baseline, 3, 6, and 12 months, based on a U.S population value set and assuming a linear relationship between utility measurements at consecutive time points.

Abbreviations: SE, standard error. SD, standard deviation. CI, confidence interval. QALY, quality-adjusted life-years. ICER, incremental cost-effectiveness ratio. PCDF, posterior cervical decompression/fusion. LP, laminoplasty. ACDF, anterior cervical decompression/fusion. EQ-5D, EuroQoL-5 Dimensions.

PAPER 60

Upper-level Instrumentation at C2 Versus C3 does Not Influence Radiographic or Clinical Outcomes After Posterior Cervical Fusion

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University of Kansas Medical Center[1] Rothman Orthopaedic Institute, Thomas Jefferson University[2] Northwestern University[3]

Introduction: For patients who require posterior cervical instrumentation for cervical spondylotic myelopathy (CSM), the evidence is sparse as to whether C2 versus C3 is the optimal upper instrumented vertebra (UIV). This study analyzes postoperative clinical and radiographic outcomes for posterior cervical decompression and fusion (PCDF) comparing constructs with UIV at C2 versus C3.

Materials and Methods: Adult patients undergoing PCDF for CSM from 2014 to 2019 at a single center were identified. Patients with UIV at either C2 or C3, and a lower instrumented vertebra (LIV) up to T2, were included. Exclusion criteria included pediatric patients, revision procedures, staged procedures, and intervention for infectious, oncologic, or traumatic indications. Patients with incomplete follow-up (e.g. less than 2 years postoperatively) were excluded from the final analysis. Demographic data, surgical characteristics, clinical outcomes, and radiographic outcomes were compared between groups. Radiographic metrics of interest included cervical sagittal vertical axis (cSVA), T1 slope, cervical lordosis (CL), T1 slope minus cervical lordosis (TS-CL), and C0-C2 angle. Student's t test for continuous variables and chi-squared or Fisher exact tests for categorical variables were utilized to compare outcomes. Multivariate logistic regression analyses were utilized to determine the effect of UIV on both clinical and radiographic outcomes.

Results: A total of 135 patients were included, of whom 47 (34.8%) had a UIV at C2 and 88 (65.2%) had a UIV at C3. On univariate analysis, patients with UIV at C2 tended to be older (66.1 vs 59.7, $p = 0.002$), more predominately female (55.3% vs 36.8%, $p = 0.039$), and have more medical comorbidities (CCI 3.2 vs 2.3, $p = 0.004$) (Table 1). There was no difference in number of levels fused, estimated blood loss. or use of osteotomies ($p > 0.05$) between patients with UIV at C2 versus C3 (Table 1). UIV at C3 resulted in significantly shorter operative time compared to C2 UIV (291.3 min vs 387.8 min, $p = 0.036$). Overall, there was no difference in 90-day readmission or 2-year reoperation between the groups ($p>0.05$) (Table 2). The mean difference from baseline to final follow-up in cSVA, T1 slope, CL, TS-CL, and C0-C2, metrics were statistically similar between groups ($p>0.05$) (Table 3). Multivariate analysis controlling for demographic factors and operative factors, did not reveal any correlation between UIV and radiographic outcomes ($p>0.05$).

Conclusion: Current evidence regarding the optimal upper instrumented level in PCDF for cervical spondylotic myelopathy is sparse. Prior studies have identified biomechanical advantages of obtaining fixation in C2, however, the long-term clinical benefits are less clear. There were no significant differences in postoperative clinical or radiographic outcomes with an upper instrumented vertebra of C2 versus C3 in patients undergoing posterior cervical decompression and fusion for cervical spondylotic myelopathy at 2 years postoperatively.

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The added complexity of C2 instrumentation does not appear to be critical in successful radiographic and clinical outcomes after posterior cervical decompression and fusion for myelopathy.

Table 1. Patient demographics and surgical variables

Variable	C2 UIV	C3 UIV	p-value
Demographics			
Age	66.13 ± 11.24	59.72 ± 11.85	0.002
Sex (% females)	55.3%	36.80%	0.039
Body Mass Index (kg/m^2)	30.6 ± 6.9	29.1 ± 5.6	0.17
Charlson Comorbidity Index	3.2 ± 1.7	2.3 ± 1.7	0.004
History of smoking	4.2%	17.2%	0.03
Diabetes mellitus	29.9%	19.8%	0.18
Osteoporosis	9.1%	11.3%	0.59
Depression	17.0%	6.90%	0.001
Surgical variables			
Levels fused	5.2 ± 2.5	4.6 ± 1.5	0.08
Estimated blood loss (ml)	399.0 ± 508.5	276.8 ± 235.9	0.06
Operative time (min)	378.8 ± 203.4	291.3 ± 239.8	0.03
Approach			0.02
Posterior	89.40%	74.70%	
Combined	8.50%	25.30%	
Osteotomy			
Smith-Peterson (SPO)	10.6%	8.50%	0.61
Pedicle subtraction (PSO)	8.1%	5.30%	0.54
VCR	2.3%	0%	0.17

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Table 2. Clinical outcome measures

Variable	C2 UIV	C3 UIV	p-value
90-day readmission	14.9%	20.7%	0.49
Reason for readmission			
Pain	25%	21%	
New neurologic symptoms	13%	5%	
Wound complication	38%	32%	
Infection	13%	16%	
Medical complication	25%	26%	
2-year reoperation	17%	14%	0.62

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Table 3. Radiographic parameters at pre-op and 1-year post-op			
	C2 UIV[1]	C3 UIV[1]	P
cSVA (mm)			
Pre-op	41.4 ± 20.3	39.1 ± 21.0	0.943
Post-op	37.1 ± 14.0	31.9 ± 15.2	0.461
Mean difference[2]	-4.3 ± 6.3	-7.2 ± 5.8	0.753
CL (degrees)			
Pre-op	-10.7 ± 18.7	-5.8 ± 21.0	0.878
Post-op	7.7 ± 14.9	10.1 ± 14.4	0.915
Mean difference[2]	18.4 ± 4.8	15.9 ± 6.6	0.797
T1s (degrees)			
Pre-op	30.9 ± 14.4	30.1 ± 17.1	0.975
Post-op	37.9 ± 12.7	32.2 ± 14.6	0.415
Mean difference[2]	7.0 ± 1.7	2.1 ± 2.5	0.181
TS-CL (degrees)			
Pre-op	44.5 ± 24.4	36.3 ± 19.2	0.797
Post-op	33.0 ± 15.1	23.1 ± 9.4	0.560
Mean difference[2]	-11.5 ± 9.3	-13.2 ± 9.8	0.910
C0-C2 (degrees)			
Pre-op	41.5 ± 9.3	39.5 ± 5.0	0.836
Post-op	35.9 ± 6.9	34.2 ± 0.9	0.743
Mean difference[2]	-5.6 ± 2.4	-5.3 ± 4.1	0.959
McGS (degrees)			
Pre-op	10.2 ± 15.6	0.7 ± 11.7	0.630
Post-op	2.9 ± 8.0	-5.5 ± 7.8	0.492
Mean difference[2]	-7.3 ± 7.6	-6.2 ± 3.9	0.887
C0 slope (degrees)			
Pre-op	3.6 ± 15.2	-3.2 ± 15.5	0.777
Post-op	-4.2 ± 8.8	-10.8 ± 10.5	0.676
Mean difference[2]	-7.8 ± 6.4	-7.6 ± 5.0	0.981
C1 slope (degrees)			
Pre-op	6.2 ± 18.9	-2.0 ± 20.2	0.791
Post-op	-2.8 ± 14.8	-13.6 ± 10.2	0.542
Mean difference[2]	-9.0 ± 4.1	-11.6 ± 10.0	0.853
C2 slope (degrees)			
Pre-op	45.1 ± 24.5	36.3 ± 20.5	0.792
Post-op	31.7 ± 15.7	23.4 ± 9.6	0.635
Mean difference[2]	-13.4 ± 8.8	-12.9 ± 10.9	0.976

[1]Reported as mean ± standard error measurement

[2]Mean difference of metric at 1-year postoperative compared to preoperative baseline

PAPER 61

Does Spinal Canal – Cord Mismatch Adversely Affect Clinical Outcomes of Anterior Cervical Discectomy and Fusion for the Treatment of Cervical Myelopathy?

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Introduction: Anterior cervical discectomy and fusion (ACDF) is a versatile surgical technique used to address various causes of degenerative cervical myelopathy. Previous studies have shown that spinal cord edema and swelling contribute to the pathology of cervical myelopathy, suggesting that widening the spinal canal beyond the size of the spinal cord may benefit clinical outcomes by providing space for cord swelling during recovery. However, in cases with combined spinal canal-cord mismatch (SCCM), akin to congenital stenosis, ACDF may not offer sufficient space for spinal cord volume expansion. A recent survey of AO Spine members has indicated a preference for the posterior approach for cervical myelopathy in the presence of SCCM, yet this preference lacks clinical evidence. Thus, this study aims to elucidate the clinical implications of SCCM on the outcomes of ACDF. We hypothesized that patients with SCCM would experience less neurological improvement after ACDF.

Materials and Methods: A total of 186 patients who underwent ACDF for degenerative cervical myelopathy and were followed up for over two years were retrospectively reviewed. Patients with a canal-cord ratio of ≥70% were classified into the SCCM group, while those with a ratio of <70% were included in the no-SCCM group. Outcome measures included C2-C7 sagittal vertical axis, C2-C7 lordosis, neck pain visual analogue scale (VAS), arm pain VAS, and Japanese Orthopedic Association (JOA) score.

Results: One hundred forty-seven patients (79.0%) were included in the no-SCCM group, while the remaining 39 patients were in the SCCM group (21.0%). Baseline characteristics and pre/postoperative radiographic results did not show significant intergroup differences (Table 1, Table 2). Both groups experienced significant improvements in neck pain VAS and arm pain VAS after the operation, with no significant differences between the two groups postoperatively. Additionally, JOA scores significantly improved in both groups postoperatively, with no significant intergroup differences in JOA score or JOA recovery rate (Table 3). Canal-cord ratio was not significantly associated with JOA recovery rate at two years postoperative in linear regression analysis (beta, -0.014; 95% confidence interval, -204.416 – 169.889; p=0.856).

Conclusion: This study demonstrates that clinical outcomes, including neck pain, arm pain, and JOA score after ACDF, are not negatively affected by SCCM. Postoperative outcomes did not significantly differ between the no-SCCM and SCCM groups, and canal-cord ratio was not significantly associated with postoperative JOA score. Contrary to common belief that canal expansion surgery, such as laminoplasty or laminectomy, may benefit patients with SCCM, ACDF appears to provide favorable outcomes for cervical myelopathy complicated by SCCM. Further studies comparing anterior and posterior approaches for treating SCCM could provide clarity on this matter. In conclusion, ACDF can be safely and effectively applied for treating cervical myelopathy, regardless of the presence of SCCM, when the number of levels, sagittal alignment, and shape of compressive pathology favor the anterior approach.

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Table 1. Patient characteristics

	No-SCCM (n = 147)	SCCM (n = 39)	P value
Age	59.7±10.9	59.4±11.0	0.875
Sex (M:F)	84:63	22:17	1.000
BMI	25.2±3.5	25.6±3.6	0.515
DM	26 (17.7%)	8 (20.5%)	0.648
Hypertension	48 (32.7%)	11 (28.2%)	0.700
Smoking	33 (22.4%)	6 (15.4%)	0.385
Number of levels operated	1.9±0.8	1.8±0.7	0.305
Follow-up period	58.1±30.2	62.2±28.5	0.441

SCCM, spinal canal – cord mismatch; M, male; F, female; BMI, body mass index

Continuous variables were analyzed using Student's t-test

Categorical variables were analyzed using a chi-square test

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Table 2. Radiographic results

		No-SCCM	SCCM	P value
Preoperative	SCOR	0.62±0.04	0.72±0.03	<0.001*
	Spondylolisthesis	10 (6.8%)	2 (5.1%)	1.000
	C2-C7 SVA	16.1±21.6	13.2±17.5	0.446
	C2-C7 lordosis	9.3±8.8	10.8±8.8	0.325
Postoperative 3 months	C2-C7 SVA	16.4±24.5	16.6±17.3	0.479
	C2-C7 lordosis	12.7±8.0	10.9±7.3	0.108
Postoperative 2 years	C2-C7 SVA	22.7±19.3	18.7±10.3	0.305
	C2-C7 lordosis	12.2±7.8	11.1±7.5	0.478

SCCM, spinal canal – cord mismatch; SCOR, spinal cord occupying radio; SVA, sagittal vertical axis

All variables were compared using Student's t-test

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Table 3. Patient reported outcome measures

		No-SCCM	SCCM	P value
Preoperative	Neck pain VAS	3.5±2.6	3.4±2.7	0.746
	Arm pain VAS	4.3±2.7	3.7±2.3	0.193
	JOA	13.7±2.5	13.8±1.6	0.812
Postoperative 3 months	Neck pain VAS	1.9±2.1	1.4±1.6	0.207
	Arm pain VAS	2.5±2.6	2.4±2.3	0.853
	JOA	14.7±2.3	15.6±1.3	0.056
	JOA recovery rate	42.1±59.5	57.9±41.2	0.085
Postoperative 2 years	Neck pain VAS	2.1±2.3	1.7±2.0	0.369
	Arm pain VAS	2.9±2.8	2.7±2.4	0.332
	JOA	14.6±2.3	15.0±2.0	0.203
	JOA recovery rate	31.9±68.5	44.1±58.1	0.350

SCCM, spinal canal – cord mismatch; VAS, visual analogue scale; JOA, Japanese Orthopedic Association

All variables were compared using a Student's t-test

PAPER 62

Outcomes After Cervical Laminectomy and Fusion versus Cervical Laminoplasty in Patients of Advanced Age

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Introduction: The prevalence of cervical spondylotic myelopathy (CSM), the most common cause of spinal cord dysfunction in adults, increases with advanced age. CSM is often effectively treated with one of a variety of surgical procedures, with the prevalent posterior options including laminectomy and fusion or laminoplasty. Both of these procedures have been associated with increased morbidity and mortality in the elderly population. However, the risks of laminectomy and fusion versus laminoplasty have not yet been fully compared to each other as a function of age. The magnitude of the increased risk remains unclear. The purpose of this study was to assess the effects of advancing age in CSM patients undergoing either cervical laminectomy and fusion or laminoplasty within a single surgeon cohort.

Materials and Methods: This study retrospectively identified patients undergoing primary laminectomy and fusion or laminoplasty procedures indicated for CSM in a single surgeon cohort (2004-2023). Data from the patients' medical background, procedure, inpatient hospital admission, and outpatient follow-up were collected. Patients were subdivided into those younger than 65 years of age and those 65 years of age or older for analysis. Multivariable logistic regression was then utilized to analyze the relationship between age group and a variety of endpoints, including rate of adverse events, reoperation rates within one year, ongoing opioid use, and peripheral nerve injury.

Results: In our cohort of 365 patients, age group had no influence on which procedure was performed, laminectomy and fusion vs laminoplasty (P=0.91). Across all ages, when compared to laminectomy and fusion, laminoplasty was associated with significantly lower odds of having an adverse postoperative event (OR = 0.12 [0.04, 0.39], p = 0.001), a complication (OR = 0.08 [0.02, 0.35], p = 0.001), a peripheral nerve injury (OR = 0.08 [0.01, 0.73], p = 0.03), or using opioids past six months postoperative (OR = 0.17 [0.06, 0.46], p =0.001). Interestingly, the younger laminectomy and fusion group had significantly higher odds of postoperative adverse events when compared to the elderly laminoplasty group (17.5% vs. 4.6%, p = 0.01), despite a lower prevalence of medical comorbidities.

Conclusion: Findings from our retrospective cohort support the implementation of cervical laminoplasty as a safer treatment alternative in patients of advanced age with cervical spondylotic myelopathy. Data suggest that cervical laminoplasty has a lower rate of adverse postoperative events, complications, peripheral nerve injuries, as well as decreased likelihood of prolonged opioid use for patients across all age groups.

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Table 1. Demographic information.

Variable[a]	<65 years old (N = 208)	≥65 years old (N = 157)	P-value[b]
Age (years)	55.1 ± 8.8 (range 14-64)	71.6 ± 5.7 (range 65-95)	<0.001*
Sex	Male: 141 (67.8%) Female: 67 (32.2%)	Male: 116 (73.9%) Female: 41 (26.1%)	0.25
BMI	30.3 ± 6.4	28.6 ± 5.4	<0.02*
ASA status	I: 11 (5.3%) II: 126 (60.6%) III: 68 (32.7%) IV: 3 (1.4%)	I: 5 (3.2%) II: 60 (38.2%) III: 86 (54.8%) IV: 6 (3.8%)	<0.001*
Prior spine surgery	73 (35.1%)	34 (21.7%)	0.005*
Opioid use <1 month prior to surgery	No: 115 (55.3%) Yes: 41 (19.7%) Unknown: 52 (25.0%)	No: 93 (59.2%) Yes: 22 (14.0%) Unknown: 42 (26.8%)	0.36
Any comorbidity	132 (63.5%)	133 (84.7%)	<0.001*
Asthma	22 (10.6%)	7 (4.5%)	0.03*
Diabetes mellitus	29 (13.9%)	38 (24.2%)	0.01*
Hypertension	80 (38.5%)	103 (65.6%)	<0.001*
Hyperlipidemia	65 (31.3%)	79 (50.3%)	<0.001*
Coronary artery disease	17 (8.2%)	35 (22.3%)	<0.001*
COPD	5 (2.4%)	3 (1.9%)	1.00
Arthritis	6 (2.9%)	20 (12.7%)	<0.001*
GERD	28 (13.5%)	18 (11.5%)	0.63

[a] Mean ± standard deviation, count (%)

[b] P-values for Mann-Whitney U test or chi-squared test

* P-value <0.05

Abbreviations: BMI – body mass index, ASA – American Society of Anesthesiologists, COPD – chronic obstructive pulmonary disease, GERD – gastroesophageal reflux disease

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Table 2. Operative information.

Variable[a]	<65 years old (N = 208)	≥65 years old (N = 157)	P-value[b]
Procedure type	LF: 120 (57.7%) LP: 88 (42.3%)	LF: 92 (58.6%) LP: 65 (41.4%)	0.91
Procedure approach	Posterior: 205 (98.6%) Anterior: 2 (1.0%) Both: 1 (0.5%)	Posterior: 157 (100.0%) Anterior: 0 (0.0%) Both: 0 (0.0%)	0.51
Anesthesia time (min)	269.4 ± 61.4	274.8 ± 54.3	0.20
Procedure time (min)	155.3 ± 54.3	151.2 ± 39.4	0.86
Estimated blood loss (mL)	339.5 ± 265.3	369.6 ± 249.0	0.22
Length of stay (days)	3.7 ± 2.5	3.7 ± 1.9	0.27
# of vertebrae instrumented	5.6 ± 1.1	5.4 ± 1.0	0.25
Most common UIV	C3: 119 (57.2%)	C3: 89 (56.7%)	n/a
Most common LIV	T1: 115 (55.3%)	T1: 69 (44.0%)	n/a

[a] Mean ± standard deviation, count (%)

[b] P-values for Mann-Whitney U test or chi-squared test

Abbreviations: LF – cervical laminectomy with fusion, LP – cervical laminoplasty with reconstruction, UIV – upper instrumented vertebra, LIV – lower instrumental vertebra

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Table 3. Outcomes by age group.

Variable[a]	<65 years old (N = 208)	≥65 years old (N = 157)	P-value[b]
Any adverse event	22 (10.6%)	15 (9.6%)	0.86
Any complication	19 (9.1%)	12 (7.6%)	0.71
C5 palsy	11 (5.3%)	7 (4.5%)	0.81
C8 palsy	1 (0.5%)	3 (1.9%)	0.32
Peripheral nerve injury	11 (5.3%)	10 (6.4%)	0.66
Reoperation within 1 year	6 (2.9%)	1 (0.6%)	0.25
Superficial SSI	1 (0.5%)	1 (0.6%)	1.00
Pulmonary embolism	2 (1.0%)	0 (0.0%)	0.51
Deep venous thrombosis	1 (0.5%)	0 (0.0%)	1.00
Stroke	0 (0.0%)	1 (0.6%)	0.43
Durotomy	2 (1.0%)	1 (0.6%)	1.00
Readmission within 30 days	2 (1.0%)	2 (1.3%)	1.00
Readmission within 90 days	7 (3.4%)	4 (2.6%)	0.76
Opioid use at ≥6 months postoperative	No: 145 (69.7%) Yes: 24 (11.5%) Unknown: 39 (18.8%)	No: 118 (75.2%) Yes: 15 (9.6%) Unknown: 24 (15.3%)	0.53

[a] Count (%)

[b] P-values for chi-squared test

Abbreviations: SSI – surgical site infection

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PAPER 63

Ossification of Posterior Longitudinal Ligament (OPLL) Growth in C1/2 Segment and its Effect on Clinical Outcome : Is C2 Laminectomy Really Necessary?

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Introduction: When performing decompressive surgery for cervical ossification of posterior longitudinal ligament (OPLL), surgeons prefer to spare C2 lamina because it plays crucial role in cervical stability. Also, the spinal canal space is relatively larger in C1/2 segment, which makes it resistant to clinical deterioration despite OPLL growth. However, radiologic progression of OPLL involving C1/2 segment which had not been surgically decompressed and its impact on clinical outcome is not yet accurately assessed in literature.This study aims to confirm that OPLL in C1/2 segment that had not been surgically decompressed is clinically silent despite radiologic growth.

Materials and Methods: This is a retrospective study from a single institution with minimum of 2 years of radiologic follow-up. Patients with cervical OPLL which involved C1/2 segment, and who underwent decompressive surgery between January 2011 and December 2018 were enrolled. Patients who were preserved with more than half of C2 lamina were grouped into C2 sparing group, and the patients who received laminectomy of more than half of C2 lamina were grouped into C2 laminectomy group. At the final follow-up, radiologic growth of OPLL was defined as: 2mm increase in either sagittal thickness or longitudinal elongation. The spinal stenosis in C1/2 segment was defined as the loss of CSF space at any level above the upper lamina of C2. Clinical outcome was collected as patient's self-report at final follow-up.

Results: 144 patients were enrolled, with 75 patients in C2 laminectomy group and 69 patients in C2 sparing group. The follow up periods were slightly longer in C2 laminectomy group (5.9 years vs.5.1 years, p=0.149). The C2 laminectomy group was confirmed with significantly larger diameter, length, and occupying ratio of C1/2 OPLL, and a higher rate of C1/2 stenosis at the baseline. The C2 laminectomy group and C2 sparing group had comparable rate of radiologic growth of C1/2 OPLL at the final follow-up. (50.7% vs. 53.6%, p=0.851). However, diagnosis of C1/2 stenosis at the final follow-up was still lower in C2 sparing group than C2 laminectomy group (12.0% vs 4.3%, p=0.174). And for both groups, most of the radiologic progression was due to the length progression, and the width progression was very rare (49.3% vs. 53.6% for length, 1.3% vs. 4.3% for width). Also, there were no new cases of clinical relapses caused by cord compression in the C1/2 segment in either group.

Conclusion: OPLL in C1/2 segment is clinically silent despite the radiologic growth. For those patients who do not present significant canal stenosis or cord compression by OPLL above C2 upper lamina, C2 lamina-sparing decompressive surgery should be preferred.

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Table 1. Basic Demographic and Surgical Data

Demographic variable	C2 laminectomy (N=75)	C2 Sparing (N=69)	*p* -value
Follow-up periods (years)	5.9 ± 2.7	5.1 ± 2.2	0.149
Age	57.3 ± 9.2	55.6 ± 8.5	0.319
Female	20 (26.7)	21 (30.4)	0.752
OPLL type			0.138
Continuous	37 (49.3)	23 (33.3)	
Mixed	37 (49.3)	44 (63.8)	
Segmental	1 (1.3)	2 (2.9)	
OPLL involved segment numbers	5.8 ± 1.5	6.0 ± 1.3	0.513
Operated segment numbers	4.7 ± 1.1	3.9 ± 0.7	<0.001
Operation			0.003
Laminectomy without instrumentation	4 (5.3)	1 (1.5)	
Laminectomy with instrumentation	42 (56.0)	22 (31.9)	
Laminoplasty	29 (38.7)	46 (66.7)	

Continuous variables are depicted as mean ± SD and categorical values as number (%)

OPLL = ossification of posterior longitudinal ligament;

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Table 2. Radiologic and Clinical Data

Demographic variable		C2 laminectomy (N=75)	C2 sparing (N=69)	*p*-value
C1/2 OPLL Size				
Maximal width (mm)				
	Baseline	3.9 ± 0.9	3.5 ± 0.9	0.014
	Final follow-up	4.4 ± 1.0	4.1 ± 1.1	0.148
	Change	0.5 ± 0.6	0.6 ± 0.6	0.223
Length (mm)				
	Baseline	22.0 ± 7.3	18.5 ± 5.7	0.003
	Final follow-up	25.2 ± 6.7	22.3 ± 5.8	0.007
	Change	3.2 ± 3.5	3.8 ± 4.2	0.614
SAC diameter (mm)				
	Baseline	13.9 ± 2.3	14.4 ± 2.0	0.179
	Final follow-up	15.1 ± 2.3	15.1 ± 2.0	0.903
	Change	1.2 ± 1.4	0.8 ± 1.2	0.097
Occupying ratio (%)				
	Baseline	28.6 ± 7.4	24.9 ± 6.9	0.003
	Final follow-up	29.6 ± 7.3	27.8 ± 7.8	0.087
	Change	1.0 ± 5.1	2.9 ± 3.8	0.013
Radiologic OPLL growth				
Width or length		38 (50.7)	37 (53.6)	0.851
Length		37 (49.3)	37 (53.6)	0.728
Width		1 (1.3)	3 (4.3)	0.350
Canal stenosis of C1/2 segment				
Baseline		14 (18.7)	3 (4.3)	0.016
Final follow-up		9 (12.0)	3 (4.3)	0.174
	Stenosis by anterior compartment	3 (4.0)	1 (1.4)	0.621
	Stenosis by posteior compartment	8 (10.7)	3 (4.3)	0.266
Clinical outcome				
Improvement of preoperative symptoms		66 (88.0)	60 (87.0)	1.000
Clinical Relapse		3 (4.0)	2 (2.9)	1.000
	OPLL progression in C1/2 segment	0 (0.0)	0 (0.0)	1.000
	OPLL progression in other segments	3 (4.0)	2 (2.9)	1.000

Continuous variables are depicted as mean ± SD and categorical values as number (%)

OPLL = ossification of posterior longitudinal ligament, SAC = space avilabe for the spinal cord ;

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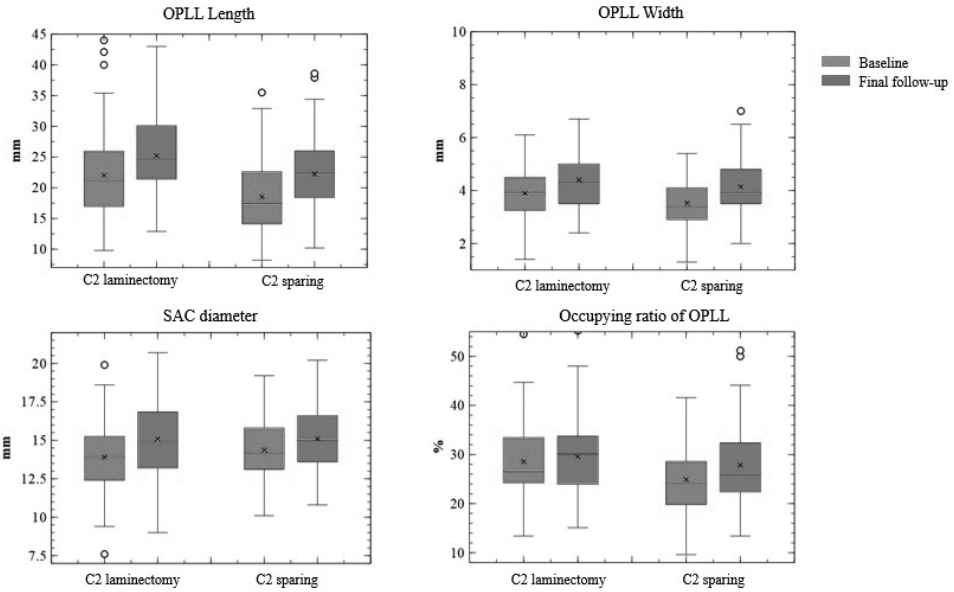

Figure 4. Box-plot illustration of change of C1/2 segment's OPLL size throughout the follow-up periods in two different groups. OPLL has significantly increased in both width and length in both groups, but in much greater scale in length. The C2 laminectomy group showed a greater increase in the SAC diameter, while the C2 sparing group showed a greater increase in occupying ratio of OPLL.

PAPER 64

Virtual Reality Hand Dexterity Training to Augment Post-Surgical Neurological Recovery in Degenerative Cervical Myelopathy: A Prospective Clinical Trial

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Introduction: Degenerative cervical myelopathy (DCM) is the most common cause of adult spinal cord dysfunction [1,2] with many patients experiencing impaired hand dexterity and diminished quality of life[3]. Over 30% of people undergoing surgery for DCM do not achieve meaningful recovery of hand dexterity and report residual disability. Currently, there are no proven interventions to rehabilitate hand dexterity after surgery for DCM. Virtual reality training is a promising therapy for upper limb rehabilitation and has several advantages over conventional occupational therapy including high repetitions, individualized training intensities, learning-based training and sensory feedback. In this prospective single-arm clinical trial, we investigate a novel virtual reality intervention to rehabilitate hand function for DCM patients after surgery.

Materials and Methods: Post-surgical (within 1 year of surgery) DCM patients (n=10) were recruited for a four-week intervention entailing three, one-hour sessions per week. During each training session, participants wore a sensor glove to train finger individuation in their self-reported more affected hand. Movement was guided by the Actuated Virtual Keyboard (AVK system, Figure 1), which allowed participants to play virtual piano keys by flexing their fingers, with one key associated with each digit. Participants had to achieve sufficient joint flexion to play the indicated key, which produced audio/video feedback. Task difficulty and speed were manipulated based on participant performance. The primary outcome measure was the Jebsen-Taylor Hand Function Test (JTHFT). Secondary outcome measures included quality of life indicators (Quickdash, EuroQol 5, SF36 physical and mental component scores (PCS & MCS), myelopathy-specific scores (Myelopathy Disability Index - MDI and Modified Japanese Orthopedic Association scale - MJOA) and quantitative hand function tests (Nine-Hole Peg Test - 9HPT, Box and Block Test - BBT, and pinch strength). Outcomes were recorded at baseline, immediately post-training, and at 4 weeks after training. The Wilcoxon signed-rank test was used to determine differences between baseline and final follow-up scores.

Results: Ten post-surgical DCM patients (median (IQR) 70.50 (63.5, 73.75), 7 men) were prospectively enrolled at an median of 4.36 (2.39, 6.11) months post-surgery. Statistically significant improvement in the JTHFT (-21.255 (-28.665, -4.113), p=0.02) (Figure 2) was noted at follow-up compared to baseline. Significant improvement in quality of life as measured by the EuroQol5 (-2.000(-2.000, -0.250), p=0.016) was noted. Quantitative hand function tests showed significant improvement at final follow-up: BBT (5.500 (3.250, 8.500), p=0.009), pinch (1.283 lbs (0.925, 2.217), p=0.009), and 9HPT (-3.720 (-4.913, -1.328), p=0.009). Improvements in quality of life (EuroQol5) and quantitative hand function tests (pinch and BBT) exceeded the minimum clinically important difference (MCID). Improvements in mJOA (0.500 (0.000, 1.000), p=0.06) and SF-36 PCS (15.183 (0.037, 19.315), p=0.06) trended towards statistical significance. There were no adverse events associated with the training.

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Conclusion: Post-surgical DCM patients showed significant, sustained and clinically meaningful improvements in hand dexterity and quality of life after participating in a 4-week virtual reality hand training paradigm. The results demonstrate the efficacy of a rehabilitative intervention to augment neurological recovery after surgery for DCM. Virtual reality hand dexterity training is a novel approach to target residual disability after surgery for DCM.

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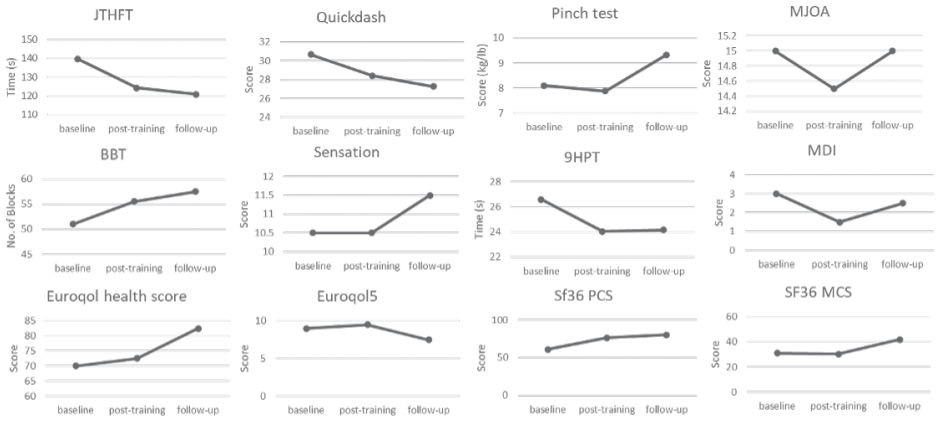

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PAPER 65

Radiographic Outcomes and Subsidence Rate in Hyperlordotic versus Standard Lordotic Interbody Spacers in Patients Undergoing Anterior Cervical Discectomy and Fusion

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Introduction: ACDF is a common surgical approach a for patients with degenerative cervical disease and current interbody spacers utilized vary based on material composition, structure, and angle of lordosis. Currently, there is a lack of literature comparing subsidence rate or long-term radiographic outcomes with hyperlordotic and standard lordotic spacers. Compare long-term radiographic outcomes, subsidence rate, and rate of fusion in patients who underwent level anterior cervical discectomy and fusion (ACDF) with hyperlordotic or standard interbody placement.

Materials and Methods: Patients who underwent 1-to-3 level ACDF with either a standard lordosis or hyperlordotic interbody from 2019-2022 were included. Preoperative and postoperative radiographs were evaluated for C2-7 lordosis (CL), sagittal vertical axis, C2 slope (C2S), and T1 slope (T1S). The rate of subsidence and fusion were also determined.

Results: 45 patients underwent ACDF with hyperlordotic interbody placement and after a 1:1 propensity match with standard lordotic patients, 90 patients were included. One-year postoperative radiographs demonstrated the hyperlordotic cohort achieved higher CL (15.3° ± 10.6 vs. 9.58° ± 8.88; p=0.007). The change in CL (8.42° ± 9.42 vs. 0.94° ± 8.67; p< 0.001), change in C2S (-4.02° ± 6.68 vs. -1.11° ± 5.42; p=0.026), and change in T1S (3.49° ± 7.30 vs. 0.04° ± 6.86 p=0.008) between pre-and postoperative imaging were larger in the hyperlordotic cohort. There was no difference in overall subsidence (p=0.183) and rate of fusion (p=0.353) between the cohorts.

Conclusion: Hyperlordotic spacer placement in 1-to-3 level ACDF can provide increased CL compared to standard lordosis spacers, which can be considered for patients requiring restoration or maintenance of CL following ACDF.

PAPER 66

Impact of Obstructive Sleep Apnea on Outcomes after ACDF: A Propensity Matched Analaysis

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Introduction: As the aging population continues to grow and rates of obesity continue to rise, comorbidities that impact patient safety are increasing.[1-2] One overlooked comorbidity is Obstructive sleep apnea(OSA) which affects up to 24% of the population.[3] Moreover, OSA is a risk factor for complications following surgery, however, patients are not routinely screened for OSA across different practice settings.[4] Given the upper airway's proximity to the cervical spine in the anterior approach, there may be cause for concern especially in anterior cervical decompression and fusion (ACDF).[4] Adding to this, the prevalence of diagnosed OSA in the U.S. has doubled over four years between 2008-2012 in patients undergoing ACDF. Therefore, the purpose of this study was to determine the impact of having a history of OSA in patients undergoing ACDF and the risk of inferior outcomes in this setting.

Materials and Methods: A retrospective study of patients >18 years who underwent 1-4 level ACDF at an urban tertiary care medical center over a six year period was performed. Patient's age, sex, BMI, CCI, hypertension, diabetes, and levels fused were propensity matched in a 3:1 fashion. Outcomes assessed included inpatient complications, 30 and 90-day ED visits, 30 and 90-day readmissions, reoperations, and 1-year Patient Reported Outcome Measures (PROMs). PROMs assessed included the Mental Component Summary (MCS-12), Physical Component Summary (PCS-12), and Visual Analog Scale (VAS) for neck and arm, Neck Disability Index (NDI), and the Modified Japanese Orthopaedic Association Scale (mJOA) which were collected from our prospectively maintained PROM database (OBERD). Standard descriptive statistics were reported as percent of total for categorical variables and means and standard deviations for continuous variables. Bivariable comparisons were conducted using t-tests or Mann-Whitney U tests for continuous parametric and non-parametric data, respectively. Chi-squared testing or Fisher's exact tests were used to compare categorical data in the case of cell counts less than 5.

Results: A total of 344 ACDF patients (86 OSA, 258 No OSA) were included. 30-day ED visits were higher among the OSA compared to the non-OSA group (5.85% vs 0%, p=0.001). Among ED visits, there were four patients with upper respiratory issues none of which warranted readmission. ED visits equalized in the 30–90-day window. There were no significant differences in inpatient complications, LOS, discharge disposition, readmissions, reoperations, and 1-year PROMs.

Conclusion: To our knowledge, this is the first institutional study evaluating the association between OSA and postoperative outcomes following ACDF. In our analysis, patients with a history of OSA underwent ACDF without an increased risk of postoperative complications, readmissions, or reoperations and experienced a complication rate much lower than previously suggested by current literature.[5] OSA patients experienced similar improvements in PROMs at

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1-year follow up. Surgeons should counsel OSA patients regarding the increased risk of 30-day ED visits. But overall, patients can expect safe and equivalent outcomes compared to non-OSA patients which lends support for safe outpatient surgery in this population.

PAPER 67

Understanding the Impact of Low-Density Lipoprotein Levels and Lipid-Lowering Agents on Rates of Pseudarthrosis After Anterior Cervical Discectomy and Fusion

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Introduction: ACDF is commonly performed to treat cervical degenerative diseases or injuries causing neck pain, myelopathy, and radiculopathy. Pseudarthrosis following ACDF can lead to persistent symptoms and may require revision surgery. Rates of pseudoarthrosis have been reported to be as high as 20% for single-level ACDF and 50% for multi-level ACDF [1-4]. Age, diabetes, and smoking are known risk factors for nonunion in the cervical spine [5]. However, no studies have explored the link between LDL levels and pseudarthrosis in ACDF.

Materials and Methods: A retrospective cohort study was conducted using TriNetX, a healthcare database with over 100 million patients. Pseudarthrosis rates at six months, one-year, and two-years following singl e-level and multi-level ACDF were compared between patients with an LDL above 142 mg/dL and below 66 mg/dL within one year before surgery. LDL thresholds represent one standard deviation above and below the mean of all LDL data within TriNetX. Pseudarthrosis rates at six months, one-year, and two-years were also compared between patients taking or not taking a statin, fish oil, ezetimibe, and niacin within six months before surgery. Average LDL levels for patients taking or not taking a lipid-lowering agent were also collected at all three time points. For all analyses, patients underwent propensity score matching in a 1:1 ratio based on age, sex, race, body mass index, osteoporosis, diabetes, tobacco use, malnutrition, metabolic syndrome, and chronic use of steroids. $P< 0.01$ was considered significant.

Results: Patients with an LDL above 142 mg/dL, compared to below 66 mg/dL, had significantly higher rates of pseudarthrosis at 6-months, 1-year, and 2-years after mu lti-level ACDF (Table 1). Patients not taking a statin, compared to those taking a statin, also had significantly higher rates of pseudarthrosis at all time points after multi-level ACDF (Table 2). The same analyses were performed for single-level ACDF, but no significant association was found (Tables 4 and 5). Patients taking a statin had significantly lower LDL levels at all time points in both multi-level ACDF (Table 3) and single-level ACDF (Table 6).

Patients taking fish oil, compared to those not taking fish oil, had lower rates of pseudarthrosis at all time points after multi-level ACDF but did not have significantly different levels of LDL (Tables 7 and 8). Fish oil had no impact on pseudarthrosis rates or LDL levels in single-level ACDF. Ezetimibe and niacin also did not significantly impact rates of pseudarthrosis or LDL levels after multi-level and single-level ACDF.

Conclusion: Low LDL levels and intake of statins or fish oil redu ce rates of pseudarthrosis after multi-level, but not single-level, ACDF. These associations may be used for pre-operative planning, patient optimization, and risk stratification in multi-level ACDF. By doing so, physicians can potentially lower rates of pseudarthrosis and therefore improve clinical outcomes, limit postoperative pain, and reduce revision surgery rates [5].

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	Patients with high LDL (n=790)		Patients with low LDL (n=790)			
Time Point	Patient Count	% of Cohort	Patient Count	% of Cohort	Odds Ratio (95% CI)	P-Value
6-months	207	26.20%	147	18.61%	1.553 (1.223-1.973)	<0.001
1-year	222	28.10%	161	20.38%	1.527 (1.210-1.927)	<0.001
2-years	229	28.99%	172	21.77%	1.467 (1.167-1.843(	0.001

Table 1: Rates of pseudarthrosis at 6-months, 1-year, and 2-years in patients with a high LDL versus low LDL within one year before multi-level ACDF

	Patients with no statin (n=5,841)		Patients with statin (n=5,841)			
Time Point	Patient Count	% of Cohort	Patient Count	% of Cohort	Odds Ratio (95% CI)	P-Value
6-months	1,052	18.01%	929	15.91%	1.161 (1.054-1.28)	0.002
1-year	1,120	19.18%	1,005	17.2%	1.114 (1.032-1.204)	0.006
2-years	1,177	20.15%	1,064	18.22%	1.133 (1.027-1.192)	0.008

Table 2: Rates of pseudarthrosis at 6-months, 1-year, and 2-years in patients taking versus not taking a statin within six months before multi-level ACDF

	Patients with no statin (n=5,841)		Patients with statin (n=5,841)		
Time Point	Average LDL (SD)	# of patients	Average LDL (SD)	# of patients	P-Value
6-months	99.29 (37.73)	704	84.93 (33.82)	1,092	<0.001
1-year	99.75 (36.67)	1,187	86.04 (34.54)	1,882	<0.001
2-years	97.32 (36.57)	1,610	86.73 (35.84)	2,330	<0.001

LDL – low density lipoprotein
Table 3: Average LDL levels at 6-months, 1-year, and 2-years in patients taking versus not taking a statin within six months before multi-level ACDF

	Patients with high LDL (n=569)		Patients with low LDL (n=569)			
Time Point	Patient Count	% of Cohort	Patient Count	% of Cohort	Odds Ratio (95% CI)	P-Value
6-months	116	20.39%	86	15.11%	1.438 (1.058-1.955)	0.020
1-year	124	21.79%	92	16.2%	1.445 (1.071-1.948)	0.016
2-years	127	22.32%	98	17.22%	1.381 (1.029-1.852)	0.031

Table 4: Rates of pseudarthrosis at 6-months, 1-year, and 2-years in patients with a high LDL versus low LDL within one year before single-level ACDF

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	Patients with no statin (n=4,284)		Patients with statin (n=4,284)			
Time Point	Patient Count	% of Cohort	Patient Count	% of Cohort	Odds Ratio (95% CI)	P-Value
6-months	661	15.43%	666	15.55%	0.991 (0.882-1.114)	0.881
1-year	695	16.22%	720	16.81%	0.959 (0.855-1.074)	0.467
2-years	732	17.09%	761	17.76%	0.954 (0.877-1.055)	0.409

Table 5: Rates of pseudarthrosis at 6-months, 1-year, and 2-years in patients taking versus not taking a statin within six months before single-level ACDF

	Patients with no statin (n=4,284)		Patients with statin (n=4,284)		
Time Point	Average LDL (SD)	# of patients	Average LDL (SD)	# of patients	P-Value
6-months	98.92 (39.96)	520	86.64 (36.59)	811	<0.001
1-year	96.83 (38.08)	841	88.65 (37.23)	1,324	<0.001
2-years	96.78 (38.32)	1,146	87.80 (36.62)	1,622	<0.001

LDL – low density lipoprotein

Table 6: Average LDL levels at 6-months, 1-year, and 2-years in patients taking versus not taking a statin within six months before single-level ACDF

	Patients without fish oil (n=175)		Patients with fish oil (n=175)			
Time Point	Patient Count	% of Cohort	Patient Count	% of Cohort	Odds Ratio (95% CI)	P-Value
6-months	29	16.57%	13	7.43%	2.475 (1.240-4.942)	0.009
1-year	31	17.71%	14	8.0%	2.476 (1.267-4.838)	0.007
2-years	33	18.86%	15	8.57%	2.479 (1.293-4.752)	0.005

Table 7: Rates of pseudarthrosis at 6-months, 1-year, and 2-years in patients taking versus not taking fish oil within six months before multi-level ACDF

	Patients without fish oil (n=175)		Patients with fish oil (n=175)		
Time Point	Average LDL (SD)	# of patients	Average LDL (SD)	# of patients	P-Value
6-months	91.5 (31.41)	18	96.07 (28.49)	27	0.615
1-year	97.33 (37.06)	27	100.27 (27.32)	44	0.703
2-years	96.19 (30.98)	30	95.79 (28.31)	56	0.948

LDL – low density lipoprotein

Table 8: Average LDL levels at 6-months, 1-year, and 2-years in patients taking versus not taking fish oil within six months before multi-level ACDF

PAPER 68

Clinical Determinants of Neurological Recovery After Acute Traumatic Cervical Spinal Cord Injury: Analysis of 655 Prospectively-Accrued Cases from the NASCIS 2 and NASCIS 3 Trials.

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Introduction: Numerous clinical factors have been studied as potential determinants of neurological recovery after acute traumatic cervical spinal cord injury (actSCI). Nevertheless, most of the prior studies were characterized by relatively small sample sizes and/or lack of adjustments for major potential confounders. This study examined a large, prospectively-accrued cohort of individuals with actSCI regarding multiple potential determinants of neurological recovery.

Materials and Methods: This retrospective cohort study included 655 cases of actSCI from the Second and Third National Spinal Cord Injury Studies (NASCIS 2&3). A series of multiple regression analyses evaluated multiple clinical factors as potential determinants of motor and sensory recovery within the first year after actSCI.

Every model was adjusted for the initial motor or sensory NASCIS scores that were obtained at admission in the emergency department. Potential determinants of neurological recovery included: age at the actSCI onset; sex/gender; racial/ethnic group; cause of actSCI; administration of methylprednisolone; Glasgow coma scale, heart rate, systolic and diastolic blood pressure at the admission in the acute care hospital; and serum albumin concentrations that were collected within 24 hours (hyperacute phase), 48-72 hours (early phase), and 7-10 days (acute phase) after actSCI.

Results: There were 567 males and 88 females with a mean age of 34.8 years, who were predominantly non-Hispanic white (n=488) or African-American individuals (n=89), and mostly had motor vehicle accident (n=306) or fall (n=137). Their initial mean NASCIS motor and sensory scores were 31.5±34.6 (range: 0-140) and 156.9±81.9 (range: 62-348), respectively.

The results of the multiple regression analysis for prediction of the NASCIS motor score at 1 year after actSCI ($F=55.96$; $R^2=0.64$; $p<0.0001$) showed that older age, higher heart rate at admission and administration of methylprednisolone had a positive impact on the motor recovery, whereas elevated serum albumin concentrations in the hyperacute phase had a negative effect on the motor recovery (Table 1). Those were similar to the results from the model including serum albumin concentrations in the early phase, but serum albumin concentration in the acute phase was not correlated with motor recovery.

The results of the multiple regression analysis for prediction of the NASCIS sensory score at 1 year after actSCI ($F=133.17$; $R^2=0.81$; $p<0.0001$) showed that female sex and administration of methylprednisolone had positive impact on the sensory recovery, and there was a trend toward positive association between older age and higher sensory recovery after adjusting for potential confounders including serum albumin concentrations in the hyperacute phase (Table 2). The models for prediction of the NASCIS sensory score, which were also adjusted for serum albumin concentrations in either the early phase or acute phase, revealed that administration of methylprednisolone consistently improved sensory recovery.

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Conclusion: The results of this study highlight key clinical factors with potential predictive value for motor recovery after actSCI, including older age, female sex and treatment with methylprednisolone (positive effects), and higher serum albumin concentrations in the hyperacute and early phases after actSCI (negative effects). The administration of methylprednisolone was the only determinant that was consistently associated with better sensory recovery at 1 year after actSCI.

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Table 1. Results of the multiple regression analysis on predicting the motor recovery at 1 year following acute traumatic SCI based on: the motor deficit at the admission in the acute care; age at the SCI onset; sex/gender; race/ethnicity (i.e., AA: African American, Hisp: Hispanic, NHW: non-Hispanic white individuals; other), cause of SCI (i.e., MVA: motor vehicle accident, fall, other); administration of methylprednisolone (MPSS); and Glasgow coma scale (GCS), heart rate (HR), systolic and diastolic blood pressure (SBP, DBP), and serum albumin concentration at the admission in the emergency department ($F=55.96$; $R^2=0.64$; $p<0.0001$).

Parameter	Estimate		Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	-5.52992470	B	19.83754209	-0.28	0.7806	-44.51730895	33.45745955
ERMOTOR	0.87747803		0.04345393	20.19	<.0001	0.79207658	0.96287948
age	0.24696300		0.09406293	2.63	0.0090	0.06209798	0.43182802
Sex Female	6.28471245	B	4.19158533	1.50	0.1345	-1.95315024	14.52257514
Sex Male	0.00000000	B	.	.	.	.	.
MPSS No	-20.54436244	B	3.05946079	-6.72	<.0001	-26.55722296	-14.53150193
MPSS Yes	0.00000000	B	.	.	.	.	.
RACE AA	-0.48105924	B	7.08817483	-0.07	0.9459	-14.41168605	13.44956757
RACE Hisp	3.74271677	B	7.94811674	0.47	0.6379	-11.87798262	19.36341615
RACE NHW	3.75646501	B	6.35110921	0.59	0.5545	-8.72558212	16.23851213
RACE Other	0.00000000	B	.	.	.	.	.
cause Fall	2.25626352	B	4.06672811	0.55	0.5793	-5.73621312	10.24874015
cause MVA	4.03315397	B	3.15983436	1.28	0.2025	-2.17697407	10.24328201
cause Other	0.00000000	B	.	.	.	.	.
GCS	1.05531749		1.16148499	0.91	0.3641	-1.22738776	3.33802274
HR	0.24751151		0.08854015	2.80	0.0054	0.07350061	0.42152242
SBP	0.09041330		0.09725052	0.93	0.3530	-0.10071639	0.28154299
DBP	-0.17065087		0.12309530	-1.39	0.1663	-0.41257417	0.07127243
ERALBUM	-0.41924296		0.20824636	-2.01	0.0447	-0.82851649	-0.00996943

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Table 2. Results of the multiple regression analysis on predicting the sensory recovery at 1 year following acute traumatic SCI based on: the sensory deficit at the admission in the acute care; age at the SCI onset; sex/gender; race/ethnicity (i.e., AA: African American, Hisp: Hispanic, NHW: non-Hispanic white individuals; other), cause of SCI (i.e., MVA: motor vehicle accident, fall, other); administration of methylprednisolone (MPSS); and Glasgow coma scale (GCS), heart rate (HR), systolic and diastolic blood pressure (SBP, DBP), and serum albumin concentration at the admission in the emergency department ($F=133.17$; $R^2=0.81$; $p<0.0001$).

Parameter	Estimate		Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	73.40551591	B	30.57212223	2.40	0.0168	13.32147338	133.48955843
ERSENS	0.94492278		0.02994693	31.55	<.0001	0.88606745	1.00377812
age	0.24521458		0.14004591	1.75	0.0806	-0.03002064	0.52044979
Sex Female	11.73243347	B	6.16365669	1.90	0.0576	-0.38113222	23.84599915
Sex Male	0.00000000	B	.	.	.	.	.
MPSS No	-28.00554563	B	4.92660412	-5.68	<.0001	-37.68790557	-18.32318570
MPSS Yes	0.00000000	B	.	.	.	.	.
RACE AA	6.71548337	B	10.47238868	0.64	0.5217	-13.86612500	27.29709174
RACE Hisp	7.16037209	B	11.77062809	0.61	0.5433	-15.97269383	30.29343802
RACE NHW	0.79730074	B	9.41314669	0.08	0.9325	-17.70255681	19.29715829
RACE Other	0.00000000	B	.	.	.	.	.
cause Fall	4.43176792	B	6.00600825	0.74	0.4610	-7.37196793	16.23550376
cause MVA	6.47725540	B	4.68188088	1.38	0.1672	-2.72414474	15.67865554
cause Other	0.00000000	B	.	.	.	.	.
GCS	-2.26631496		1.85784358	-1.22	0.2232	-5.91757449	1.38494457
HR	0.14868671		0.13132630	1.13	0.2582	-0.10941166	0.40678508
SBP	0.08046230		0.14488045	0.56	0.5789	-0.20427433	0.36519894
DBP	-0.30085054		0.18355729	-1.64	0.1019	-0.66159960	0.05989851
ERALBUM	-0.29875333		0.30854650	-0.97	0.3334	-0.90514634	0.30763967

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Shifting Trends and Regional Disparities in Intraoperative Neuromonitoring Usage for Anterior Cervical Discectomy and Fusion

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Introduction: Intraoperative neuromonitoring (IONM) is frequently used during anterior cervical procedures to mitigate risk of neurologic injury. Prior studies have demonstrated decreasing utilization of IONM in ACDFs. However, no recent studies have re-assessed these trends. The purpose of this study was to (1) evaluate recent trends in the use of intraoperative neuromonitoring (IONM) for anterior cervical discectomy and fusion (ACDF) in the United States, (2) assess regional variations in use of IONM, and (3) assess the association between IONM and clinical outcomes.

Materials and Methods: Cases of cervical myelopathy and radiculopathy that underwent ACDF from 2011 to 2021 were identified via the PearlDiver Patient Record Database. Rates of IONM were compared based on patient age, gender, income and region. Complications, 30-day readmissions and reimbursement rates were also assessed.

Results: We identified 285,939 patients undergoing isolated ACDF, with 45,943 (16.1%) of these cases using IONM. There was a significant increase in the use of IONM for ACDFs over the study period ($R^2 = 0.87$, $p < 0.001$). Significant regional variability was observed in the utility of IONM (Northeast; 21.2%, Midwest; 16.3%, South; 14.7%, West; 14.2%; $p < 0.001$). Younger age and higher patient income were associated with increased utility of IONM ($p < 0.001$). IONM was associated with significantly higher costs but no reduction in rates of postoperative neurologic complications ($p < 0.001$ and $p = 0.29$, respectively).

Conclusion: This study demonstrates a significant increase in IONM utilization during ACDFs over the past decade. Considerable differences exist in IONM use concerning patient demographics, income and geographic region, with highest utilization in the Northeast. Notably, despite the association of IONM with over a 20% increase in reimbursement rates, its implementation was not associated with a reduction in rates of neurologic complications.

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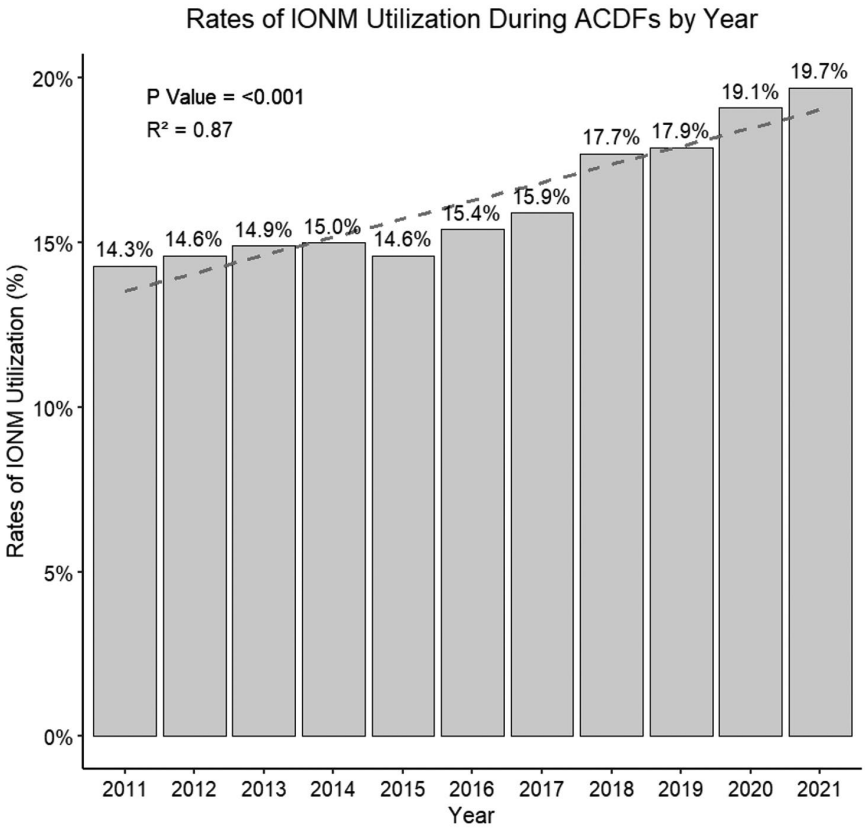

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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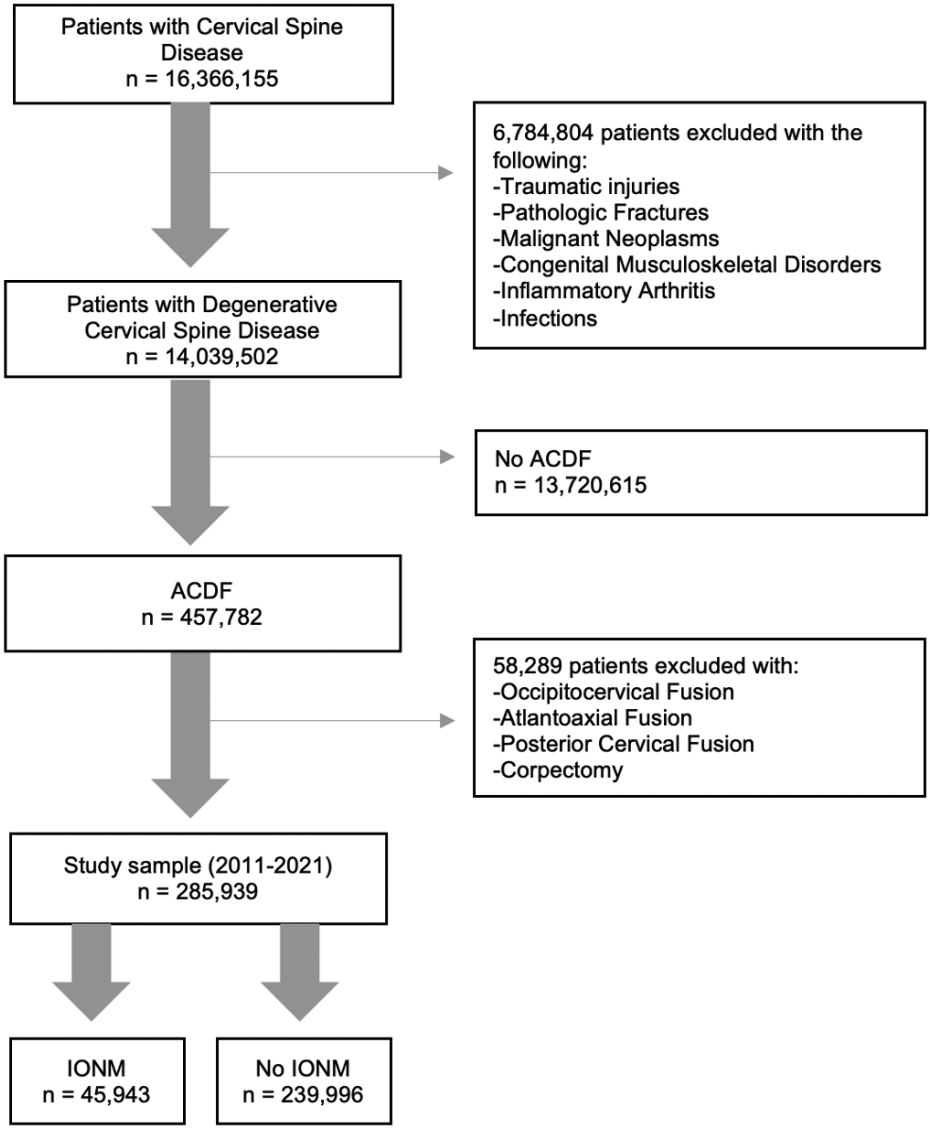

PAPER 70

Neuromonitoring in Cervical Spine Surgery: Demographics and Geographical Trends
A Survey of the Cervical Spine Research Society

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Introduction: Intraoperative neuromonitoring (NM) is generally regarded as standard of care for deformity surgery by reducing neurological complications. However, the use of NM in degenerative cervical spine surgery (myelopathy and radiculopathy) remains controversial. Prior studies indicate that NM is utilized equally between orthopedic surgeons and neurosurgeons. Recent trends demonstrate NM is more commonly used for myelopathy and less commonly for radiculopathy. Additionally, private practice groups utilize NM more frequently. Surgeons have cited using NM for prevention of positioning and hypotension-related neurological complications as well as medicolegal protection. The purpose of this study is to survey the use of NM in cervical spine surgeons. The survey focuses on pathology for which NM is utilized, geographic location, and private versus academic setting.

Materials/Methods: A survey was distributed to members of CSRS to evaluate NM practices during cervical spine surgery. The survey was 10 questions focusing on specialty, years of practice, the use of NM, practice location and population size, academic versus private practice, and hospital versus surgery center setting.

Materials and Methods: A survey was distributed to members of CSRS to evaluate NM practices during cervical spine surgery. The survey was 10 questions focusing on specialty, years of practice, the use of NM, practice location and population size, academic versus private practice, and hospital versus surgery center setting.

Results: 60 total responses were obtained. Majority were from academic surgeons (64%) with 20% being private practice, 15% being hybrid. There was overall a relative balance of practices based on geography, most responses being from the West Coast, Great Lakes, Southeast, and Mideast. Majority of surgeons practiced in cities with populations >2.5 million (46%). 27.1% were in cities 1-2.5 million. 49% of surgeons had been in practice over 15 years with only 27.1% having <5 years of experience. Half worked in a city considered a high litigation region while the other half did not. For 64% of surgeons, litigation played a role in the use of NM. 63% of surgeons operated in a hospital exclusively while 37% operated out of a surgery center. 95% of surgeons utilized NM in cervical surgery. Of those that use NM, 88% utilized NM for all cervical surgery, while 8% used NM for posterior only surgery. 23% reported use during in only myelopathy cases whereas 71% utilized NM for both radiculopathy and myelopathy patients. 87% use NM for ACDF, laminoplasty and PCDF. Only 67% use NM for arthroplasty and posterior laminoforaminotomy. SSEP were most utilized at 97% with 90% using MEP and 78% using EMG. 20% monitor for recurrent laryngeal nerve.

Conclusion: The utilization of NM within spine surgery remains a controversial issue with no clear consensus among surgeons. This survey gives insight into current usage across the US. Almost all surgeons still use NM in nondeformity surgery. SSEPs are the most commonly used modality. NM is used mostly in myelopathic patients and for ACDF, laminoplasty and posterior cervical fusions. 64% of surgeons use NM for litigation protection. This data gives a baseline for future practice guidelines based on current surgeon trends.

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

POSTER 1

WITHDRAWN

POSTER 2

Using PROMs to Assess Clinical Success of Anterior Cervical Discectomy & Fusion for Degenerative Cervical Spine Conditions Causing Isolated Radiculopathy

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Introduction: The use of patient-reported outcome measures, or PROMs, as part of routine clinical spine care continues to increase. This trend is likely to continue as payors, including the U.S. Centers for Medicare and Medicaid Services (CMS), further incorporate PROMs into novel surgical payment models, including most recently for total joint replacement. One can expect spine surgery will follow shortly. Thus, it becomes critical for spine surgeons to lead the work to assess and define how best to use and evaluate PROMs scores. In this study, we aimed to determine the percentage of patients with appreciable clinical improvement following anterior cervical discectomy and fusion (ACDF) for degenerative cervical spine conditions causing isolated radiculopathy.

Materials and Methods: In this multicenter observational study, a sample of 112 patients with complete preoperative and 1-year PROMs were identified. All included patients underwent an ACDF for degenerative spine conditions with isolated radiculopathy. All revisions were excluded. At both time points, the following PROMs were collected: patient-reported outcomes measurement information system (PROMIS) Pain Intensity Short-Form (SF) 3a, PROMIS Pain Interference SF 4a, PROMIS Global Health v1.0– Mental Health sub-score, PROMIS Global Health v1.0– Physical Health sub-score, and PROMIS Physical Function SF 10a. The minimal clinically important difference (MCID), or the minimum change in a PROM score that reflects appreciable clinical change, was defined for each PROM using a distribution-based approach of ½ standard deviation.

Results: Of the 112 patients, 61 patients were female (54%) and a majority were self-reported White race (n = 103; 92%). A majority of patients had commercial insurance (n = 89; 79%). The average ASA score was 2 (range, 1-3). Just over half of all surgeries were done at the academic medical center (n = 57; 51%). The MCID cut-off estimates for PROMIS Pain Intensity SF 3a, PROMIS Pain Interference SF 4a, PROMIS Global Health v1.0– Mental Health sub-score, PROMIS Global Health v1.0– Physical Health sub-score, and PROMIS Physical Function SF 10a were 3.7, 3.7, 5.2, 3.9, and 3.3, respectively. The proportion of patients achieving appreciable clinical improvement at 1-year across PROMIS Pain Intensity SF 3a, PROMIS Pain Interference SF 4a, PROMIS Global Health v1.0– Mental Health sub-score, PROMIS Global Health v1.0– Physical Health sub-score, and PROMIS Physical Function SF 10a was 61% (n = 68), 58% (n = 65), 26% (n = 29), 49% (n = 55), and 55% (n = 62), respectively.

Conclusion: In patients with a degenerative cervical spine and isolated radiculopathy only, primary ACDF appears to do best at relieving pain and discomfort, though up to 40% of patients continue to not appreciate clinical improvement by 1-year postoperatively when

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using the PROMIS domains outlined above. These findings suggest that the PROMIS domains above may be too general in this patient population or how the method of MCID estimation may impact clinical assessment. Further research is warranted to determine which PROMs may be best to assess improvement in this patient population.

POSTER 3

Identification of a Novel Genetic Variant Associated with Adjacent Segment Disease: Analysis of Spinal Fusions in the UK BioBank

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Introduction: The prevalence of symptomatic spinal disease requiring fusion is increasing with an aging population. Patients are counseled there is a 3% annual risk of additional surgery due to AdSD, though this may not account for advances in surgical technique[1–4]. The UKB is a large population-based cohort of 500,000 deidentified people, with in-depth genetic and non-genetic information, as well as linked hospital records. The database is regularly updated and includes >20 years of hospital records[5]. We investigated the rate of AdSD after primary cervical and lumbar fusion in the UKB cohort, as well as risk factors that may contribute.

Materials and Methods: UKB patients that underwent primary lumbar or cervical fusion, as well as anterior (ACF) or posterior cervical spine fusion (PCF) were identified using OPCS-4 codes. AdSD was the endpoint, defined as subsequent fusion, revision, or decompression within the same spine. Risk factors were assessed using multivariable Cox regression analysis. Cumulative incidence was calculated to estimate the annualized risk of AdSD. GWAS analysis was performed to identify small nucleotide polymorphisms (SNPs) associated with AdSD.

Results: 3487 patients underwent primary fusion in the cervical (N=1732, ACF = 1571, PCF = 121, combined = 42) or lumbar (N=1755) spine. 211 (12.1%) cervical and 230 (13.1%) lumbar patients were revised for AdSD. 5-year AdSD rate was 8.19% (cervical) and 10.16% (lumbar), and at 20-years was 20% (cervical) and 19.84% (lumbar), amounting to an annual risk of ~1% (Table 1, Figure 1). The 5-year AdSD rate for ACF and PCF was 8.02% and 1.98% ($p<0.05$). Subgroup sample size limited detection of significant demographic and genetic differences between ACF and PCF AdSD cases. Unemployed/Retired status achieved significance as a risk factor for all AdSD patients ($p=0.0063$). GWAS analysis (Figure 2) for all AdSD patients identified a novel SNP (rs116459848, Chromosome 5). Previously reported SNPs[6] associated with degenerative pathologies (spondylolisthesis, disc disease, spinal stenosis) failed to achieve significance.

Conclusion: The combined risk of AdSD for lumbar and cervical spine fusion is lower than previously reported, 1% annually with about 40% of cases occurring within the first 5 years. The rate of AdSD between the ACF and PCF was different at 5 years. The low patient population for PCF precluded AdSD projection beyond 5.3 years (3.43%). There may be risk factors accounting for the increased early rate of AdSD, including surgical factors and patient factors. We identified a novel SNP that associated with AdSD cases in the absence of SNPs associated with degenerative pathologies. This suggests there may be a novel genetic component to AdSD, and AdSD may represent a separate disease.

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Table 1. Point Estimate for 5, 10, 15, 20 years since primary spinal fusion

Year since primary spinal fusion	For all types of primary spinal fusion surgery				For primary cervical fusion surgery				For primary lumbar fusion surgery			
	Survival Probability (%)	95% CI for Survival Probability	Cumulative Incidence (%)	95% CI for Cumulative Incidence	Survival Probability (%)	95% CI for Survival Probability	Cumulative Incidence (%)	95% CI for Cumulative Incidence	Survival Probability (%)	95% CI for Survival Probability	Cumulative Incidence (%)	95% CI for Cumulative Incidence
5	90.81	89.82-91.81	9.19	8.19-10.18	91.67	90.31-93.05	8.33	6.95-9.69	89.76	88.28-91.26	10.24	8.74-11.72
10	86.25	84.96-87.57	13.75	12.43-15.04	86.87	85.05-88.72	13.13	11.28-14.95	85.27	83.37-87.22	14.73	12.78-16.63
15	83.27	81.67-84.89	16.73	15.11-18.33	83.97	81.74-86.26	16.03	13.74-18.26	82.15	79.84-84.53	17.85	15.47-20.16
20	80.19	78.05-82.39	19.81	17.61-21.95	80	76.87-83.25	20	16.75-23.13	80.16	77.32-83.11	19.84	16.89-22.68

Year since primary spinal fusion	For anterior cervical fusion surgery				For posterior cervical fusion surgery			
	Survival Probability (%)	95% CI for Survival Probability	Cumulative Incidence (%)	95% CI for Cumulative Incidence	Survival Probability (%)	95% CI for Survival Probability	Cumulative Incidence (%)	95% CI for Cumulative Incidence
5	91.98	90.58-93.41	8.02	6.59-9.42	98.02	95.33-100	1.98	0-4.67
10	87.62	85.78-89.5	12.38	10.5-14.22	96.57	92.75-100	3.43	0-7.25
15	84.89	82.65-87.2	15.11	12.8-17.35	96.57	92.75-100	3.43	0-7.25
20	80.96	77.75-84.3	19.04	15.7-22.25	96.57	92.75-100	3.43	0-7.25

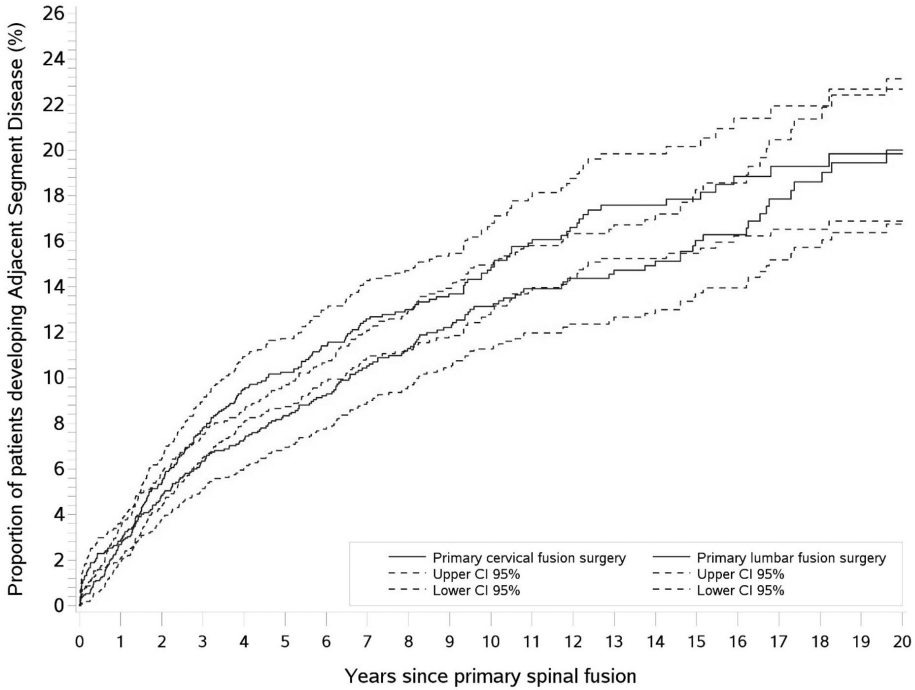

Figure 1: Rate of Adjacent Segment Disease for Cervical and Lumbar Spinal Fusion

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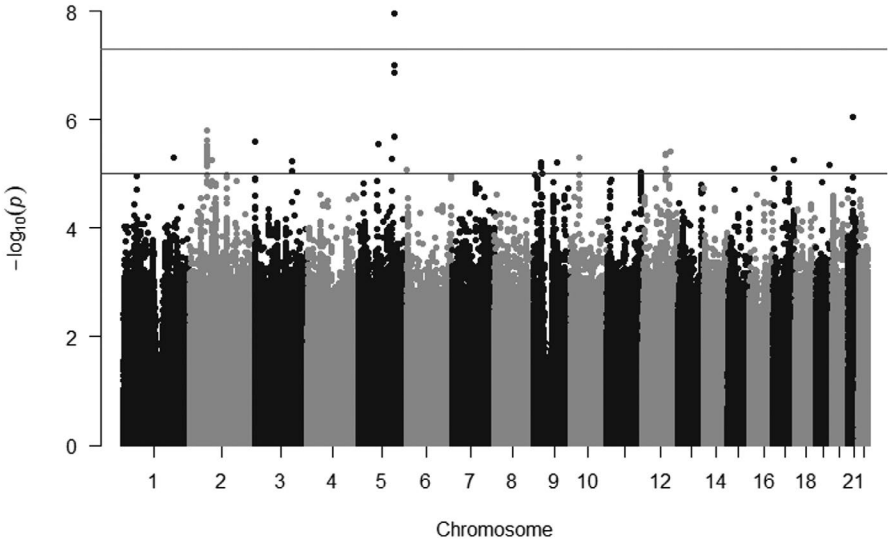

Figure 2: GWAS analysis for adjacent segment disease cases. The red line indicates genome-wide significance threshold set to $5x10^{-8}$

POSTER 4

Comparison of Surgical and Patient-reported Outcomes in Patients with Normal Versus Abnormal Dentition Status Following ACDF.

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Introduction: Oral health directly affects physical and mental health and has known effects on the perioperative and postoperative course of patients undergoing orthopedic surgery.[1,2] Accordingly, oral health management guidelines from AAOS and ADA have been developed for hip and knee joint replacement.[3] However, this relationship has yet to be elucidated for spine surgery. It remains unclear whether dentition status, which serves as a readily available marker for overall health status determined on lateral cervical spine x-ray, is associated with surgical complications and patient-reported outcomes (PROs) following anterior cervical decompression and fusion (ACDF). Therefore, the purpose of this study was to investigate the impact of dentition status on readmission rates, reoperation rates, complication rates, and PROs following ACDF.

Materials and Methods: We evaluated records of 1,153 ACDF cases to record dentition status as normal or abnormal. Record of dentures, partials, implants, and/or caps placed patients into "Dental Work" abnormal subgroup. Record of any missing teeth placed patients into the "Missing Teeth" abnormal subgroup primarily. Chi-square tests assessed differences in surgical outcomes within 90 days of discharge based on dentition status and subgroup. Mixed effect logistic regression was used to determine the association of dentition status with Neck Disability Index (NDI) and Numeric Pain Rating Scales (NPRS) in a subset of patients who completed PROs, controlling for age, sex, race, ethnicity, surgical diagnosis, number of vertebral levels and the Surgical Invasiveness Index.

Results: Among 1,153 included ACDF cases, patients with abnormal dentition (n=379) were more likely than those with normal dentition to be readmitted (28.0% vs. 8.0%, $p<0.001$), undergo reoperation (6.6% vs. 1.9%, $p<0.001$), and experience complications (8.7% vs. 1.6%, $p<0.001$). Compared to the Dental Work subgroup, patients in the Missing Teeth subgroup were more likely to experience complications (12.2% vs. 5.4%, $p=0.022$) including dysphagia, postoperative infection, cardiac and respiratory issues, and pain control. There was no significant difference between readmission or reoperation rate between the Dental Work and Missing Teeth subgroups. Patient with abnormal dentition reported significantly greater NDI between 9-12 months postoperatively (mean difference [95%CI]: 12.8 [6.4, 19.3], $p<0.001$) and VAS-Pain score between 1 month (mean difference [95%CI]: 1.0 [0.6, 1.5]) and 15 months (1.14 [0.5, 1.8] $p=0.001$) postoperatively.

Conclusion: Abnormal dentition was associated with higher rates of postoperative surgical complications and poorer PROs following ACDF compared to those with normal dentition. These findings suggest that dental health, which can be quickly discerned from the lateral cervical spine x-ray, can help prognosticate outcomes following ACDF. Further investigation is required to delineate whether dentition serves as a proxy measure for health or if it directly affects outcomes due to its impact on physical and mental health.

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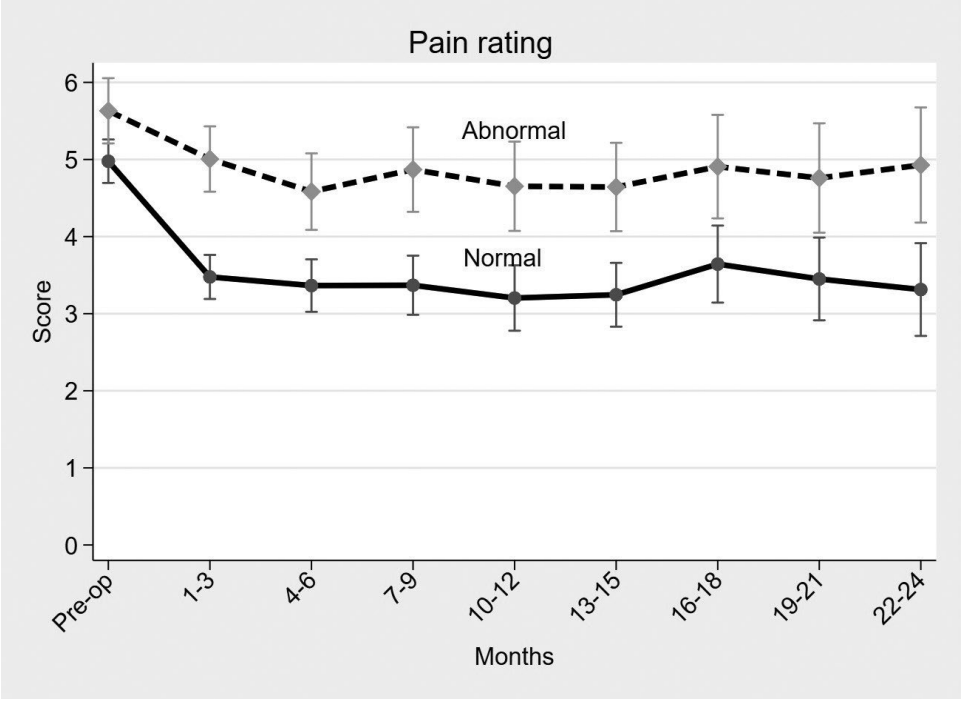
Table 3. Comparison of surgical outcomes overall and by dentition status.

Complication	Overall	Normal Dentition	Abnormal Dentition	*P* value*
	Prevalence *n* (%)			
N (% of total)	1153 (100)	774 (67.1)	379 (32.9)	
90-day Readmit	168 (14.6)	62 (8.0)	106 (28.0)	**< 0.001**
90-day Reoperation	40 (3.5)	15 (1.9)	25 (6.6)	**< 0.001**
Other Complications	46 (4.0)	12 (1.6)	33 (8.7)	**< 0.001**
Dysphagia	8	3	5	
Dural tear/CSF leak	1	1	--	
Hematoma	2	--	2	
PO Infection	5	--	5	
Neurological/Nerve damage	9	3	6	
Cardiac	4	1	3	
Respiratory	4	--	4	
Pain Control	11	4	7	
Ileus	1	--	1	

Table 4. Comparison of surgical outcomes by abnormal dentition status subtype.

	Abnormal Dentition		
Complication	Dental Work	Missing Teeth	*P* value*
	Prevalence *n* (%)		
N (% of total)	184 (16.0)	189 (16.4)	
90-day Readmit	49 (26.6)	57 (30.2)	0.450
90-day Reoperation	13 (7.1)	12 (6.3)	0.782
Other Complications	10 (5.4)	23 (12.2)	**0.022**
Dysphagia	1	4	
Dural tear/CSF leak	--	--	
Hematoma	1	1	
PO Infection	1	4	
Persistent Radiculopathy/Palsy	3	3	
Cardiac	--	3	
Respiratory	1	3	
Pain Control	2	5	
Ileus	1	--	

POSTER 4 continued



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POSTER 5

Preliminary Results of a RAND/UCLA Appropriateness Method Evaluation of Bone Graft and Biologics in Anterior Cervical Discectomy and Fusion

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Introduction: A preliminary chart review of one- and two-level anterior cervical discectomy and fusion (ACDF) at a large academic healthcare system in the Northeast shows there is a large disparity in the use of graft products in routine ACDF. However, many commercially available graft products are expensive and have limited data regarding efficacy. The purpose of this study was to evaluate the appropriateness of various bone graft and biologic products in one and two-level ACDFs to understand why there is variability in graft usage, to establish best practices, and cut costs.

Materials and Methods: A RAND/UCLA appropriateness method (RAM) study was planned in accordance with the RAM guidelines. A thorough background literature review of bone graft and biologic products in one and two-level ACDFs was conducted and summarized for the spine surgeons involved. A total of 15 spine surgeons from across a large academic health system were selected to include a mixture of neurosurgeons and orthopedic surgeons, and a variety of practice types and hospital locations. 240 survey questions were administered. The bone graft products assessed were ICBG, local autograft, structural allograft, bone morphogenetic protein (BMP), demineralized bone matrix (DBM), ceramic grafts, P-15 peptide, and mesenchymal stem cells (MSC) and cellular bone matrix. Clinical scenarios included degenerative cervical myelopathy, acute disc herniation with cervical radiculopathy, degenerative disc with bilateral foraminal stenosis, and adjacent segment disease. Pseudarthrosis risk factors assessed were uncontrolled diabetes, active tobacco usage, osteoporosis, obesity, and chronic steroid usage. Each question involves rating the "appropriateness" of the graft product for a particular clinical scenario on a scale from 1 to 9, with 1 being "highly inappropriate" and 9 being "highly appropriate". An average response of 3 or less indicated inappropriate use, between 3 and 7 indicated uncertainty, and 7 or above indicated appropriate use.

Results: To date nine surgeons have completed the first round RAM survey. Preliminary analysis shows that across all clinical scenarios median responses indicate 74 graft options are appropriate, 66 inappropriate, and 100 uncertain. When combined among all scenarios, ICBG had an average score of 7.8, local autograft averaged 5.6, structural allograft averaged 7.6, BMP averaged 1.3, DBM averaged 7.5, ceramic grafts averaged 4.6, P-15 averaged 4.1, and mesenchymal stem cells/cellular bone matrix averaged 1.9. ICBG, structural allograft, and DBM would thus be considered appropriate. BMP and MSCs/cellular bone matrix would be considered inappropriate. Local autograft, ceramics, and P-15 peptides are uncertain. The most variation between surgeons was seen with ICBG, local autograft, and P-15 peptides. Pseudarthrosis risk factors did not significantly change how surgeons rated appropriateness of graft products ($p=0.85$). Clinical scenarios did not significantly alter graft appropriateness ratings, either ($p=0.38$).

Conclusion: Preliminary analysis of a RAM study of graft product usage in one and two-level

POSTER 5 continued

ACDFs suggests that surgeons consider ICBG, structural allograft, and DBM as "appropriate" graft options. BMP and MSCs/cellular bone matrix were mostly considered "inappropriate". Ceramics and P-15 peptides were the most uncertain and warrant further study in ACDF. Clinical scenario and pseudarthrosis risk factors do not significantly affect rating of graft appropriateness.

POSTER 6

Utilization of the Fragility Index to Assess Randomized Controlled Trials Comparing Cervical Total Disc Arthroplasty to Anterior Cervical Discectomy and Fusion

*Austin Carroll,, Sarah Lucas, MD[1], **Zachary Backstrom, BS[2]**, Kory Pasko, BS[2], Addisu Mesfin, MD[1]*
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Introduction: Cervical total disc arthroplasty (CTDA) remains an alternative to anterior cervical discectomy and fusion (ACDF) in select patients with cervical radiculopathy or myelopathy secondary to degenerative disc disease. Randomized controlled trials (RCTs) comparing CTDA to ACDF often have conflicting conclusions and varying quality. The purpose of the current study was to utilize the fragility index (FI), a metric that can be used to assess the robustness of statistically significant, dichotomous outcome variables in RCTs, in order to investigate the fragility of RCTs comparing CTDA to ACDF.

Materials and Methods: A systematic review was performed by searching PubMed, Ovid MEDLINE, Web of Science, and Embase for RCTs with two parallel study arms and 1:1 allocation of subjects to treatment or control groups investigating CTDA vs. ACDF with at least one statistically significant, dichotomous outcome. The FI was calculated by individually shifting one patient from the event group to the non-event group with re-calculation of Fisher's Exact test until the reported P value was no longer statistically significant ($p > 0.05$).

Results: The search identified identified 928 abstracts. Of these abstracts, 19 of them were RCTs that met the inclusion criteria (Fig. 1). The majority of articles (n=16, 84.2%) compared CTDA to ACDF at a single level. Of the included studies, 14 reported a potential funding source conflict, and 11 reported some form of blinding, either with patients or assessors, with full blinding in only 3 studies. The mean patient sample size was 276.4 (median 209, range 30-541). The number of patients lost to follow-up was 0 in only 1 of the studies and ranged from 0-229 (mean 69.7, median 45). The mean FI of all included studies was 4.6 (range 0-30, median 2) with 2 of the studies having an associated FI of 0. Loss to follow up exceeded the fragility index in all but two of the 19 included studies.

Conclusion: Randomized controlled trials comparing anterior cervical discectomy and fusion to cervical total disc arthroplasty are quite fragile with loss to follow-up frequently exceeding the fragility index. In many cases, one to two patients having an alternative outcome can change the statistically significant result assessed in these trials. Although the FI is unable to assess continuous variables, it offers an additional metric with which surgeons can analyze these trials prior to changing clinical practice.

POSTER 6 continued

Fig. 1 Preferred Reporting Items for Systemic Reviews and Meta-analysis (PRISMA) flow diagram

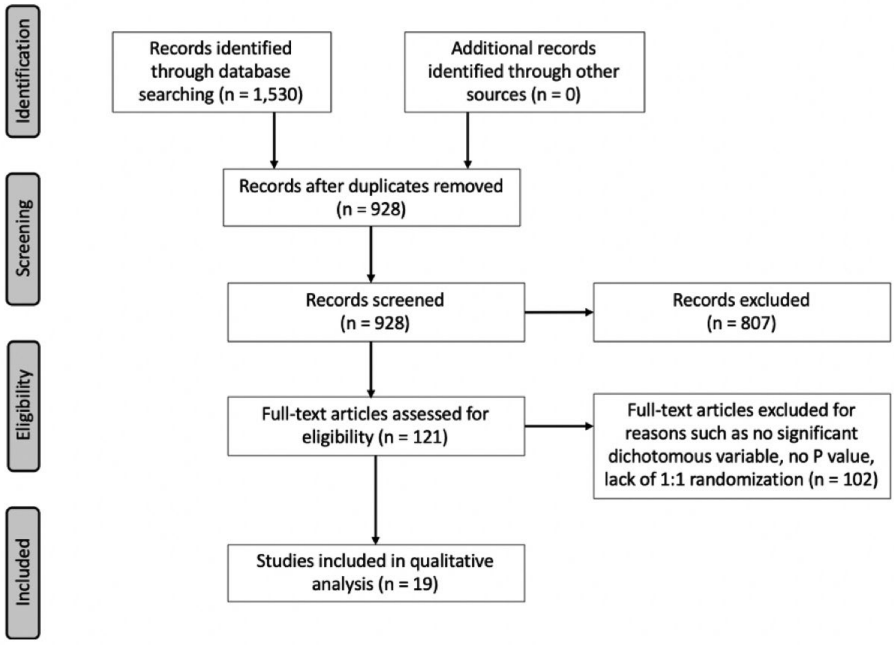

Table 1: FI CTDA vs ACDF Data

Study	Journal	Study comparison	Primary outcome (dichotomy)	Significant dichotomous outcome	No. treated	No. pts lost to follow-up	P value	FI	FQ	Impact factor
Anderson et al, 2008[25]	Spine	Single Level	Adverse events (dichotomous)	General medical events unrelated to the operation	463	46	0.049	0	0.000	3.0
Burkus et al, 2014[26]	JNS Spine	Single Level	Overall success (dichotomous)	Overall success with functional spinal unit	541	146	0.01	6	0.011	4.1
Cheng et al, 2011[30]	Clinical Orthopaedics and Related Research	1-3 level	-	Fusion rate	83	2	<0.001	30	0.361	4.2
Coric et al, 2011[27]	JNS Spine	Single Level	Neck disability index (not dichotomous), visual analog scale (not dichotomous), overall clinical success (dichotomous)	Overall clinical success	269	35	0.05	7	0.026	4.1
Coric et al, 2018[15]	JNS Spine	Single Level	-	Overall success	269	93	<0.05	11	0.041	4.1
Delamarter et al, 2010[28]	SAS Journal	Single Level	-	Secondary surgical procedures	209	95	0.0292	1	0.005	3.0
Delamarter et al, 2013[29]	Spine	Single Level	Reoperation rates (dichotomous)	Reoperation rates	209	76	0.0079	6	0.029	3.0
Heller et al, 2009[16]	Spine	Single Level	Overall Success (dichotomous)	Overall Success	463	39	0.01	4	0.009	3.0
Hou et al, 2016[20]	JBJS	Single Level	Japanese Orthopaedic Association score (not dichotomous), visual analog scale for pain (not dichotomous), incidence of further surgery (dichotomous)	Incidence of further surgery	108	8	0.049	1	0.009	5.3
Janssen et al, 2015[31]	JBSJ	Single Level	Neck disability index (not dichotomous), neurologic success (dichotomous), secondary surgical procedures (dichotomous), and adverse events (dichotomous)	Secondary surgical procedures	165	57	0.0201	2	0.012	5.3
Lavelle et al, 2019[32]	Spine	Single Level	Overall Success (dichotomous)	Overall Success	463	231	0.005	4	0.009	3.0
Loidolt et al, 2021[33]	Spine Journal	Single Level	Adverse Events (dichotomous)	Adverse events resulting from trauma	463	229	0.04	2	0.004	4.2
Murrey et al, 2009[34]	Spine Journal	Single Level	-	Neurological success at 6 mo	209	7	0.046	1	0.005	4.2
Phillips et al, 2015[35]	Spine	Single Level	-	NDI success	403	110	0.026	2	0.005	3.0
Qizhi et al, 2016[36]	Clinical Spine Surgery	2 Non-contiguous Levels	-	Rate of Adjacent Segment Disease	30	0	0.04	0	0.000	1.9
Sasso et al, 2011[37]	JBJS	Single Level	Overall Success (dichotomous)	Overall success	463	144	0.004	6	0.013	5.3
Sundseth et al, 2017[21]	European Spine Journal	Single Level	-	Frequency of Reoperation	136	23	0.029	1	0.007	3.2
Yang et al, 2018[38]	Orthopedics	2 Contiguous Levels	-	Incidence of adjacent-segment degeneration	96	16	<0.05	3	0.031	5.2
Zigler et al, 2013[39]	Spine	Single Level	-	Rate of Secondary Surgery	209	76	0.0292	1	0.005	3.0

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Table 2.

Criterion	Data
No. of patients treated	
Mean	276.4
Median	209
Range	30-541
Loss to follow up	
Mean	69.7
Median	45
Range	0-229
No. of studies with funding bias (%)	14 (73.7)
No. of studies with blinding	
Assessors blinded (%)	1 (5.3)
Participants blinded (%)	2 (10.5)
P value	
Mean	0.029
Median	0.029
Range	0.001 - 0.050
Fragility index	
Mean	4.6
Median	2
Range	0-30
≤2 (%)	10 (52.6)
>2 (%)	9 (47.4)
Fragility quotient	
Mean	0.031
Median	0.009
Range	0.000-0.361
A priori analysis (%)	9 (47.4)

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

POSTER 7

A Comparison of Demographic and Microorganism Differences between De Novo and Postoperative Infections

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Introduction: While spine infections are relatively rare, current literature suggests that both de novo and postoperative infection rates are increasing. It is estimated that up to 75% of cases may exhibit diagnostic delays, which can result in devasting short and long term effects on patient health. Patients who develop spinal infections commonly have predisposing factors such as diabetes, malnutrition, and substance abuse. However, though a variety of prior studies have examined risk factors and outcomes of de novo and postoperative infections, there are, to our knowledge, no prior studies that directly compare these two patient cohorts to each other. Thus, the purpose of this study is to compare demographic and microbiological factors of de novo and postoperative infections and to analyze these trends overtime. Our goal is to discern significant distinctions within each group that can integrated into the initial assessment of patients entering the hospital with a suspected spinal infection; this serves not only to expedite the diagnostic process but also facilitate prompt administration of effective treatment interventions.

Materials and Methods: Patients aged 18 years or older who underwent an irrigation and debridement (I&D) for de novo and postoperative infections from 2017-2022 were compared. All patients were retrospectively reviewed for demographic information (age, sex, race, body mass index (BMI)), comorbidities (Charlson Comorbidity Index, smoking status, diabetes, hepatitis C, chronic kidney disease (CKD), prior IV drug use) and social factors (Distressed Community Index Score and marital status). Tissue microbiology of both cohorts were compared by broad classes (e.g. gram positive vs negative, aerobic vs anaerobic, monomicrobial vs polymicrobial) and individual microbes (e.g. Staph aureus, E. Coli, Pseudomonas, etc.).

Results: 153 patients underwent an I&D in the setting of de novo infection, while 239 patients underwent an I&D in the setting of postoperative infection. Patients who developed de novo infections were on average younger ($p=0.002$) with lower BMIs ($p<0.001$) and were more likely to be current smokers ($p=0.005$). These patients also had higher rates of hepatitis C ($p<0.001$), CKD ($p=0.009$), and prior IV drug use ($p<0.001$) and were more likely have never gotten married ($p<0.001$) and live in communities with a higher average DCI ($p=0.050$) than those with postoperative infections. Patients with de novo spinal infections were more likely to have an infection of the cervical spine ($p<0.001$). De novo infections have higher rates of gram positive ($p=0.004$), monomicrobial ($p=0.013$) and aerobic ($p=0.026$) infections than postoperative infections. Streptococcus ($p=0.002$) infections were more common among de novo infections, while Pseudomonas ($0=0.021$), Proteus ($p=0.008$), and Corynebacterium ($p=0.008$) were more common among postoperative infections.

Conclusion: Significant demographic and microbiological differences exist among patients who develop de novo and postoperative spine infections. Further research into the nature

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of these differences is warranted for the development of potentially different evaluative and treatment protocols specific to these different classes of infections. In addition, a comprehensive management plan that addresses the medical and social aspects of patients with spine infections is also recommended improve outcomes and reduce disease burden.

Table 1: Demographic and Socioeconomic Factors of De Novo and Postoperative Infections

	De Novo (N=153)	Post-Op (N=239)	P Value
Age	57.4 (14.5)	62.1 (13.0)	**0.002**
Race			**0.014**
White	118 (77.1%)	200 (83.7%)	
Black	22 (14.4%)	35 (14.6%)	
Asian	5 (3.27%)	1 (0.42%)	
Other	8 (5.23%)	3 (1.26%)	
Sex			0.389
Male	87 (56.9%)	124 (51.9%)	
Female	66 (43.1%)	115 (48.1%)	
BMI	28.0 (6.59)	31.4 (6.98)	**<0.001**
Smoking Status			**0.005**
Never	58 (37.9%)	124 (51.9%)	
Former	40 (26.1%)	63 (26.4%)	
Current	55 (35.9%)	52 (21.8%)	
CCI	4.16 (2.66)	3.92 (2.22)	0.522
Infection Location			**<0.001**
Cervical	58 (37.9%)	50 (20.9%)	
Thoracic	29 (19.0%)	13 (5.44%)	
Thoracolumbar	11 (7.19%)	19 (7.95%)	
Lumbar	55 (35.9%)	157 (65.7%)	
Facility			0.051
Tertiary	132 (86.3%)	186 (77.8%)	
Community	21 (13.7%)	53 (22.2%)	

	De Novo (N=153)	Post-Op (N=239)	P Value
Co-Morbidities			
Diabetes	49 (32.0%)	70 (29.3%)	0.382
HIV/AIDs	2 (1.31%)	3 (1.26%)	1.000
Hepatitis C	45 (29.4%)	12 (5.02%)	**<0.001**
CKD	33 (21.6%)	27 (11.3%)	**0.009**
IV Drug Use	49 (32.0%)	18 (7.53%)	**<0.001**
DCI Average	45.6 (29.6)	36.1 (28.0)	**0.002**
DCI Quintile			0.050
Prosperous	41 (26.8%)	93 (38.9%)	
Comfortable	33 (21.6%)	52 (21.8%)	
Mid-Tier	30 (19.6%)	46 (19.2%)	
At Risk	12 (7.84%)	13 (5.44%)	
Distressed	37 (24.2%)	35 (14.6%)	
Marital Status			**<0.001**
Married	59 (38.6%)	153 (64.0%)	
Single	65 (42.5%)	45 (18.8%)	
Divorced	15 (9.80%)	25 (10.5%)	
Widowed	14 (9.15%)	16 (6.69%)	

Data listed as either: mean (SD) or n (%)

BMI=Body Mass Index; CCI=Charlson Comorbidity Index, CKD=Chronic Kidney Disease, DCI=Distressed Community Index (higher DCI corresponds to a more distressed community)

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Table 2: Tissue Microbiology of De Novo and Postoperative Infections By Broad Classes

	De Novo (N=153)	Post-Op (N=239)	P Value
Composition			**0.013**
Monomicrobial	127 (83.0%)	171 (71.5%)	
Polymicrobial	26 (17.0%)	68 (28.5%)	
Classification			**0.004**
Gram Positive	122 (79.7%)	154 (64.4%)	
Gram Negative	15 (9.80%)	50 (20.9%)	
Gram Positive and Negative	5 (3.27%)	21 (8.79%)	
Non Staining	0 (0.00%)	2 (0.84%)	
Gram Staining and Non Staining	1 (0.65%)	1 (0.42%)	
Fungus	5 (3.27%)	4 (1.67%)	
Fungus and Bacteria	5 (3.27%)	7 (2.93%)	
Oxygen Dependence			**0.026**
Aerobes	115 (75.2%)	151 (63.2%)	
Anaerobes	17 (11.1%)	49 (20.5%)	
Both Aerobes and Anaerobes	21 (13.7%)	39 (16.3%)	
Data listed as n (%)			

POSTER 7 continued

Table 3: Tissue Microbiology of De Novo and Postoperative Infections By Individual Organisms

	De Novo (N=153)	Post-Op (N=239)	P Value
Staphylococcus Aureus	83 (54.2%)	110 (46.0%)	0.138
MRSA	31 (37.3%)	32 (29.1%)	0.291
Staphylococcus Epidermidis	13 (8.50%)	33 (13.8%)	0.152
Coagulase Negative Staph	9 (5.88%)	8 (3.35%)	0.343
Streptococcus spp.	26 (17.0%)	16 (6.69%)	**0.002**
Enterococcus	6 (3.92%)	11 (4.60%)	0.945
VRE	1 (16.7%)	4 (36.4%)	0.600
Pseudomonas	5 (3.27%)	24 (10.0%)	**0.021**
Serratia	3 (1.96%)	11 (4.60%)	0.273
Proteus	0 (0.00%)	11 (4.60%)	**0.008**
Escherichia Coli	5 (3.27%)	11 (4.60%)	0.697
Klebsiella	2 (1.31%)	11 (4.60%)	0.137
Propionibacterium (Cutibacterium)	15 (9.80%)	25 (10.5%)	0.969
Corynebacterium	0 (0.00%)	13 (5.44%)	**0.008**
Tuberculosis	1 (0.65%)	3 (1.26%)	1.000
Candida	9 (5.88%)	12 (5.02%)	0.889
Other Bug*	17 (11.11%)	26 (10.88%)	

Data listed as n (%)

**Other bugs Include Pantoea, Parvimonas, Actinomyces, Enterobacter, Providencia, Bacteriodes, Citrobacter, Prevotella. Coccidiomycosis, Morganella, Acinetobacter, Finegolida, Rothia, Micrococcus, Haemophilus, Stenotrophomonas Aerococcus, Mycobacterium avium, Coryneform spp. and Brevundimonas*

MSSA=Methicillin-Susceptible Staph Aureus; MRSA=Methicillin-Resistant Staph Aureus; VRE=Vancomycin-resistant Enterococcus

POSTER 8

Not All Cervical Traumas Are Created Equal: Assessing In-Hospital Complications After Fusion for Cervical Traumas with Neurologic Deficits of Varying Severity

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Introduction: Traumatic injuries to the cervical spine are have high morbidity and mortality, particularly when neurovascular structures are involved. For many patients, urgent surgical intervention is required for both spinal stabilization and the preservation of sensory, autonomic and motor functioning. Despite its benefits, cervical fusion carries its own risks that may be compounded by accompanying neurologic deficits. The purpose of this study is to compare postoperative surgical complications seen in trauma patients with concomitant neurologic injuries of high severity to those of trauma patients who are less neurologically compromised.

Materials and Methods: Patients aged 18 years or older who underwent an anterior cervical discectomy and fusion (ACDF) or posterior cervical discectomy and fusion (PCDF) from 2015-2020 in the setting of trauma were identified. Severity of neurologic deficit was determined by a patient's American Spinal Injury Association (ASIA) Impairment Scale grade upon admission to the hospital, in which ASIA A and B grades were compared to ASIA C-E grades. Location of fusion (axial vs. sub-axial), presence of additional pathologies (vertebral fracture, dislocation, ligamentous injury), and the necessity for additional non-spinal surgery were collected for all traumatic patients. A 1:1 propensity matched cohort of elective cervical fusions was conducted for baseline comparison. All patients were retrospectively reviewed for 35 in-hospital complications, along with hospital length of stay (LOS) and mortality rates. Acute postoperative outcomes collected included 30 and 90 day hospital readmission rates and the need for revision surgery.

Results: We identified 111 trauma patients (85 with ASIA C-E neurologic injuries and 26 with ASIA A-B injuries) that were matched with 111 elective surgical fusions. When compared to ASIA C-E patients, ASIA A-B patients with neurologic deficits were more likely to be male ($p=0.049$) with a sub-axial injury ($p<0.017$), and a longer LOS ($p<0.001$). These patients also had higher incidence of conduction arrhythmias ($p=0.024$), deep venous thrombosis ($p=0.034$), pneumonia ($p<0.001$), respiratory arrest ($p<0.001$), and urinary tract infections ($p=0.032$). No statistically significant differences existed between trauma cohorts with regards to in-hospital mortality ($p=0.233$). Additionally, no significant differences existed between trauma cohorts with regards to 90 day hospital readmission rates, and the need for revision surgery.

Conclusion: Patients with more severe neurologic deficits in the setting of cervical trauma are at significantly higher risk of a variety of in-hospital complications. These findings emphasize the need for more comprehensive and multidisciplinary management strategies as well as further research into the optimization of care for this vulnerable population.

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Table 1: Cardiopulmonary, Hematologic and Neurological Complications

	Elective (N=111)	Trauma		P Value (Trauma vs Elective)	P Value (Elective vs ASIA C-E)*	P Value (ASIA C-E vs ASIA A-B)*
		ASIA C-E (N=85)	ASIA A-B (N=26)			
Myocardial Infarction	0 (0.00%)	3 (3.53%)	1 (3.85%)	0.084		
Cardiogenic Shock	0 (0.00%)	1 (1.18%)	0 (0.00%)	0.500		
Heart Failure Exacerbation	0 (0.00%)	2 (2.35%)	1 (3.85%)	0.088		
Conduction Arrhythmia	5 (4.50%)	18 (21.2%)	12 (46.2%)	**<0.001**	**0.001**	**0.024**
Respiratory Arrest	1 (0.90%)	11 (12.9%)	20 (76.9%)	**<0.001**	**0.001**	**<0.001**
Atelectasis	0 (0.00%)	8 (9.41%)	9 (34.6%)	**<0.001**	**0.002**	**0.004**
Stroke/TIA	0 (0.00%)	6 (7.06%)	1 (3.85%)	**0.011**	**0.018**	
Encephalopathy	3 (2.70%)	17 (20.0%)	9 (34.6%)	**<0.001**	**0.001**	
Seizures	0 (0.00%)	1 (1.18%)	1 (3.85%)	0.103		
Neurogenic Shock	0 (0.00%)	2 (2.35%)	8 (30.8%)	**<0.001**		**<0.001**
Deep Vein Thrombosis	0 (0.00%)	4 (4.71%)	5 (19.2%)	**<0.001**	**0.034**	**0.034**
Pulmonary Embolism	0 (0.00%)	2 (2.35%)	2 (7.69%)	**0.017**		
Hemorrhage/Hematoma	1 (0.90%)	8 (9.41%)	2 (7.69%)	**0.013**	**0.033**	
Post-Op Anemia	2 (1.80%)	30 (35.3%)	14 (53.8%)	**<0.001**	**<0.001**	
Hypovolemic Shock	1 (0.90%)	3 (3.53%)	0 (0.00%)	0.450		
Received Transfusion	1 (0.90%)	17 (20.0%)	8 (30.8%)	**<0.001**	**<0.001**	
Pre-Op Transfusion	0 (0.00%)	5 (5.88%)	1 (3.85%)	**0.020**	**0.043**	
Intra-Op Transfusion	1 (0.90%)	4 (4.71%)	2 (7.69%)	0.096		
Post-Op Transfusion	0 (0.00%)	11 (12.9%)	6 (23.1%)	**<0.001**	**<0.001**	
Thrombophlebitis	0 (0.00%)	3 (3.53%)	0 (0.00%)	0.143		

Data listed as either: mean (SD) or n (%)
TIA=Transient Ischemic Attack

Only statistically significant values reported

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Table 2: Gastrointestinal, Renal, and Infectious Complications

	Elective (N=111)	Trauma		P Value (Trauma vs Elective)	P Value (Elective vs ASIA C-E)*	P Value (ASIA C-E vs ASIA A-B)*
		ASIA C-E (N=85)	ASIA A-B (N=26)			
Nausea, Vomiting and Diarrhea	5 (4.50%)	0 (0.00%)	0 (0.00%)	0.086		
Ileus	0 (0.00%)	29 (34.1%)	12 (46.2%)	**<0.001**	**<0.001**	
Dysphagia	2 (1.80%)	30 (35.3%)	15 (57.7%)	**<0.001**	**<0.001**	
Acute Renal Failure	0 (0.00%)	7 (8.24%)	3 (11.5%)	**0.001**	**0.007**	
Fluid/Electrolyte Disorders	3 (2.70%)	29 (34.1%)	15 (57.7%)	**<0.001**	**<0.001**	
Urinary Retention/ Hydronephrosis	3 (2.70%)	29 (34.1%)	7 (26.9%)	**<0.001**	**<0.001**	
Urinary Incontinence	2 (1.80%)	1 (1.18%)	1 (3.85%)	1.587		
Rhabdomyolysis	0 (0.00%)	1 (1.18%)	1 (3.85%)	0.103		
Pneumonia	2 (1.80%)	14 (16.5%)	16 (61.5%)	**<0.001**	**0.001**	**<0.001**
Urinary Tract Infections	0 (0.00%)	10 (11.8%)	8 (30.8%)	**<0.001**	**<0.001**	**0.032**
Wound Infection	1 (0.90%)	3 (3.53%)	2 (7.69%)	0.107		
Sepsis	0 (0.00%)	6 (7.06%)	4 (15.4%)	**0.001**	**0.009**	
Septic Shock	0 (0.00%)	3 (3.53%)	1 (3.85%)	0.084		
Cellulitis	0 (0.00%)	2 (2.35%)	0 (0.00%)	0.367		
Skin Ulcers/Abscesses	1 (0.90%)	3 (3.53%)	3 (11.5%)	**0.020**		

Data listed as either: mean (SD) or n (%)

**Only statistically significant values reported*

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Table 3: Mortality, Readmissions and Reoperations Within 90 Days

	Elective (N=111)	Trauma		P Value (Trauma vs Elective)	P Value (Elective vs ASIA C-E)*	P Value (ASIA C-E vs ASIA A-B)*
		ASIA C-E (N=85)	ASIA A-B (N=26)			
Mortality	0 (0.00%)	2 (2.35%)	2 (7.69%)	**0.017**		
90 Day Readmissions	6 (5.41%)	19 (22.4%)	7 (26.9%)	**<0.001**	**0.003**	
Average Number of 90 Day Readmissions	0.06 (0.28)	0.28 (0.57)	0.50 (0.99)	**<0.001**	**0.011**	
0-30 Day Readmissions	0.04 (0.19)	0.08 (0.28)	0.19 (0.49)	**0.030**		
30-90 Day Readmissions	0.03 (0.21)	0.20 (0.51)	0.31 (0.62)	**<0.001**	**0.010**	
Readmission Reason						
SSI	0 (0.00%)	2 (10.5%)	1 (14.3%)	1.000		
Non SSI Infections	1 (16.7%)	5 (26.3%)	3 (42.9%)	0.646		
Nonunion	0 (0.00%)	2 (10.5%)	0 (0.00%)	1.000		
Subsequent Trauma	3 (50.0%)	4 (21.1%)	0 (0.00%)	0.101		
Hardware Loosening	1 (16.7%)	0 (0.00%)	1 (14.3%)	0.157		
Medical Etiology	1 (16.7%)	11 (57.9%)	5 (71.4%)	0.125		
Surgery within 90 Days	4 (3.60%)	8 (9.41%)	4 (15.4%)	0..048		
Procedure Performed				0.295		
Revision	1 (25.0%)	6 (75.0%)	2 (50.0%)			
I&D	3 (75.0%)	2 (25.0%)	2 (50.0%)			

Data listed as either: mean (SD) or n (%)

** Only statistically significant values reported*

***Performed at same hospital visit*

SSI=Surgical Site Infection; I&D=Irrigation and Debridement

POSTER 9

A Comparative Analysis of Natural Language Processing Architectures in Automating Current Procedural Terminology (CPT) Coding for Patients Undergoing Cervical Spine Fusions

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Introduction: Healthcare administration accounts for 31.0% of the United States' rapidly growing healthcare expenditures[1]. Natural language processing (NLP) may automate labor-intensive healthcare administration tasks such as CPT coding. In spine surgery, CPT coding is further complicated by the complexities in surgical approach and variability in surgical vernacular. Previous literature has demonstrated NLP's capabilities to derive CPT codes from operative reports; however, these studies are trained on a single surgeon's notes, contain small training sets, and do not compare NLP architectures statistically[2,3]. In this study, we assess the efficacy of NLP models on a large, multi-surgeon set of cervical spine fusion operative reports to generate CPT codes. We hypothesize that a large language model (LLM) trained on medical documentation (ClinBERT) will outperform general LLMs (XLNet) and non-transformer models (XGBoost, BiLSTM).

Materials and Methods: Operative reports and CPT codes submitted for billing from a single academic, tertiary institution were assembled from 2006 to 2023 for patients undergoing elective anterior and/or posterior cervical fusion. Patients were excluded for diagnoses of infection, trauma, or spine oncology. Incomplete reports or procedures containing a CPT code occurring in <1% of the overall cohort were excluded. Four different models, XGboost, BiLSTM, XLNet, and ClinBERT, were trained, validated, and tested using a standard 70:15:15 split. Models were evaluated for accuracy, precision, recall, F1 score, specificity, AUROC, and AUPRC on the test set. The DeLong test was conducted on individual receiver operating curves (ROC) for each CPT code between models. Feature importance was analyzed in the best-performing model via generation of SHapley Additive exPlanation (SHAP) values for a sample of 50 operative reports[4].

Results: 4,389 operative reports were included with 25 unique CPT codes. The 5 most frequent CPT codes were 22551 (67.7%), 22845 (52.0%), 22552 (41.4%), 22853 (31.5%), 22600 (22.7%). ClinBERT outperformed all other models on F1-Score (Table 1). Each model's AUROC and AUPRC scores are comparable with ClinBERT having the highest on the test set. DeLong testing shows that ClinBERT is a significantly better overall classifier by AUROC. ClinBERT is also significantly better in classifying the five most frequent CPT codes, but underperforms XGBoost in lower frequency instrumentation codes. Interestingly, XLNet underperforms ClinBERT in AUROC considerably (Figure 1). This might be due to the non-clinical corpus this LLM was trained on. An illustrative example of SHAP analysis is shown in Figure 2, where the intensity of highlight signifies the importance of key phrases. The bar chart shows that ClinBERT assigns importance to spinal level (c4, t1) and approach (posterior) in classifying this operative report correctly with 22614.

Conclusion: Our results demonstrate the tradeoffs between NLP models tasked with coding cervical spine surgery procedures: no single model outperforms others in all situations. LLMs

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perform significantly better on high-frequency codes, indicating more training data is required for LLMs performance to improve on rare CPT codes. LLMs in this study are limited by their relatively small sequence length maximum of 512 tokens. Further studies should utilize new models like Clinical-Longformer and train models across broader spine procedure groups to achieve full CPT coding automation[5].

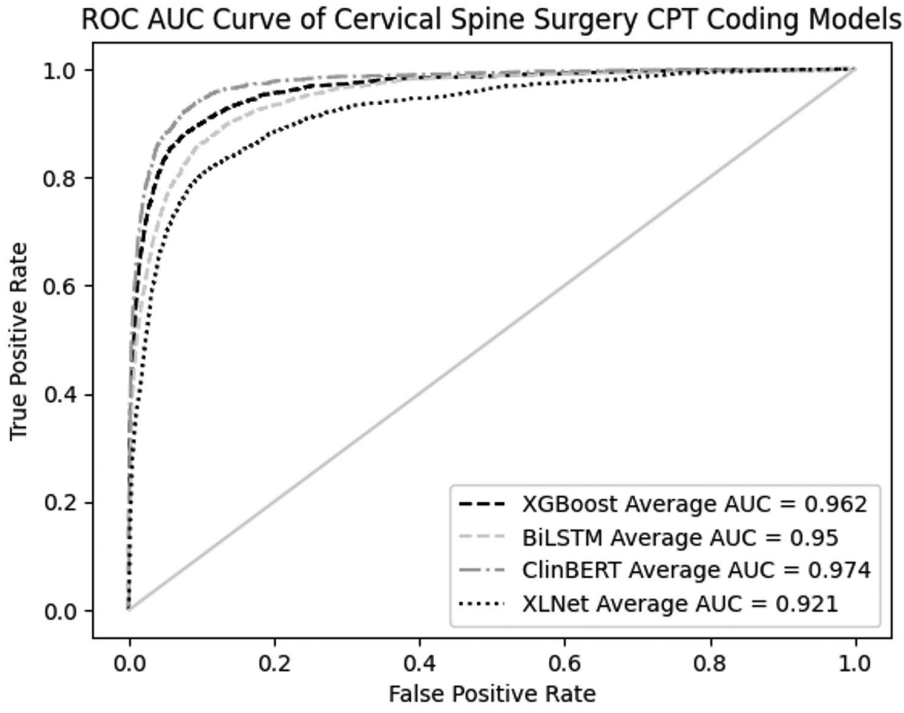
Table 1. Testing characteristics of all four machine learning models on overall cervical spine surgery CPT code prediction.

Model:	Accuracy:	Precision:	Recall:	F1 Score:	Specificity:	AU-ROC:	AU-PRC:
Null Model*	0.227	0.131	0.871	0.228	0.129	0.500	0.131
XGBoost	**0.943**	**0.827**	0.712	0.766	**0.977**	0.962	0.850
W2V-BiLSTM	0.929	0.754	0.686	0.718	0.966	0.950	0.848
XLNet	0.884	0.540	0.810	0.648	0.896	0.921	0.839
ClinBERT	0.933	0.686	**0.897**	**0.778**	0.938	**0.974**	**0.853**

Best characteristic performance

*Null model is baseline of random predictions based on CPT code frequency distributions

Figure 1: Receiving Operating Curves of Model Prediction of Cervical Spine Surgery Codes. ClinBERT performs significantly better than both transformer and non-transformer models.



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

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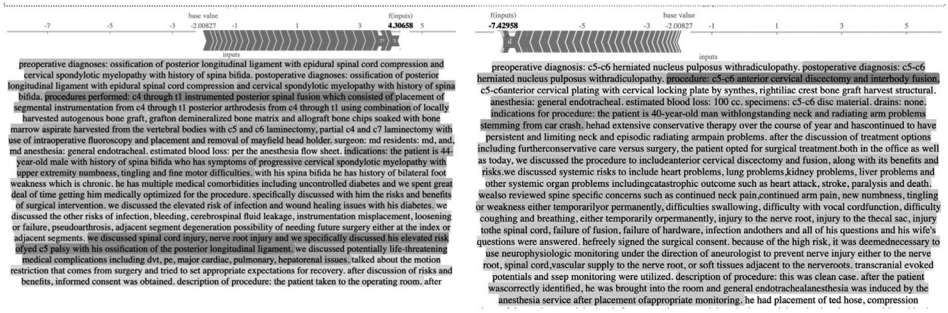
Figure 2: SHapley Additive exPlanation values overlaid on example operative reports for predicting the CPT Code 22614. Red indicates a positive prediction for the CPT code (left) and blue indicates a negative prediction (right).



POSTER 10

C3 Laminectomy versus Conventional Open Door C3–C7 Laminoplasty: a Systematic Review and Meta-analysis

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Introduction: Conventional open-door laminoplasty is commonly used to treat multilevel cervical disorders but often leads to complications such as loss of cervical lordosis, limited neck motion, and axial symptoms. These issues stem from the extensive disruption of musculature and structural alterations involved in traditional methods. To address these shortcomings, the C3 laminectomy technique has been developed as a modification of traditional laminoplasty, with the aims to preserve the semispinalis cervicis muscle attached to the C2 spinous process, potentially improving postoperative outcomes by maintaining muscle integrity and stability of the cervical spine. This study seeks to evaluate the clinical benefits of C3 laminectomy in comparison to conventional laminoplasty approaches.

Materials and Methods: We conducted a comprehensive search across multiple databases, including PubMed, Scopus, EMBASE, Web of Science, and the Cochrane Library, to identify randomized controlled trials (RCTs), cohort studies, and case-control studies that compare the clinical outcomes of open laminoplasty and C3 laminectomy. The outcome measures assessed were operative time, Neck Disability Index (NDI), Japanese Orthopaedic Association (JOA) scores, length of hospital stay, complications, pain indices, and cervical range of motion (ROM). Statistical analyses were performed using RevMan software to evaluate the differences between the two surgical techniques.

Results: Our analysis included 12 studies encompassing 502 participants. The meta-analysis revealed no significant differences between patients undergoing open door laminoplasty with and without C3 laminectomy regarding operation time (mean difference, MD: 5.08, 95% confidence interval, CI: -3.04 to 13.21), length of hospital stay (MD: -0.33, 95% CI: -1.43 to 0.77), Japanese Orthopaedic Association (JOA) scores (MD: 0.18, 95% CI: -0.03 to 0.40), Neck Disability Index (NDI) scores (MD: -0.14, 95% CI: -4.00 to 3.72), and complication rates (risk difference: 0.01, 95% CI: -0.03 to 0.04). However, participants in the group that underwent laminoplasty with C3 laminectomy exhibited a significantly greater range of motion (MD: 4.13, 95% CI: 0.07 to 7.20) and lower postoperative pain scores (standard mean difference: -0.57, 95% CI: -1.05 to -0.10).

Conclusion: Our study suggests that open-door laminoplasty with C3 laminectomy improves range of motion and reduces pain compared to traditional laminoplasty, with no differences in other clinical outcomes. Further studies are needed to confirm these results.

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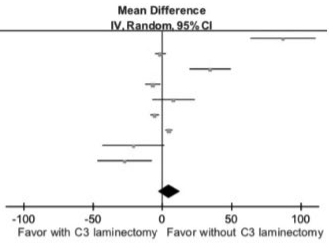
1.1 Operation time

Study or Subgroup	With C3 laminectomy Mean	SD	Total	Without C3 laminectomy Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Bakr O 2023	284	67	59	197	72	76	6.7%	87.00 [63.46, 110.54]
Chen C 2020	88.78	10.09	37	90.2	10.66	74	14.6%	-1.42 [-5.48, 2.64]
Chen Y 2020	142.5	28.1	16	108	14.7	27	10.1%	34.50 [19.66, 49.34]
Fang M 2020	119	10	28	126	12	30	14.1%	-7.00 [-12.67, -1.33]
Kim JH 2023	126	42	51	118	40	58	9.8%	8.00 [-7.45, 23.45]
Lee GW 2017	87.5	6.9	27	93.1	6.3	39	14.8%	-5.60 [-8.87, -2.33]
Macki M 2023	138.8	5.1	39	134	8.2	61	14.9%	4.80 [2.19, 7.41]
Matsuoka H 2023	134.6	34.4	20	155.6	34.2	16	7.0%	-21.00 [-43.54, 1.54]
Yu W 2024	129.88	40.18	40	157.25	46.55	36	8.0%	-27.37 [-47.02, -7.72]
Total (95% CI)			**317**			**417**	**100.0%**	**5.08 [-3.04, 13.21]**

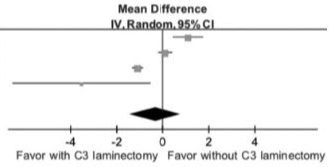
Heterogeneity: Tau² = 113.47; Chi² = 115.50, df = 8 (P < 0.00001); I² = 93%
Test for overall effect: Z = 1.23 (P = 0.22)



2.1 Length of stay

Study or Subgroup	With C3 laminectomy Mean	SD	Total	Without C3 laminectomy Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Bakr O 2023	4.2	2.2	59	3.1	1.5	76	28.5%	1.10 [0.45, 1.75]
Lee GW 2017	6.9	0.6	27	6.8	0.7	39	30.9%	0.10 [-0.22, 0.42]
Macki M 2023	3.5	0.2	39	4.6	0.9	61	31.2%	-1.10 [-1.33, -0.87]
Yu W 2024	12.8	4.54	40	16.33	8.09	36	9.5%	-3.53 [-6.52, -0.54]
Total (95% CI)			**165**			**212**	**100.0%**	**-0.33 [-1.43, 0.77]**

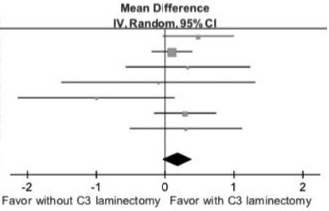
Heterogeneity: Tau² = 0.99; Chi² = 65.65, df = 3 (P < 0.00001); I² = 95%
Test for overall effect: Z = 0.59 (P = 0.55)



3.1 JOA

Study or Subgroup	With C3 laminectomy Mean	SD	Total	Without C3 laminectomy Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Chen C 2020	14.01	1.33	37	13.53	1.28	74	16.4%	0.48 [-0.04, 1.00]
Chen Y 2020	16.8	0.4	16	16.7	0.6	27	44.6%	0.10 [-0.20, 0.40]
Fang M 2020	14.36	1.7	28	14.03	1.82	30	5.5%	0.33 [-0.58, 1.24]
Lee DH 2016	16	2.4	14	16.1	2.2	45	2.3%	-0.10 [-1.51, 1.31]
Matsuoka H 2023	14.9	2.4	20	15.9	0.9	16	3.5%	-1.00 [-2.14, 0.14]
Yu W 2024	15.6	1.1	40	15.31	0.92	36	21.0%	0.29 [-0.16, 0.74]
Zhou Y 2018	13.8	1.6	40	13.5	2.1	40	6.8%	0.30 [-0.52, 1.12]
Total (95% CI)			**195**			**268**	**100.0%**	**0.18 [-0.03, 0.40]**

Heterogeneity: Tau² = 0.00; Chi² = 6.24, df = 6 (P = 0.40); I² = 4%
Test for overall effect: Z = 1.69 (P = 0.09)

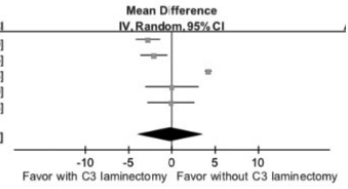


POSTER 10 continued

4.1 NDI

Study or Subgroup	With C3 laminectomy Mean	SD	Total	Without C3 laminectomy Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Chen C 2020	5.88	2.45	37	8.68	5.08	74	20.6%	-2.80 [-4.20, -1.40]
Fang M 2020	10.36	2.55	28	12.47	3.46	30	20.5%	-2.11 [-3.67, -0.55]
Kim JH 2023	12.8	1	51	8.6	1	58	21.1%	4.20 [3.82, 4.58]
Lee DH 2016	6.3	5.2	14	6.3	5.1	45	18.6%	0.00 [-3.10, 3.10]
Yu W 2024	7.28	4.01	40	7.39	7.47	36	19.1%	-0.11 [-2.85, 2.63]
Total (95% CI)			**170**			**243**	**100.0%**	**-0.14 [-4.00, 3.72]**

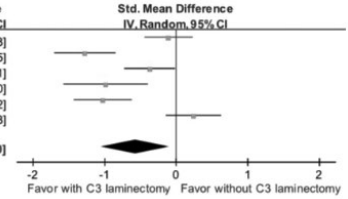
Heterogeneity: Tau² = 18.29; Chi² = 151.44, df = 4 (P < 0.00001); I² = 97%
Test for overall effect: Z = 0.07 (P = 0.94)



5.1 Pain score

Study or Subgroup	With C3 laminectomy Mean	SD	Total	Without C3 laminectomy Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Bakr O 2023	3.6	2.9	59	3.9	2.7	76	17.4%	-0.11 [-0.45, 0.23]
Chen C 2020	1.2	0.53	37	4.4	3	76	16.6%	-1.28 [-1.71, -0.85]
Kim JH 2023	2.8	0.3	51	3.7	3.1	76	17.3%	-0.37 [-0.73, -0.01]
Lee DH 2016	0.9	1.3	14	3.8	3.1	76	14.8%	-0.99 [-1.58, -0.40]
Yu W 2024	1.13	0.97	40	3.8	3.1	76	16.8%	-1.03 [-1.43, -0.62]
Zhou Y 2018	2.7	1.5	40	2.36	1.33	74	17.0%	0.24 [-0.14, 0.63]
Total (95% CI)			**241**			**454**	**100.0%**	**-0.57 [-1.05, -0.10]**

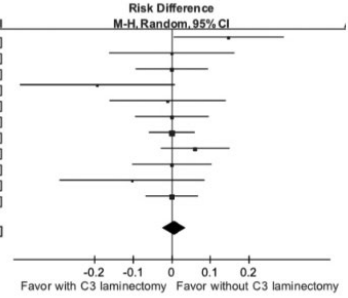
Heterogeneity: Tau² = 0.31; Chi² = 41.73, df = 5 (P < 0.00001); I² = 88%
Test for overall effect: Z = 2.35 (P = 0.02)



6.1 Complication rate

Study or Subgroup	With C3 laminectomy Events	Total	Without C3 laminectomy Events	Total	Weight	Risk Difference M-H, Random, 95% CI
Bakr O 2023	18	59	12	76	4.6%	0.15 [0.00, 0.29]
Chen C 2020	8	37	16	74	3.6%	0.00 [-0.16, 0.16]
Chen Y 2020	0	16	0	27	10.3%	0.00 [-0.09, 0.09]
Fang M 2020	3	28	9	30	2.4%	-0.19 [-0.39, 0.01]
Kim JH 2023	10	51	12	58	4.1%	-0.01 [-0.16, 0.14]
Lee DH 2016	0	14	0	45	10.0%	0.00 [-0.10, 0.10]
Lee GW 2017	0	27	0	39	23.8%	0.00 [-0.06, 0.06]
Macki M 2023	3	39	1	61	11.3%	0.06 [-0.03, 0.15]
Matsuoka H 2023	0	20	0	16	8.6%	0.00 [-0.10, 0.10]
Yu W 2024	7	40	10	36	2.7%	-0.10 [-0.29, 0.09]
Zhou Y 2018	1	40	1	40	18.7%	0.00 [-0.07, 0.07]
Total (95% CI)		**371**		**502**	**100.0%**	**0.01 [-0.03, 0.04]**
Total events	50		61			

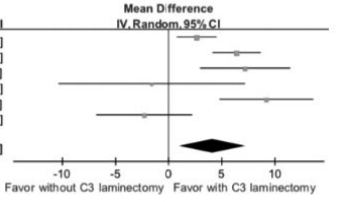
Heterogeneity: Tau² = 0.00; Chi² = 10.41, df = 10 (P = 0.41); I² = 4%
Test for overall effect: Z = 0.37 (P = 0.71)



7.1 ROM

Study or Subgroup	With C3 laminectomy Mean	SD	Total	Without C3 laminectomy Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Chen C 2020	35.24	4.72	37	32.59	4.83	74	22.1%	2.65 [0.77, 4.53]
Chen Y 2020	38.5	3.6	16	32.1	3.8	27	21.3%	6.40 [4.13, 8.67]
Lee DH 2016	33.7	6	14	26.5	9.7	45	16.5%	7.20 [2.97, 11.43]
Matsuoka H 2023	25.9	14.6	20	27.5	12.3	16	8.1%	-1.60 [-10.39, 7.19]
Yu W 2024	31.15	10.05	40	21.95	9.53	36	16.1%	9.20 [4.80, 13.60]
Zhou Y 2018	35	10.9	40	37.3	9.7	40	15.8%	-2.30 [-6.82, 2.22]
Total (95% CI)			**167**			**238**	**100.0%**	**4.13 [1.05, 7.20]**

Heterogeneity: Tau² = 10.22; Chi² = 22.71, df = 5 (P = 0.0004); I² = 78%
Test for overall effect: Z = 2.63 (P = 0.009)



POSTER 11

A Retrospective Analysis of 141 Patients Undergoing Correction Surgery for Cervicothoracic Deformity by a Single Surgical Team: Are Elderly Patients at an Elevated Risk for Complications

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Chang Gung Memorial Hospital, Orthopedic Department, Spine Division[1] Department of Neurological Surgery, UCSF[2] Department of Orthopedics, UCSF[3] Department of Neurological Surgery[4] UC Berkeley[5]

Introduction: Cervicothoracic deformity correction surgeries are complex procedures with potential complications. This study examines the outcomes and complication rates in patients over 70 years old compared to younger patients undergoing these surgeries.

Materials and Methods: A retrospective analysis was conducted on 141 patients who underwent cervicothoracic deformity correction surgery by a single surgical team between March 2011 and March 2023. The patients were divided into two groups: those younger than 70 years (97 patients) and those older than 70 years (44 patients). Data on clinical, demographic, and comorbidity details, along with radiographic and complication profiles, were collected and compared between the groups. To assess health-related quality of life (HRQL), the Oswestry Disability Index (ODI), Numerical Rating Scale (NRS) for pain, and the Scoliosis Research Society-22 revised (SRS-22r) questionnaire were recorded pre-operatively, and at 6 weeks and 1 year post-operatively.

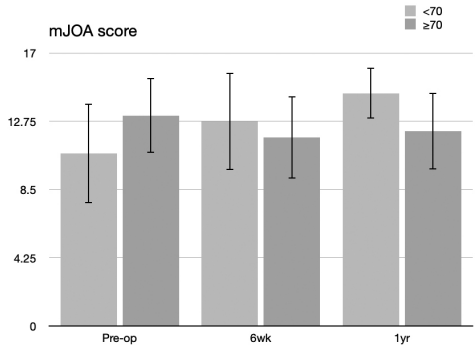
Results: Demographically, there were no significant differences between the two groups except for age and age-adjusted Charlson comorbidity index (CCI). The usage of 3-column osteotomy (3-CO) was not significantly different, with 68 (70.10%) in the younger group and 30 (68.18%) in the older group. Hospital and ICU stays were comparable between the groups. Complication rates—including overall, medical, surgical, and post-operative neurologic deficits—remained similar. Infection rates, junctional failure, implant failure, and re-operation due to these etiologies also showed no significant difference.

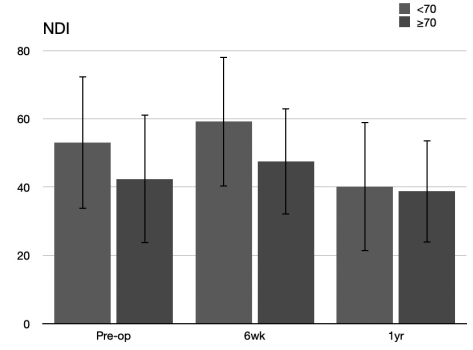
Regarding health-related quality of life (HRQoL) outcomes, mJOA scores improved gradually in the younger group but not in the older group, even one year post-operatively. NDI scores showed significant improvement at one year post-operatively for the younger group, with a similar trend in the older group, though not statistically significant. SRS-22r scores improved significantly for both groups, with the younger group showing this improvement as early as six weeks post-operatively. NRS scores for neck and back pain improved in both groups at six weeks post-operatively and maintained this improvement, while NRS for arm pain showed less pain in elderly patients at baseline, with improvement in the younger group at one year post-operatively.

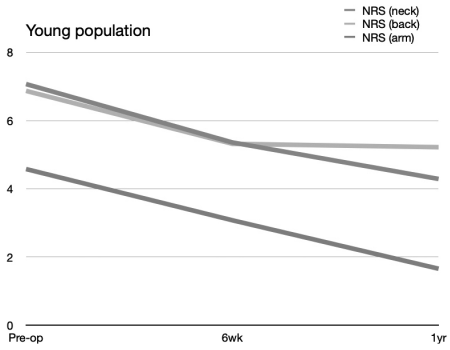
Optimal radiographic correction results were achieved in both groups at 1 year post-operatively, with the following outcomes (younger vs. older): SVA at 2.93 cm vs. 4.25 cm; C2-7 SVA at 4.09 cm vs. 3.64 cm; cervical lordosis at -20.87 degrees vs. -18.12 degrees; T1 slope at 31.47 degrees vs. 34.65 degrees; and T1 slope minus cervical lordosis at 17.25 degrees vs. 20.47 degrees. These results were comparable between groups at all time points.

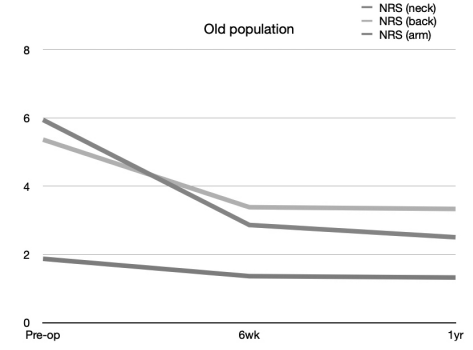
POSTER 11 continued

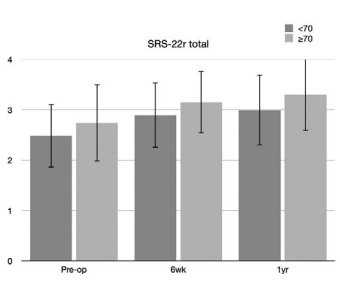
Conclusion: Elderly patients undergoing cervicothoracic deformity correction surgery did not experience a significantly higher rate of complications compared to younger patients. While HRQoL outcomes improved more significantly in younger patients, radiographic corrections were comparable between groups. These findings suggest that age alone should not be a barrier to these surgeries, though careful patient selection and management are crucial.

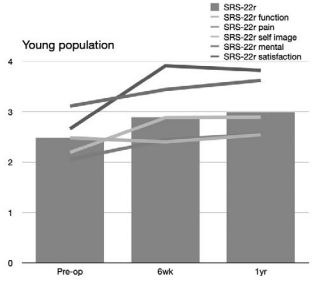


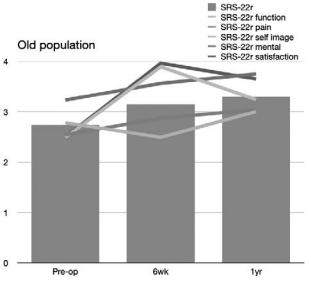












POSTER 11 continued

Demographic data and complications

	<70	≥70	*p*-value
Number	97	44	
Age	59.70± 9.25	75.48± 4.10	<0.0001
Gender (M:F)	34: 63	18: 26	0.5042
BMI	27.16± 6.18	28.03± 6.14	0.4415
Myelopathy	59 (60.82%)	24 (54.55%)	0.4929
CCI	2.04± 1.53	2.02± 1.59	0.9456
A-CCI	3.54± 1.81	5.20± 1.58	<0.0001
Frailty	5.82± 2.98	5.64± 3.05	0.8697
Smoker	52 (53.61%)	16 (36.36%)	0.0576
3-column osteotomy	68 (70.10%)	30 (68.18%)	0.8184
Fusion level	12.92± 4.33	13.90± 4.10	0.1775
EBL (ml)	1181.63± 1595.43	1238.05± 807.70	0.8074
OP time (minute)	273.78± 99.44	273.89± 86.55	0.9950
ICU stay (day)	2.97± 2.72	3.58± 3.49	0.2592
Hospital stay (day)	10.11± 17.66	11.64± 9.98	0.5139
F/u length (month)	23 (0-158)	19 (0-55)	0.2487
Complication	39 (40.20%)	19 (43.18%)	0.7394
Medical complication	24 (24.74%)	14 (31.81%)	0.7698
Surgical complication	20 (20.62%)	5 (11.36%)	0.1825
Post neuro-deficit	16 (16.49%)	6 (13.64%)	0.6647
30-day readmission	7 (7.22%)	3 (6.82%)	0.9320
Infection	7 (7.22%)	4 (9.10%)	0.7006
Junctional failure	13 (13.40%)	11 (25.00%)	0.0895
Implant failure	12 (12.37%)	5 (11.36%)	0.8648
Re-operation	19 (19.59%)	7 (15.91%)	0.6018

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

POSTER 12

Novel Radiologic Parameter for Assessing Decompression Adequacy in Anterior Cervical Decompression Surgery: The V-line

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Introduction: Anterior cervical decompression surgeries, such as Vertebral Body Sliding Osteotomy (VBSO) and Anterior Cervical Corpectomy and Fusion (ACCF), serve as vital surgical options for managing cervical myelopathy. Despite their effectiveness, incomplete expansion of the spinal canal can occur in certain cases. However, many patients still experience positive clinical outcomes after these surgeries, suggesting that assessing outcomes based solely on the lesion's canal-occupying effect may be limited. In cases of anterior-based fusion surgery, changes in cervical alignment can occur postoperatively. Since traditional measures like the canal occupying ratio (COR) consider only the absolute size of the lesion, they may overlook improvements in clinical symptoms due to enhanced lordosis. This study introduces the V-line, a novel radiologic parameter, to universally evaluate decompression outcomes in these procedures.

Materials and Methods: This retrospective analysis encompassed 93 patients treated for cervical myelopathy due to ossification of the posterior longitudinal ligament through either VBSO (N=76) or ACCF (N=17) (Table 1). The V-line, defined on a plain lateral radiograph in the neutral position, connects the lowest point on the posterior margin of the vertebral body immediately above the osteotomy site to the highest point on the posterior margin immediately below it. The V-line classification was "V-line (-)" if the postoperative pathologic lesion contacted the V-line and "V-line (+)" if it did not (Figure 1). Patients were categorized based on postoperative COR and the V-line assessment. Radiological evaluations included C2–7 lordosis, segmental lordosis, and COR. The Japanese Orthopedic Association (JOA) scores were assessed preoperatively, at 1-year postoperatively, and at the final follow-up.

Results: The V-line (+) group achieved a higher final JOA score (15.3 ± 1.91) and JOA recovery rate (62.16 ± 32.22) compared to the V-line (-) group, which recorded a final JOA score (14.25 ± 2.33, $p = 0.037$) and a JOA recovery rate (24.71 ± 32.00, $p<0.001$). Additionally, postoperative C2-7 lordosis (18.05 ± 9.59, $p < 0.001$) and segmental lordosis (18.53 ± 8.49, $p = 0.008$) in the V-line (+) group were significantly greater than in the V-line (-) group (10.68 ± 8.38; 11.42 ± 7.87). However, when comparing groups based on postoperative COR, significant differences were observed only in the JOA recovery rate, with no notable differences in final JOA score, C2-7 lordosis and segmental lordosis between the groups (Table 2).

Conclusion: Since the V-line accounts for both the mass effect of the pathological lesion and cervical alignment, this parameter effectively reflects the reduced impact of spinal cord compression when cervical lordosis is restored, even with residual canal-occupying lesions present. These findings underscore the importance of considering changes in alignment, not just the reduction in lesion size, in assessing decompression adequacy. Therefore, the V-line provides a more comprehensive measure of decompression adequacy than the traditional COR, which may fail to capture the clinical significance of changes in postoperative spinal alignment.

POSTER 12 continued

Table 1. Preoperative baseline characteristics

Variables	Postop COR = 0% (N = 49)	Postop COR > 0% (N = 44)	*P*	Postop V-line (+) (N = 59)	Postop V-line (-) (N = 34)	*P*
Age (y)	61.63 ± 9.71	57.45 ± 9.28	0.019*	60.63 ± 9.65	57.97 ± 9.68	0.102
Sex (Male)	31 (63.3%)	28 (63.6%)	0.970	35 (59.3%)	24 (70.6%)	0.277
VBSO	41(83.7%)	35 (79.5%)	0.607	47 (79.7%)	29 (85.3%)	0.498
ACCF	8 (16.3%)	9 (20.5%)		12 (20.3)	5 (14.7%)	
DM	11 (22.4%)	6 (13.6%)	0.607	13 (29.5%)	4 (11.8%)	0.217
HTN	18 (36.7%)	8 (18.2%)	0.047*	20 (33.9%)	6 (17.6%)	0.093
Malignancy	1 (2.0%)	1 (2.3%)	0.939	1 (1.7%)	1 (2.9%)	0.690
BMI (kg/m^2)	24.91 ± 3.12	25.23 ± 3.20	0.332	24.90 ± 3.09	25.35 ± 3.28	0.285
Smoking status	7 (14.3%)	11 (25%)	0.192	9 (15.3%)	9 (26.5%)	0.187
Number of op segment	2.60 ± 0.50	2.65 ± 0.49	0.325	2.58 ± 0.50	2.69 ± 0.47	0.173
Follow-up (y)	4.17 ± 2.70	5.07 ± 2.67	0.077	4.33 ± 2.76	5.05 ± 2.59	0.140
Preop JOA score	13.0 ± 2.28	13.18 ± 2.51	0.393	12.97 ± 2.22	13.25 ± 2.61	0.334
Preop C2-7 lordosis (º)	6.49 ± 8.15	6.74 ± 8.45	0.443	6.95 ± 8.15	6.03 ± 8.50	0.308
Preop segmental lordosis (º)	0.66 ± 11.88	0.75 ± 11.44	0.484	1.36 ± 11.65	-0.40 ± 11.64	0.247
Preop COR (%)	40.40 ± 14.42	49.05 ± 14.50	0.002*	40.94 ± 14.42	50.66 ± 14.20	0.001*

Postop, postoperative; COR, canal occupying ratio; VBSO, vertebral body sliding osteotomy; ACCF, anterior cervical corpectomy and fusion; DM, diabetes mellitus; HTN, hypertension; BMI, body mass index; Preop, preoperative; JOA, Japanese Orthopaedic Association

Age, BMI, Number of op segment, Follow-up, Preop JOA score, Preop C2-7 lordosis, Preop segmental lordosis and Preop COR were analyzed using a student's t-test

Sex, VBSO, ACCF, DM, HTN, Malignancy and Smoking status were analyzed using a chi-square test or Fisher's exact test

* $P < 0.05$

POSTER 12 continued

Table 2. Comparison of the clinical and radiologic outcomes

Variables	Postop COR = 0% (N = 49)	Postop COR > 0% (N = 44)	*P*	Postop V-line (+) (N = 59)	Postop V-line (-) (N = 34)	*P*
Postop 1 year JOA score	14 ± 2.00	13.52 ± 2.53	0.087	14.27 ± 1.98	13.52 ± 2.66	0.124
Final JOA score	15 ± 1.96	14.61 ± 2.33	0.214	15.3 ± 1.91	14.25 ± 2.33	0.037*
JOA recovery rate (%)	57 ± 31.41	34.87 ± 39.01	0.013*	62.16 ± 32.22	24.71 ± 32.00	<0.001*
Postop C2-7 lordosis (°)	11.64 ± 9.32	11.61 ± 8.69	0.494	18.05 ± 9.59	10.68 ± 8.38	<0.001*
Postop segmental lordosis (°)	13.31 ± 8.46	12.86 ± 8.29	0.407	18.53 ± 8.49	11.42 ± 7.87	0.008*
Postop COR (%)	0.00 ± 0.00	17.70 ± 9.83	<0.001*	1.66 ± 4.19	20.01 ± 9.75	<0.001*

Postop, postoperative; COR, canal occupying ratio; JOA, Japanese Orthopaedic Association

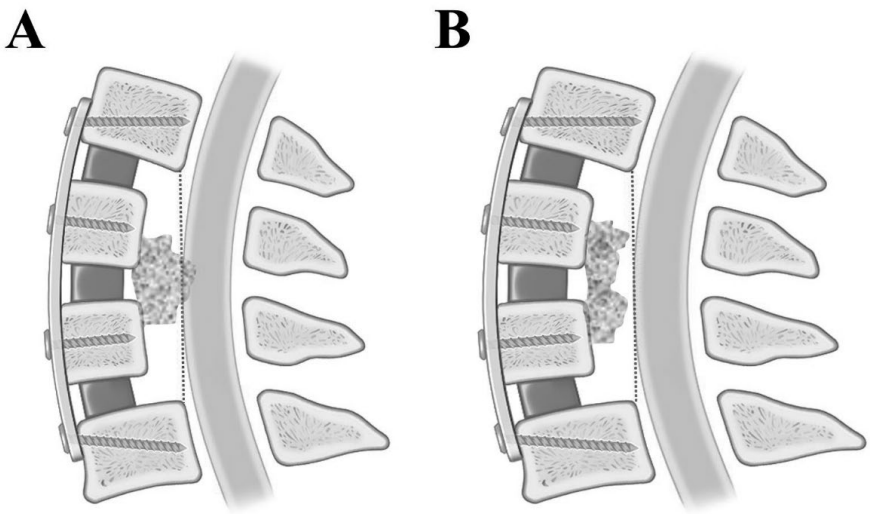
All analyzes were performed using a student's t-test

* $P < 0.05$

POSTER 12 continued

Figure 1. Visualization of V-line assessment method

The red dashed line represents the V-line, drawn by connecting the lowest point on the posterior margin of the vertebral body immediately above the osteotomy site to the highest point on the posterior margin immediately below it. (A) and (B) both have a postoperative canal occupying ratio greater than 0%, but (A) is V-Line (-) and (B) is V-Line (+).



POSTER 13

Bioactive Glass Ceramic vs Allograft: A Comparison of Clinical and Radiological Outcome in Single level ACDF

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Yonsei College of Medicine[1]

Introduction: For satisfactory outcome after anterior cervical discectomy and fusion (ACDF), successful bone union is crucial. Successful fusion largely depends on the type of inserted graft. Graft materials have significantly evolved over time, most recently, to bioactive glass ceramic (BGC) which offer mechanical robustness as well as chemical bondage to the bone with potentials of osteointegration. This study is designed to compare the clinical and radiologic outcomes of the allograft and the BGC.

Materials and Methods: 167 patients who underwent single-level ACDF due to degenerative cervical spine disease were included in this study. Revision, infection, trauma cases were excluded. Patients with rheumatoid arthritis, steroid use, follow-up period of less than a year or those without sufficient radiologic study were also excluded (67 patients were excluded).

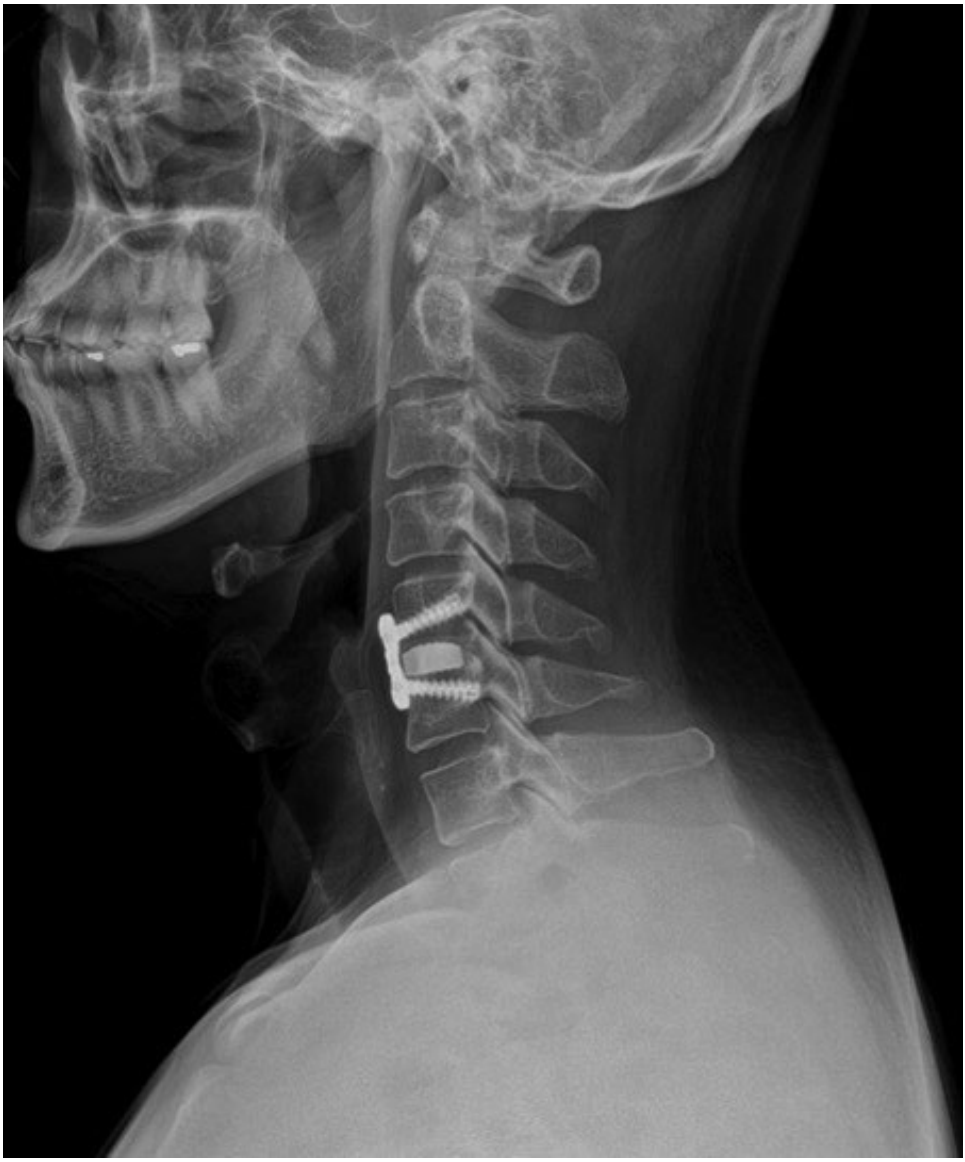
The spacers used in each ACDF were either a BGC or an allograft. Clinical outcomes were evaluated pre-operatively and at 6 weeks and 3, 6 and 12 month follow up. Clinical outcome was measured, including Visual Analogue Scale (VAS) of neck and arm pain, Japanese Orthopedic Association score (JOA), Neck Disability Index (NDI), and patient reported satisfactory rate. Inter-spinous motion (ISM) at one year was measured using flexion and extension lateral radiographs. Bridwell interbody fusion grade was assessed using the one-year postoperative CT scan. Subsidence was measured using lateral radiographs. Factors which may affect fusion rate such as body mass index, smoking history, alcohol consumption, bone quality, etc. were evaluated to assess if there were any significant difference in groups.

Results: Overall, total of 100 patients (30 and 70 patients in the BGC and allograft groups, respectively) were recruited. The demographics or the comorbidities of the two groups did not differ with any significance.

29 (96.7%) and 67 (95.7%) patients in the BGC and allograft groups, respectively, were fused 12 months post-operatively, as assessed by ISM in dynamic lateral radiograph and bone bridging formation proven with CT scan. The average ISM of the BGC group was 0.355mm whilst the allograft group was 0.561mm but no statistical significance was noted between the two groups. One year subsidence was 0.974mm and 0.998mm for the BGC and allograft groups, respectively with no significant difference. Both groups showed substantial improvement in neck and arm pain VAS, JOA score, and NDI but no significant difference was found.

Conclusion: The bioactive glass ceramic group showed satisfactory clinical outcomes with high fusion rate and minimal subsidence, which were comparable to allograft group in single level ACDF.

POSTER 13 continued



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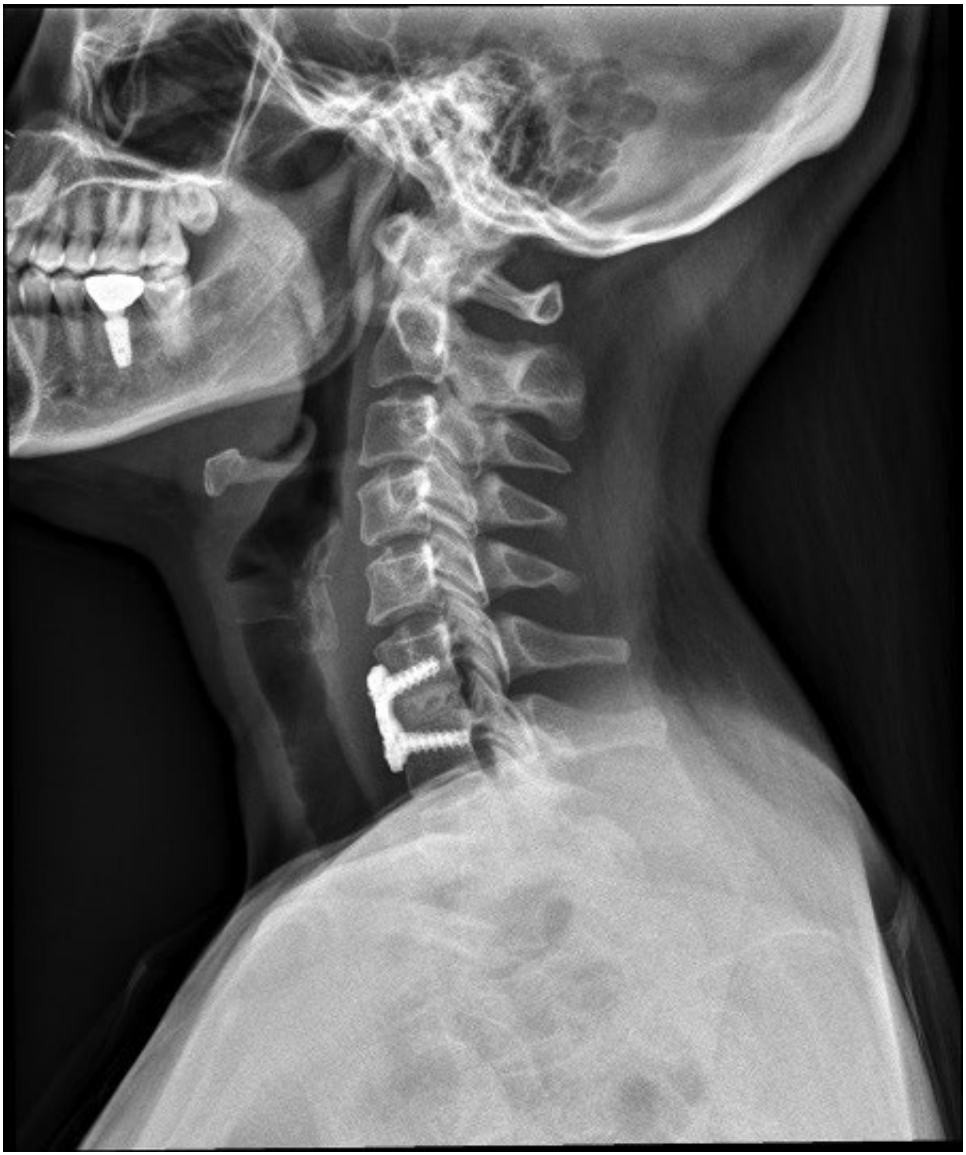

POSTER 14

Funnel-shaped Oblique Keyhole Foraminotomy for Better Foraminal Decompression in Patients with Cervical Spondylotic Radiculopathy

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Introduction: Posterior cervical keyhole foraminotomy is a motion-preserving indirect decompressive surgery that involves removing part of the posterior facet in patients who are complaining of radiating pain caused by disc herniation and foraminal stenosis. However, posterior foraminotomy has also been reported to have a higher rate of inadequate decompression or recurrence of symptoms in patients with severe uncinate process hypertrophy and lower cervical levels. The objective of this study was to provide a 2-year follow-up on the clinical and radiological outcomes of funnel-shaped oblique keyhole foraminotomy in patients with cervical spondylosis.

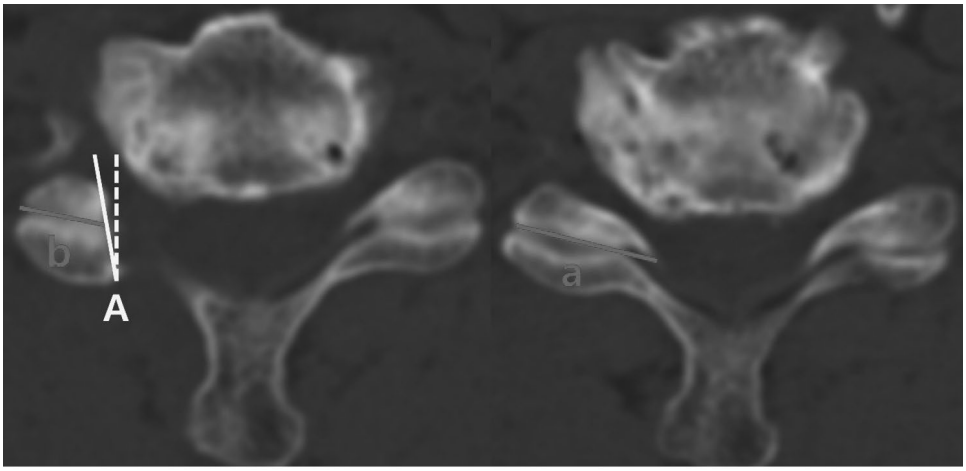
Materials and Methods: The pre-and postoperative clinical and radiographic parameters of 66 patients who underwent keyhole foraminotomy were enrolled, and each of the 33 patients underwent funnel-shaped (Group F) and conventional-type foraminotomy (group C) respectively. Patients with cervical myelopathy, deformities, malignancies, and trauma were excluded. To grind the superior articular process (SAP), the microscope was tilted toward the direction of the lesion, and the burr was tilted as much as possible to match the angle of the facet joint.

Preoperative radiographic parameters of disc height, uncinate process height, and maximal narrowest width of foramen were evaluated. Pre- and postoperative clinical parameters of the visual analog scale of neck pain (NP), arm pain (AP), and neck disability index (NDI) and radiographic parameters of inferior articular process (IAP) and SAP diameter, IAP and SAP resection rate, and inclination angle were compared. The IAP and SAP resection rates were defined as the ratio of the removed IAP and SAP diameters measured in the axial cut on postoperative 3-dimenstional computed tomography to the preoperative entire facet diameter, and the inclination angle was defined as the angle between the resected facet line and an imaginary vertical line.

Results: Foraminotomy was performed in 98 segments of a total of 66 patients (F: C-group = 48: 50 segments), the average age was 58.2 years, and the male ratio was 0.72. The average disc height, uncinate process height, and narrowest foraminal width were 4.7mm, 5.6mm, and 2.6mm respectively. There were no differences in preoperative NP, AP, and NDI between the two groups; however, postoperative AP was significantly lower in group F than in group C (2.5 ± 0.8 vs. 3.4 ± 1.4, <0.05). There was no difference between the two groups in preoperative IAP and SAP diameter, post-operative IAP diameter, and IAP resection rate. However, the postoperatively remained SAP diameter was significantly smaller in group F than in group C (6.21mm ± 2.3 vs. 7.45mm ± 2.8, <0.05). Also, the postoperative SAP resection rate (56.3% ± 4.7 vs. 43.7% ± 5.8, $p<0.01$) and resection inclination angle were significantly higher in group F (14.5° ± 2.7 vs. 3.7° ± 1.4, $p<0.01$). Satisfaction with surgery was significantly higher in group F (94% vs. 83%), and 2 patients in group C required revision surgery ($p<0.01$).

Conclusion: Funnel-shaped oblique keyhole foraminotomy is a useful procedure that enables sufficient SAP decompression without increasing the overall facet resection in cervical spondylotic radiculopathy patients.

POSTER 14 continued



- **Figure.** A schematic drawing represents the facet resection rate and inclination angle. The resection rate was defined as the proportion of the preoperative facet diameter to the postoperative resected diameter * 100 (%) [(a-b)/a * 100]. The inclination angle was defined as the angle between the resected facet line and an imaginary vertical line (A).

POSTER 14 continued

Table 1. Demographic characteristics and surgical levels of study populations

Parameters	Funnel-shape foraminotomy (segments=48)	Conventional foraminotomy (segments=50)	p-value
Age (years)	59.1 ± 9.5	57.3 ± 12.0	0.419
Sex (M %)	0.71 ± 0.37	0.72 ± 0.44	0.377
BMI	25.3 ± 3.7	24.5 ± 2.3	0.287
Disc height (mm)	4.76 ± 1.1	4.71 ± 1.3	0.532
Uncinate process height (mm)	5.59 ± 2.7	5.63 ± 2.5	0.461
Narrowest foraminal width (mm)	2.61 ± 1.47	2.58 ± 1.53	0.729
Surgical levels			0.655
C3-4	3	3	
C4-5	8	9	
C5-6	16	16	
C6-7	19	21	
C7-T1	2	1	

POSTER 14 continued

Table 2. Comparison of pre- and post-operative clinical and radiographic outcomes between groups

Parameters	Funnel-shape foraminotomy (segments=48)	Conventional foraminotomy (segments=50)	p-value
Pre-op Neck pain	3.6 ± 2.2	3.9 ± 2.4	0.589
Pre-op Arm pain	4.7 ± 2.6	4.8 ± 2.3	0.853
Pre-op NDI	15.0 ± 7.7	16.9 ± 8.0	0.371
Post-op Neck pain	3.9 ± 2.6	3.7 ± 1.3	0.281
Post-op Arm pain	2.5 ± 0.8	3.4 ± 1.4	<0.05
Post-op NDI	12.0 ± 4.2	13.1 ± 5.2	0.359
Pre-op IAP diameter (mm)	14.86 ± 2.5	14.62 ± 2.8	0.723
Pre-op SAP diameter (mm)	15.43 ± 2.8	15.13 ± 3.0	0.835
Post-op IAP diameter (mm)	7.32 ± 2.6	7.38 ± 2.7	0.421
Post-op SAP diameter (mm)	6.21 ± 2.3	7.45 ± 2.8	<0.05
IAP resection rate (%)	49.6 ± 5.1	48.3 ± 5.2	0.620
SAP resection rate (%)	56.3 ± 4.7	43.7 ± 5.8	<0.01
Resection inclinati on angle (°)	14.5 ± 2.7	3.7 ± 1.4	<0.01

POSTER 15

A Biomechanical Comparison of Alternatives to C2 Pedicle Screws

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Columbia University[1] Globus Medical[2]

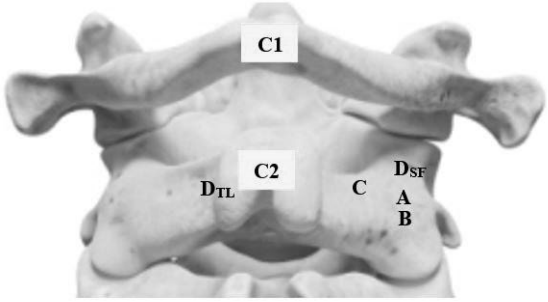
Introduction: Variations in vascular and pedicle anatomy of the C2 vertebra (high riding vertebral artery (HRVA), narrow pedicle) can make C2 fixation difficult [1-5]. Although short pars screws may be safe, their purchase may be suboptimal [6, 7]. Two novel trajectories, the medial in-out-in and subfacetal, may be alternatives. The medial in-out-in trajectory enables three-column and multi-cortical fixation [8] while the subfacetal trajectory compliments patients with HRVA [9-11]. This biomechanical study compares C2 fixation methods: pedicle, short pars, translaminar, medial in-out-in, and subfacetal screws.

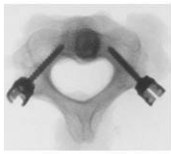
Materials and Methods: Polyaxial screws were inserted in the bilateral C1 lateral mass and bilateral C2 vertebrae of 12 fresh frozen human cadaver specimens. Specimen were assigned to one of four test groups based off C2 screw trajectory: pedicle, short pars, medial in-out-in, and subfacetal combined with translaminar (fig 1). Range of motion (ROM) in flexion/extension (FE), lateral bending (LB), and axial rotation (AR) were measured at C1-2 using a custom-built six-degrees-of-freedom motion simulator and motion analysis software. Two ROM tests were performed on each specimen: 1) intact ROM and 2) surgical construct with screw-rod ROM. Following ROM, C2 screws were subjected to pullout testing using a uniaxial MTS machine at 5mm/min.

Results: Average ROM for intact specimens was 11.04° in FE, 3.21° in LB, and 59.43° in AR (fig 2). A two-way mixed ANOVA showed there was no significant difference in ROM between C2 trajectory groups for FE ($p=.786$), LB ($p=.468$), or AR ($p=.998$). There was a significant difference ($p<.001$) between intact specimens and screw-rod fixated specimens. Although not significantly different, medial in-out-in showed 10% higher pullout strength compared to the pedicle screw and subfacetal showed an 80% increase in pullout strength compared to the pars screw.

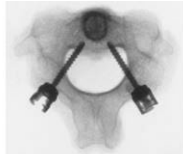
Conclusion: This study suggests that two novel C2 screw trajectories, medial-in-out in and subfacetal screws, have comparable biomechanical fixation strength and ROM to traditional C2 trajectories: pedicle, short pars, and translaminar.

POSTER 15 continued

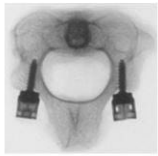




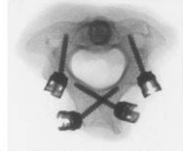
A) Pedicle



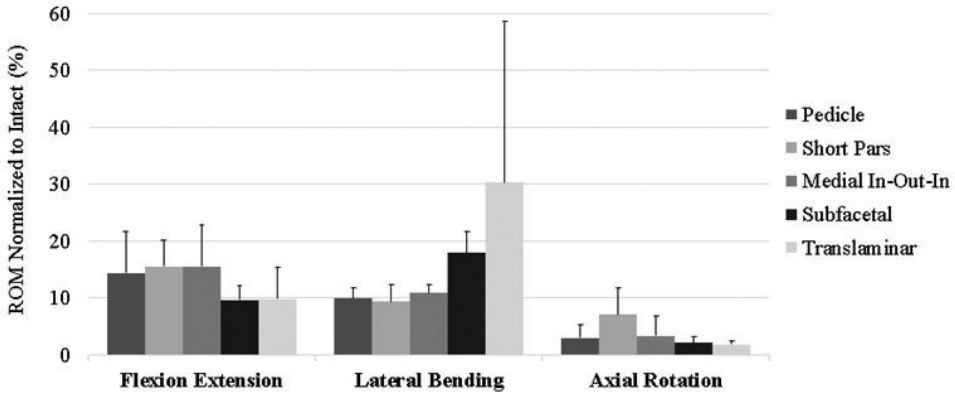
C) Medial In-Out-In

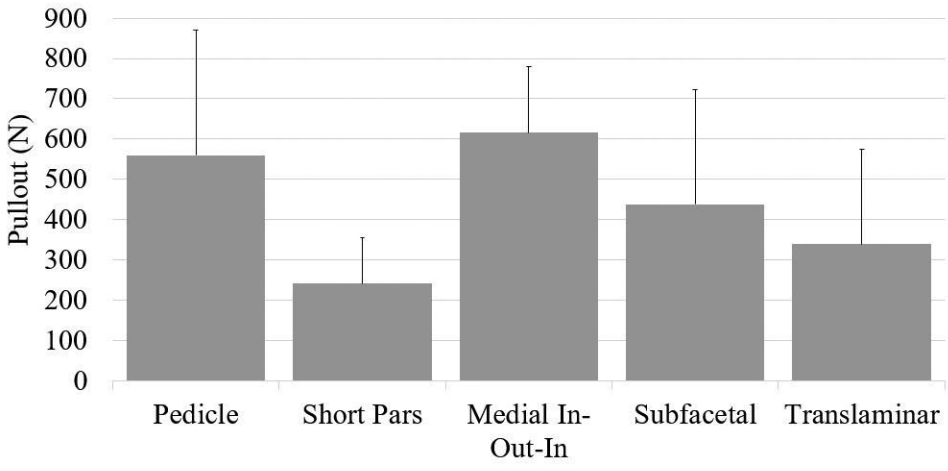


B) Short Pars



D) Subfacetal (SF) & Translaminar (TL)





POSTER 16

Mortality From Falls Leading to Simultaneous Fractures of the Atlas (C1) and Axis (C2)

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University of Pittsburgh[1]

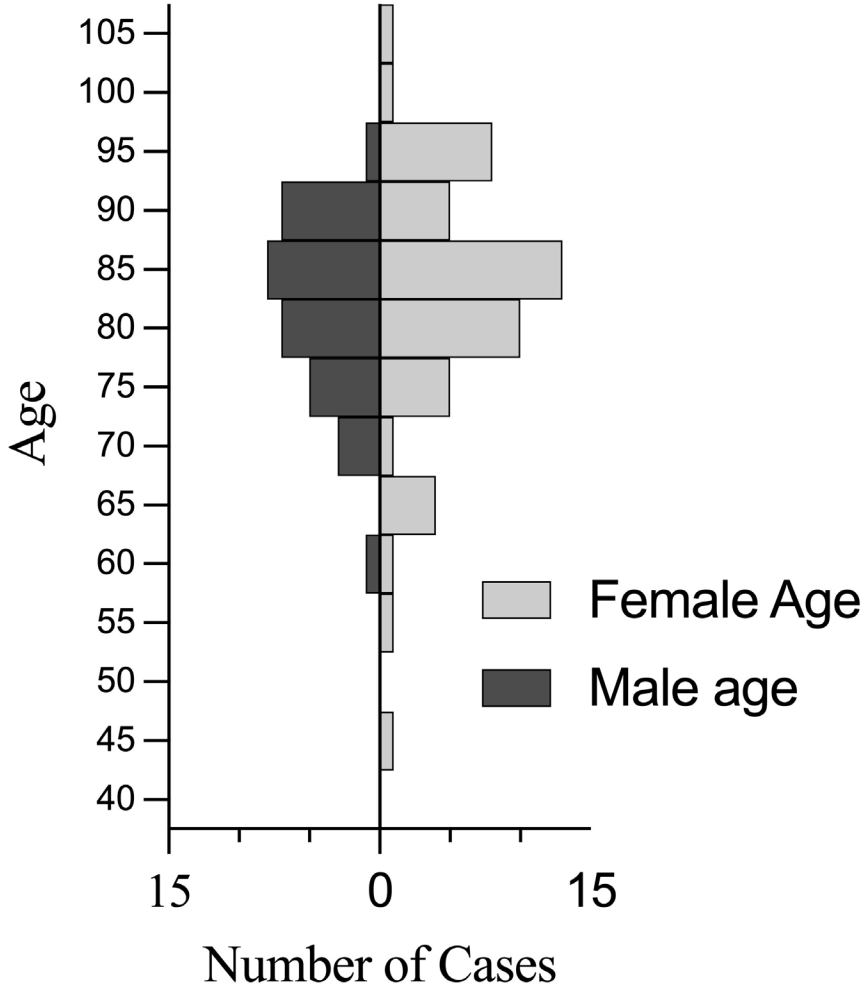
Introduction: The advanced age and comorbid disease burden of patients with simultaneous fractures of the atlas and axis can complicate surgical decision-making. The prognosis of the affected patient population could help inform management decisions.

Materials and Methods: All patients with simultaneous, traumatic fractures of the atlas and axis due to falls treated at our institution from 2012 to 2022 were retrospectively analyzed. Clinical, demographic, and radiographic data were collected. Multivariable regression was used to identify factors that predicted mortality within this patient population, and to assess whether fracture nonunion affects mortality.

Results: 83 patients were identified. The population was disproportionately female (62.2%, p=0.0352), and mostly age≥80 years (59.0%) with a severe comorbid disease burden (Charlson Comorbidity Index ≥5 for 54.9%). Most traumas were minor, with most patients (57.7%) having no other injuries, and only 3 (3.7%) having a major trauma (injury severity score (ISS) ≥15). Mortality was 11.4% at 30 days, 17.3% at 90 days, 22.5% at 6 months, 28.4% at 12 months, 38.7% at 18 months, and 40.7% at 24 months, which followed a linear trend (R-squared=0.9719, p=0.0003). On multivariable analysis, mortality was associated with older age (HR=1.048, p=0.0420), male sex (HR 4.554, p=0.0009) and dementia (HR=5.419, p=0.0011). Patients with dementia had a higher early mortality rate (40.0% vs. 4.7% at 30 days, OR=13.56, p=0.0011) that converged over time with patients without dementia (p=0.0373). Men had a similar mortality rate at 30 days, but their mortality rates diverged over time (p=0.0460). Male sex with dementia had a 100% positive predictive value (PPV) for death by 2 years (PPV=1.00 [0.61, 1.00], p=0.0039). Fracture nonunion did not affect mortality at any time point, and had a calculated treatment effect on mortality of 0.0% at 2 years (p=1.000).

Conclusion: Patients with simultaneous atlantoaxial fractures from falls are typically female octogenarians with severe comorbid disease burdens but only minor associated injuries. Despite minor injuries, mortality rates are high, and are not affected by fracture nonunion. Patients with dementia have a higher short-term mortality rate than patients without it, but that difference narrows over time. Men have a higher mortality rate than women, and gap widens over time.

POSTER 16 continued



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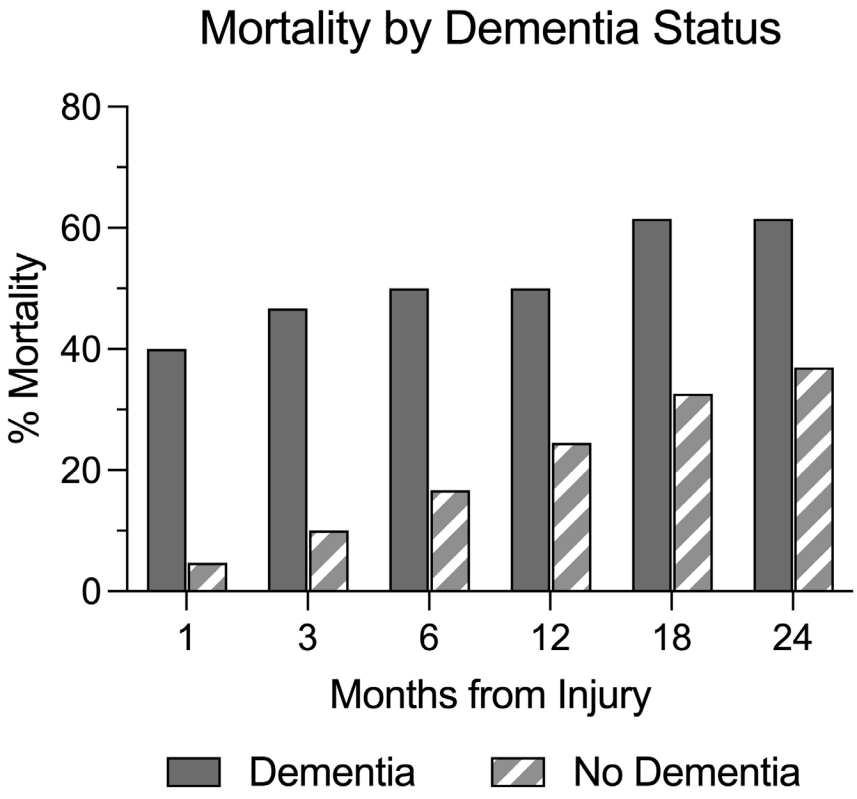

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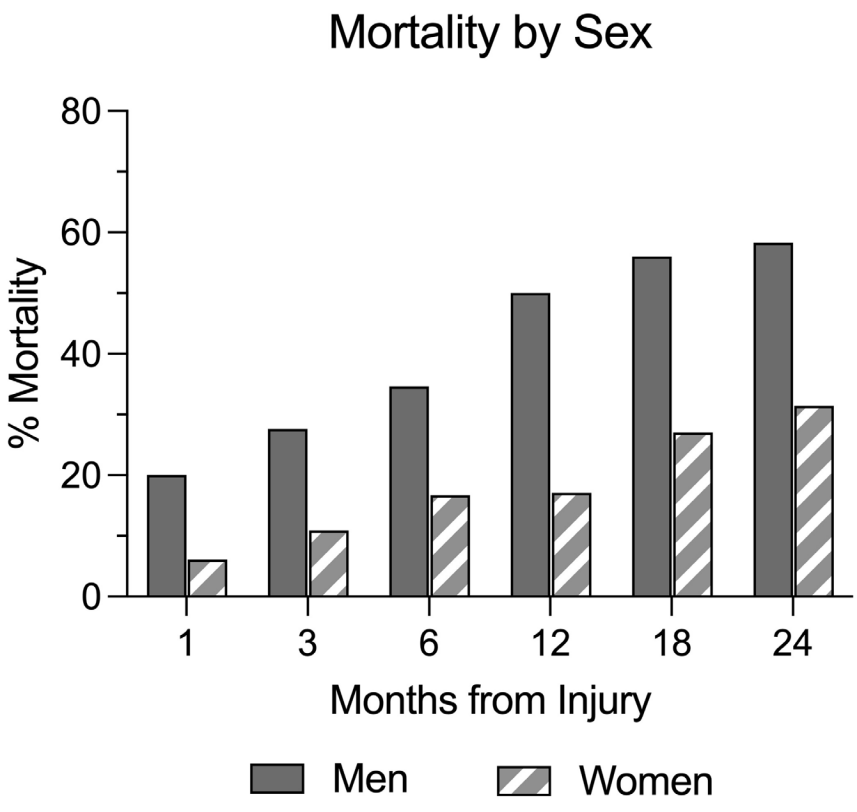

POSTER 17

Obesity Does Not Impact Clinical Outcomes in Anterior Cervical Disc Replacement

Daniel Coban, MD[1], *George Abdelmalek, MD*[2], *Neil Patel, MD*[3], *Stuart Changoor, MD*[3], *Nikhil Sahai, MD*[3], *Kumar Sinha, MD*[3], *Ki Hwang, MD*[3], *Arash Emami, MD*[3]
St. Joseph' University Medical Center[1] St. Joesph's University Medical Center[2] St. Joseph's University Medical Center[3]

Introduction: Obesity has been shown to increase the risk of developing degenerative spine pathologies requiring surgical intervention. Anterior cervical disc replacement (ACDR) is an increasingly popular technique used to treat various pathologies of the cervical spine. ACDR offers several advantages over anterior cervical discectomy and fusion (ACDF) including motion preservation leading to lower rates of adjacent segment disease (ASD). Despite the rise in obesity globally, there is a paucity of literature studying the safety and efficacy of ACDR in this patient population. Purpose: To compare long-term clinical and functional outcomes of 1- and 2-level ACDR performed on obese versus non-obese patients.

Materials and Methods: A retrospective review at a single institution was performed on all patients who underwent either 1- or 2-level ACDR between 2017 to 2021 with a minimum of 2-year follow-up. Patients were divided into two cohorts according to their BMI, non- obese [BMI <30 kg/m 2] and obese [BMI >30 kg/m 2]. Patient reported outcome scores including visual analog scale for neck pain (VAS-n), arm pain (VAS-a) and NDI were collected at the preoperative and each postoperative visit. A subgroup analysis was performed to compare outcomes on patients who were normal weight (18.5 kg/m 2 - 24.9 kg/m 2), overweight (25.0 kg/m 2), class I obesity (30.0 kg/m 2 - 34.9 kg/m 2), class II obesity (35.0 kg/m 2 - 39.9 kg/m 2) and class III obesity (≥ 40 kg/m 2).

Results: 116 total patients were included in the final analysis (71 non-obese, 45 obese). Demographic and perioperative results were similar between obese and non- obese cohorts. Rates of dysphonia, dysphagia, surgical site infection, spontaneous fusion and ASD were similar between the two cohorts. There was no significant difference in the degree of improvement of VAS-n (non-obese: -3.0 vs obese: -3.1, p=0.871), VAS-a (non-obese: -3.3 vs obese: -3.5, p=0.565) or NDI (non-obese: -22.2 vs obese: -23.3, p=0.308) scores between preoperative and final postoperative periods. The rate of heterotopic ossification (HO) significantly differed between the two groups (non-obese: 29.6% vs obese: 48.9%, p=0.036). The subgroup analysis revealed similar results across weight classes.

Conclusion: In conclusion, ACDR may be comparably safe and efficacious in obese and non-obese patients. Both groups demonstrated similar patient reported outcomes and postoperative complications; however, rates of HO were significantly higher in the obese cohort compared to the non-obese cohort.

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Variable	Non-Obese Group	Obese Group	P-value
Number of Patients	71	45	-
Mean BMI (kg/m²)	26.4	34.8	**<0.001***
Age (years)	31.1	44.7	0.451
Proportion of 2-Level Operations (%)	28.2	42.2	0.118
Length of Follow-up (months)	44.1	44.0	0.994
Proportion of Male Patients (%)	49.3	46.7	0.782
Smokers (%)	29.6	26.7	0.735
Patients with Hypertension (%)	16.9	28.9	0.126
Patients with Chronic Obstructive Pulmonary Disease (%)	1.4	0.0	0.424
Patients with Obstructive Sleep Apnea (%)	5.6	13.3	0.150
Patients with Diabetes Mellitus (%)	9.9	22.2	0.067

* and Bolded Values indicate statistical significance

Complication	Non-Obese Group	Obese Group	P-value
Dysphonia (%)	2.8	2.2	0.844
Dysphagia (%)	19.7	22.2	0.746
Surgical Site Infection (%)	0.0	2.2	0.207
Spontaneous Fusion (%)	0.0	4.4	0.073
Adjacent Segment Disease (%)	1.4	2.2	0.743
Overall Complication Rate (%)	21.1	26.7	0.491
Heterotopic Ossification (%)	29.6	48.9	**0.036***

* and Bolded Values indicate statistical significance

POSTER 17 continued

Clinical Outcome Measure	Timepoint	Non-Obese Group	Obese Group	p-value
Visual Analog Scale-Neck (VAS-n)	Preoperative	7.0	7.3	0.440
	6-months Postop	5.2	5.0	0.673
	12-months Postop	4.3	4.5	0.330
	Final Follow-Up	4.0	4.2	0.135
	Mean Improvement	3.0	3.1	0.871
Visual Analog Scale-Arm (VAS-a)	Preoperative	6.8	7.1	0.423
	6-months Postop	4.9	5.0	0.787
	12-months Postop	3.8	3.9	0.645
	Final Follow-Up	3.5	3.6	0.437
	Mean Improvement	3.3	3.5	0.565
Neck Disability Index (NDI)	Preoperative	37.4	39.2	0.342
	6-months Postop	28.6	30.5	0.223
	12-months Postop	20.5	22.2	0.344
	Final Follow-Up	15.2	15.9	0.457
	Mean Improvement	22.2	23.3	0.308

POSTER 18

Increased Risk of Adverse Events in Patients with Systemic Lupus Erythematosus Undergoing Single-level Anterior Cervical Discectomy and Fusion

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Yale School of Medicine[1]

Introduction: Patients with systemic lupus erythematosus (SLE) may be candidates for spine surgery such as anterior cervical discectomy and fusion (ACDF). However, the correlation of SLE with postoperative adverse outcomes following ACDF remains poorly understood. The current study aimed to evaluate the 90-day postoperative outcomes of SLE patients who underwent ACDF using exact matching controls.

Materials and Methods: Adult patients with and without SLE who underwent single-level ACDF were identified from a national database, excluding those who had experienced trauma, neoplasm, or infection within 90 days before the procedure, as well as those who underwent any other cervical procedures on the same day. Exact matching (1:4) was performed to balance age, sex, and Elixhauser Comorbidity Index between the two groups.

Univariable and multivariable logistic regression, controlling for age, sex, and Elixhauser Comorbidity Index (ECI), were conducted to compare 90-day postoperative adverse events, readmissions, and emergency department (ED) visits. Aggregate as well as individual severe adverse events (consisting of surgical site infection, sepsis, venous thromboembolism, and cardiac events) and minor adverse events (consisting of wound complications, pneumonia, urinary tract infection, acute kidney injury, and transfusion) were assessed.

Results: A total of 2,098 patients with SLE and 8,342 matched controls were identified. Multivariable analysis revealed that SLE was independently associated with the following in decreasing odds ratio (OR) order ($p<0.001$ for all of the following): transfusion (OR 5.87), urinary tract infection (OR 5.09), minor adverse events (OR 4.58), pneumonia (OR 4.40), all adverse events (OR 4.08), myocardial infarction (OR 3.46), deep vein thrombosis (OR 3.29), wound dehiscence (OR 3.26), ED visits (OR 3.18), severe adverse events (OR 3.18), acute kidney injury (OR 3.17), cardiac event (OR 2.95), surgical site infection (OR 2.90), pulmonary embolism (OR 2.73), sepsis (OR 2.65), and hematoma (OR 2.61).

Conclusion: Patients with SLE who underwent ACDF had significantly higher rates of postoperative complications and ED visits within 90 days compared to matched controls without SLE. Due to its autoimmunity and systemic inflammation, SLE likely disrupts normal wound healing and increases infection risks, which may be further exacerbated by immunomodulatory treatments like glucocorticoids and immunosuppressants that impair tissue repair and immune function. These findings highlight the importance of recognizing SLE as a risk factor for complications following ACDF and underscore the need for close monitoring and individualized care for this patient population.

POSTER 19

WITHDRAWN

POSTER 20

Clinical and Radiographic Outcome Comparison of Seven Cervical Disc Arthroplasty Devices

David Foley, MD/MBA, *Graham Beutler, MD[1], Daniel Robinson, MD[2], Rick Sasso, MD[2], Michael McCarthy, MD[2]*
IU Health SCOM[1] Indiana Spine Group[2]

Introduction: Cervical disc arthroplasty (CDA) is hypothesized to reduce the shear strain and related complications that result following fusion procedures. Consequently, motion-sparing procedures such as CDA have gained significant traction in recent decades. Limited studies are available which examine the rates of heterotopic ossification (HO), range of motion (ROM), and clinical outcomes among the different disc implant options. This is the first study which directly compares the clinical and radiographic performance of a variety of cervical disc arthroplasty implants.

Materials and Methods: This project retrospectively reviews prospectively collected data on one and two-level cervical disc arthroplasty patients from C3/C4 to C7/T1. Patients underwent surgery as part of either randomized, controlled trials or standard clinical practice beginning in 2002 or 2018, respectively. Patients with minimum 1-year follow-up were included. Patients that received hybrid constructs and those with prior cervical spine surgical history have been excluded. Clinical and radiographic data were evaluated at preoperative, postoperative, 1-year, 2-year, 3-year, 5-year, 10-year, and 20-year time points as applicable. Clinical assessments included reoperation history at the index, superior and inferior adjacent, and remote levels of cervical spine. Patient reported outcome measures of Visual Analog Scale (VAS) neck, VAS arm, and Neck Disability Index scores have been included. Radiographic evaluation consisted of lateral dynamic cervical spine XRs to determine alignment and ROM metrics, HO grading, implant/endplate interface lucency.

Results: One hundred and forty-eight patients underwent CDA at 169 distinct cervical levels which included 97 trial patients and 51 patients treated as part of standard clinical practice. Mean follow-up for the entire cohort was 6.09 years (range 0.92 – 20.4 years; SD 5.51 years). Seven unique disc designs were utilized: milled-endplate (1), diamond-like carbon coated (2), woven polyethylene annulus (3), cobalt-on-polyethylene (4), metal-on-metal (5), PEEK-on-polyethylene (6), and titanium-on-polyethylene (7) arthroplasty implants. Trial patients had a greater proportion of females, longer follow-up, and less 2-level procedures. The recruitment groups did not differ statistically in their comorbidity profile, age, or treated cervical level. Severe HO (grades 3 and 4) occurred in 6.6% of total implants at 1 year, 14.5% at 2 years, 19.5% at 3 years, and 25.4% at 5 years. At 5 years, 5.6% of implants demonstrate complete fusion of the index level. Incidence and severity of HO between the implants were statistically different at the 1, 2, 3, and 5-year periods ($p < 0.01$).

Conclusion: HO is a common complication that occurs following cervical disc arthroplasty. This condition continues to progress from the 3 to 5-year follow-up postoperative periods. Unique arthroplasty devices are associated with different incidences of HO, which may limit their long-term viability. This is the first study that the authors are aware of that directly compares the radiographic and clinical outcomes of multiple cervical disc arthroplasty implants. More studies with larger cohorts are needed to improve our understanding of disc implant performance.

POSTER 21

Posterior Cervical Laminectomy and Fusion may Demonstrate Better Maintenance of Horizontal Gaze Compared with Laminoplasty

Bradley Hammoor, MD[1], *Lara Cohen, MD[1], Grace Xiong, MD[2], Harry Lightsey, MD[2], Matthew Lindsey, MD[3], Stuart Hershman, MD[1]*
Mass General Brigham[1] Rothman Institute[2] Mayo Clinic[3]

Introduction: Laminectomy and fusion (LF) and laminoplasty (LP) are common surgeries for the treatment of cervical spondylotic myelopathy and myeloradiculopathy with substantial post-operative improvement in pain and disability. LF and LP offer similar clinical improvement, however, LF entails bony fusion while LP offers a motion sparing alternative with faster postoperative recovery. Cervical sagittal alignment, which correlates with health-related quality of life, is a key consideration when deciding between LF and LP. More recently, maintenance of horizontal gaze has emerged as another important factor associated with functional outcomes following cervical spine surgery. The impact of LF or LP on this alignment parameter is unclear. This retrospective cohort study evaluated post-operative horizontal gaze and cervical sagittal alignment parameters in patients undergoing either LF or LP for cervical spondylotic myelopathy or myeloradiculopathy.

Materials and Methods: 75 patients were analyzed (30 LF, 45 LP) with a minimum 1-year of postoperative followup. Patient demographics, surgical details, and pre/post-operative cervical sagittal alignment parameters including C2-7 lordosis, C2-7 SVA, Occiput-C2 angle, and T1-slope were collected. The McGregor slope was measured as a surrogate for horizontal gaze using 8° of flexion to 13° of extension as the normal reference range. (Figure 1) Statistical analyses including student t-tests, chi-squared tests, and multivariable analysis were utilized to assess odds of malalignment between groups while adjusting for demographic covariates (Age, Gender, Smoking, BMI, Race, Charlson Score).

Results: There were no significant inter-cohort differences in patient characteristics or radiographic measurements pre-operatively. Postoperative Occiput-C2 angles were 27.6° and 24.7° (p=0.49), post-operative C2-7 Lordosis were 5.0° and 10.0° (p=0.10), post-operative C2-7 SVA were 35.8 mm and 36.5 mm (p = 0.87), and post-operative T1-slope were 32.9° and 31.3° (p=0.52) for LF and LP, respectively.

The mean McGregor slope post-operatively between LF and LP cohorts was -1.4° and 1.9°, respectively (p = 0.14). LF patients demonstrated higher rates of normal horizontal gaze than laminoplasty patients (90.0% vs. 57.8%, p =0.01). Furthermore, the LF cohort also demonstrated more patients who maintained appropriate alignment preoperatively to postoperatively (66.7% vs 35.6%, p = 0.02) and fewer patients transitioning from normal alignment to malalignment (6.7% vs 20.0%, p = 0.02) (Table 1). Differences in horizontal gaze remained significant in multivariable logistic analysis with an odds ratio of 9.04 ([2.3-51.2], p<0.01) for malalignment following laminoplasty.

Conclusion: LF and LP yielded comparable outcomes in post-operative cervical sagittal alignment parameters when performed for cervical spondylotic myelopathy or myeloradiculopathy. However, LF demonstrated better maintenance of horizontal gaze with more patients maintaining normal alignment and fewer patients transitioning to malalignment during the study period. These findings suggest that despite the motion sparing benefit of

POSTER 21 continued

laminoplasty, laminectomy and fusion may be superior in optimizing this important alignment criteria.

Figure 1

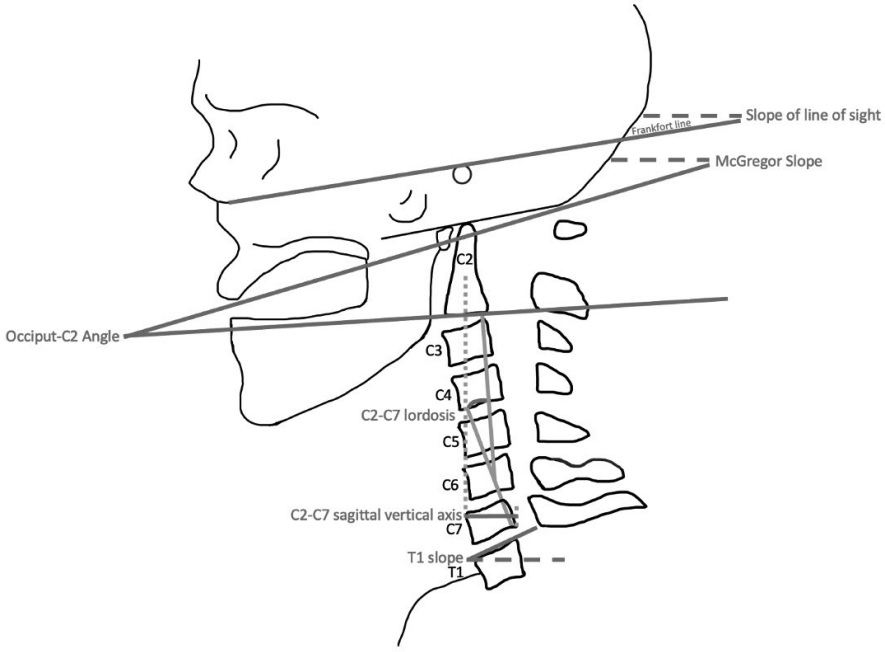

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Table 1

	Laminectomy and Fusion (N=30)	Laminoplasty (N=45)	P-value
Pre-Operative Horizontal Gaze			
Aligned	22 (73.3%)	25 (55.6%)	0.19
Malaligned	8 (26.7%)	20 (44.4%)	
Post-Operative Horizontal Gaze			
Aligned	27 (90.0%)	26 (57.8%)	0.01
Malaligned	3 (10.0%)	19 (42.2%)	
Change in Horizontal Gaze			
Aligned to Malaligned	2 (6.7%)	9 (20.0%)	0.02
Malaligned to Aligned	7 (23.3%)	10 (22.2%)	
Remained Aligned	20 (66.7%)	16 (35.6%)	
Remained Malaligned	1 (3.3%)	10 (22.2%)	

POSTER 22

Comparison After Anterior Cervical Discectomy and Fusion with BGS-7 spacer (NOVOMAX FUSION) and Allograft Spacer: A Matched Case Multicenter Study

Giwuk Jang, MD[1], *Bongju Moon, MD, PhD[1], Dongkyu Chin, MD, PhD[1], Hyunjoon Jang, MD[1]*
Gangnam Severance Hospital[1]

Introduction: In the context of anterior cervical discectomy and fusion (ACDF), a variety of graft materials such as autograft, allograft, and synthetic graft have been utilized to facilitate optimal spinal fusion. Particularly in the anterior cervical approach, an allograft spacer is predominantly employed for fusion procedures. The synthetic bone graft material BGS-7 (consisting of CaO-SiO2-P2O5-B2O3, known as Bioactive Glass-Ceramic) exhibits the capability to interact with adjacent bone tissue through the formation of a hydroxyapatite layer bone bridge, thereby promoting accelerated graft osseointegration. The primary objective of this research was to compare the clinical efficacy of a BGS-7 spacer against that of an allograft spacer in the realm of anterior cervical discectomy and fusion surgery.

Materials and Methods: A total of 29 patients who underwent 1-level ACDF using a BGS-7 spacer to treat degenerative cervical radiculopathy/myelopathy were enrolled in multicenter (3 hospitals) prospectively. Propensity score matching was performed with 253 patients who underwent 1-level ACDF using an allograft spacer from 2013 to 2022, and a control group of 54 patients and an experimental group of 27 patients were established. The fusion rate was assessed by CT, and subsidence, breakage, and migration of the spacer were evaluated at postoperative six-month and one-year periods by X-ray and CT. Demographic data, visual analog scale (VAS) for neck and arm pain, Neck Disability Index (NDI), Japanese Orthopedic Association (JOA) score, and other complications were also checked. The mechanical performance of the BGS-7 and allograft was confirmed using finite element analysis. Implant models and a three-dimensional cervical spine vertebral body model were constructed. The region of interest between implants and bone-implant interface was set up using different element sizes that could be distinguished from other parts.

Results: The VAS for neck and arm pain, NDI, and JOA scores were not significantly different at 6-month and 1-year follow-ups between the two groups. At 6-month follow-up, the fusion grade in the BGS-7 group was statistically significantly higher than that in the allograft spacer group. Fusion grades were not significantly different at 1-year follow-up. In the BGS-7 group, subsidence occurred in 3 out of 27 patients, and in the Allograft group, subsidence occurred in 13 out of 54 patients, showing a statistically significant difference. Additionally, in the allograft group, spacer breakage occurred in 2 patients, screw breakage in 1 patient, and screw loosening occurred in 2 patients, while it did not occur in the BGS-7 group, showing a statistically significant difference. Regarding the mechanical efficacy of the spacers, the PVMS of BGS-7 was about 39% and the contact pressure was about 30%. In addition, the breakage possibility of Allograft is about 49% and that of BGS-7 fusion is about 11%. At the same compressive load, the compressive strength of BGS-7 is higher.

Conclusion: In the BGS-7 group, it was advantageous in creating an early fusion state and compared to allograft, it was confirmed that it was not inferior in VAS, NDI, JOA score, and complications, so the use of BGS-7 can be recommended for ACDF surgery.

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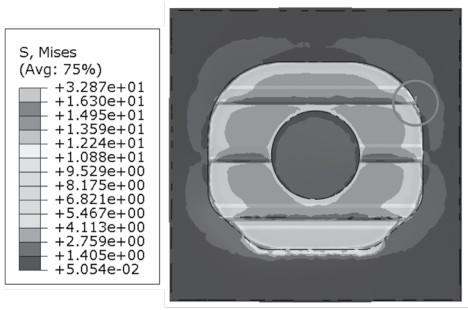
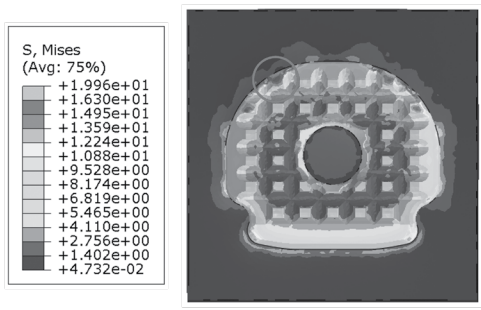
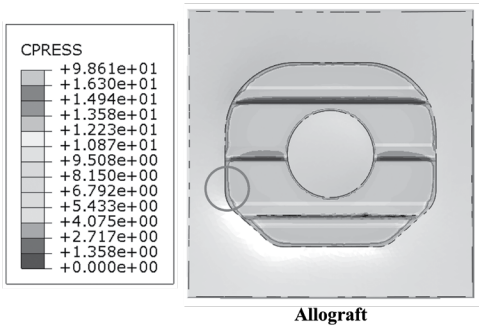


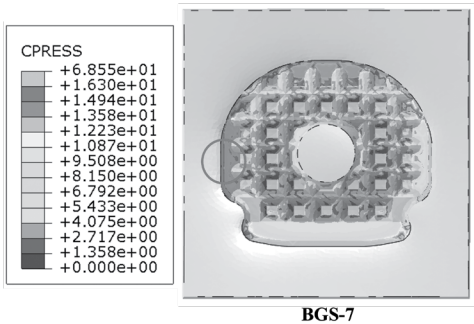
Allobone cage
(32.9 MPa)



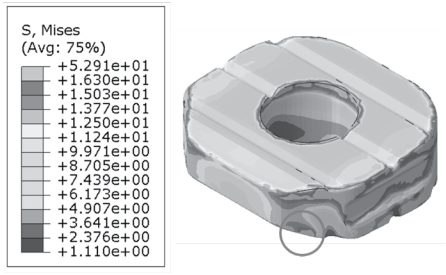
Novomax fusion
(20 MPa)



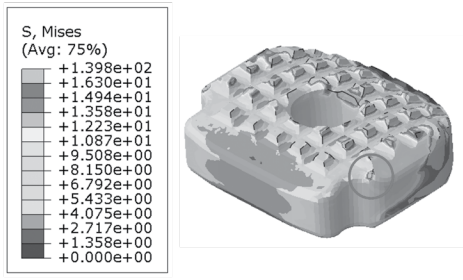
Allograft
(98.6 MPa)



BGS-7
(68.6 MPa)



Allograft
(52.9 MPa)



BGS-7
(139.8 MPa)

POSTER 23

WITHDRAWN

POSTER 24

Which Surgical Strategy Could Result in Optimal Outcome for Cervical Myelopathy Combined with Radiculopathy?: Comparison Between Laminoplasty with Foraminotomy Versus Anterior Cervical Discectomy and Fusion

Sehan Park, MD[1], Dong-Ho Lee, MD, PhD[1], Chang Ju Hwang, MD, PhD[1], Jae Hwan Cho, MD, PhD[1], Gumin Jeong, MD[1], San Kim, MD[1], Ji uk Choi, MD[1], ***Hyuk-joon Sohn, MD[1]***
Asan Medical Center[1]

Introduction: Cervical myelopathy, caused by cervical cord compression, often coincides with cervical radiculopathy resulting from root compression. This clinical scenario is commonly termed cervical myeloradiculopathy (CMR) in previous literature. While myelopathy symptoms primarily include movement coordination issues, numbness, and weakness, CMR patients also experience pain along the compressed root pathway. The choice between anterior and posterior approaches for CMR treatment depends on patient symptoms, sagittal alignment, and the location of compressive pathology. The anterior approach typically involves anterior cervical discectomy and fusion (ACDF) to decompress the cord and root by removing the disc, spurs, and uncinate process (see Figure 1). For the posterior approach, laminoplasty for cord decompression combined with foraminotomy for root decompression (LPF) can be considered (see Figure 2). However, the advantages and limitations of these two surgical procedures for CMR treatment are not clear. Therefore, this study aimed to compare the clinical and radiographic outcomes of laminoplasty combined with foraminotomy versus ACDF for CMR treatment.

Materials and Methods: A retrospective propensity score-matched analysis was conducted. We retrospectively reviewed 219 patients who underwent ACDF (ACDF group) or LPF (LPF group) for CMR treatment and were followed up for more than two years. Radiographic measurements included C2-C7 lordosis, C2-C7 sagittal vertical axis (SVA), and cervical range of motion (ROM). Patient-reported outcome measures, including neck pain visual analogue scale (VAS), arm pain VAS, neck disability index (NDI), and Japanese Orthopedic Association (JOA) score, were assessed and compared between the ACDF and LPF groups.

Results: After propensity score matching, 42 patients were included in both the LPF and ACDF groups. C2-C7 lordosis significantly decreased only in the LPF group ($p<0.001$), while cervical lordosis at two years postoperative was significantly greater in the ACDF group ($p<0.001$). However, ROM significantly decreased only in the ACDF group ($p<0.001$), with ROM significantly greater in the LPF group compared to ACDF at the two-year postoperative period ($p<0.001$). The LPF group demonstrated significantly greater neck pain VAS compared to the ACDF group at six months postoperative ($p=0.026$), although the difference was not significant at two years postoperative ($p=0.502$). Similarly, NDI showed a similar trend, with NDI significantly greater in the LPF group at six months postoperative ($p=0.021$). Arm pain VAS significantly improved in both groups after the operation ($p<0.001$ for both), with no intergroup differences postoperatively. Moreover, JOA scores significantly improved after the operation in both groups, with no postoperative intergroup differences ($p=0.131$, 0.222, respectively) (see Figure 3).

Conclusion: ACDF and LPF effectively improved arm pain and facilitated neurological recovery as demonstrated by the JOA score. Therefore, anterior decompression by ACDF and posterior

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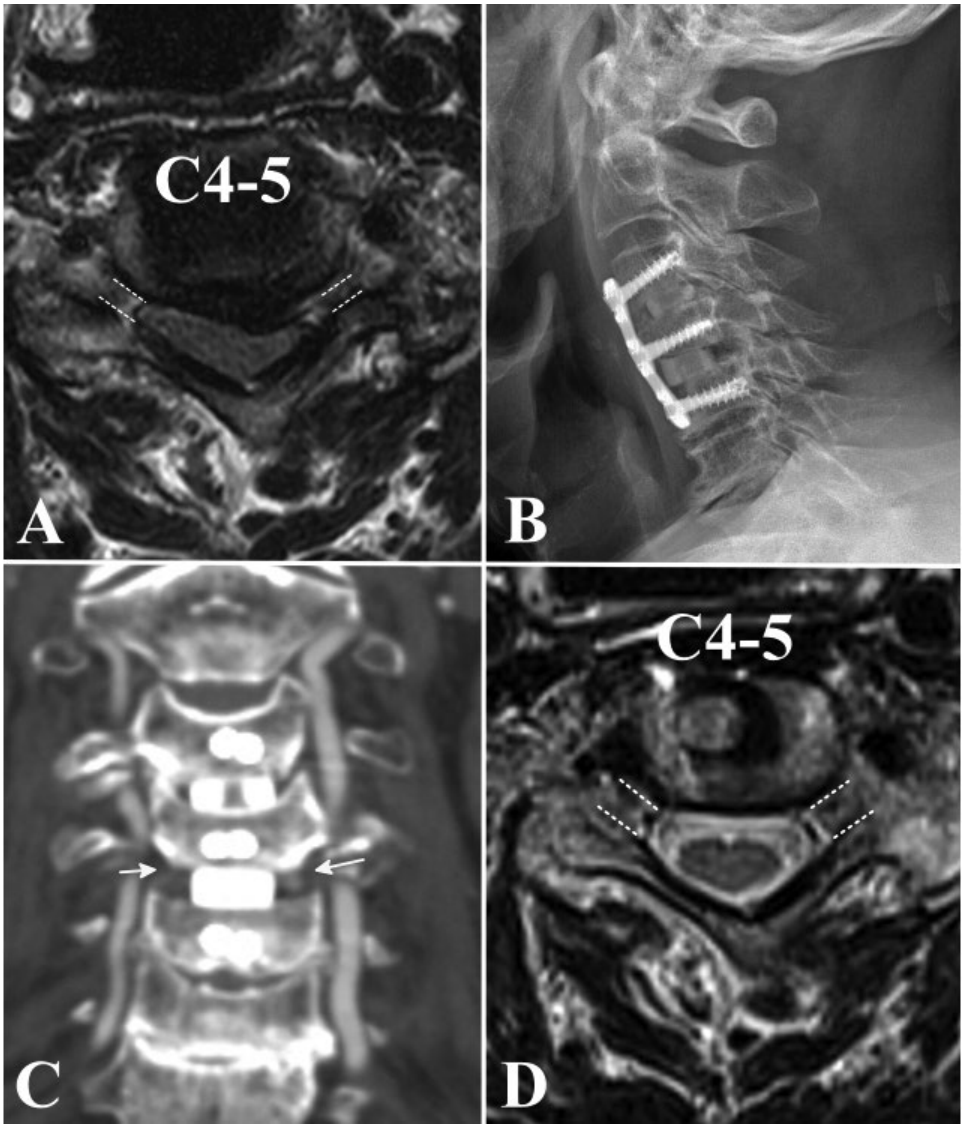
decompression by LPF could be considered equally effective decompressive procedures for CMR treatment. However, LPF resulted in significantly greater early postoperative neck pain and neck disability compared to ACDF, although the difference appears to decrease with long-term follow-up. Muscle injury with LPF seems to cause more significant early postoperative neck pain compared to ACDF, necessitating caution in operative planning.



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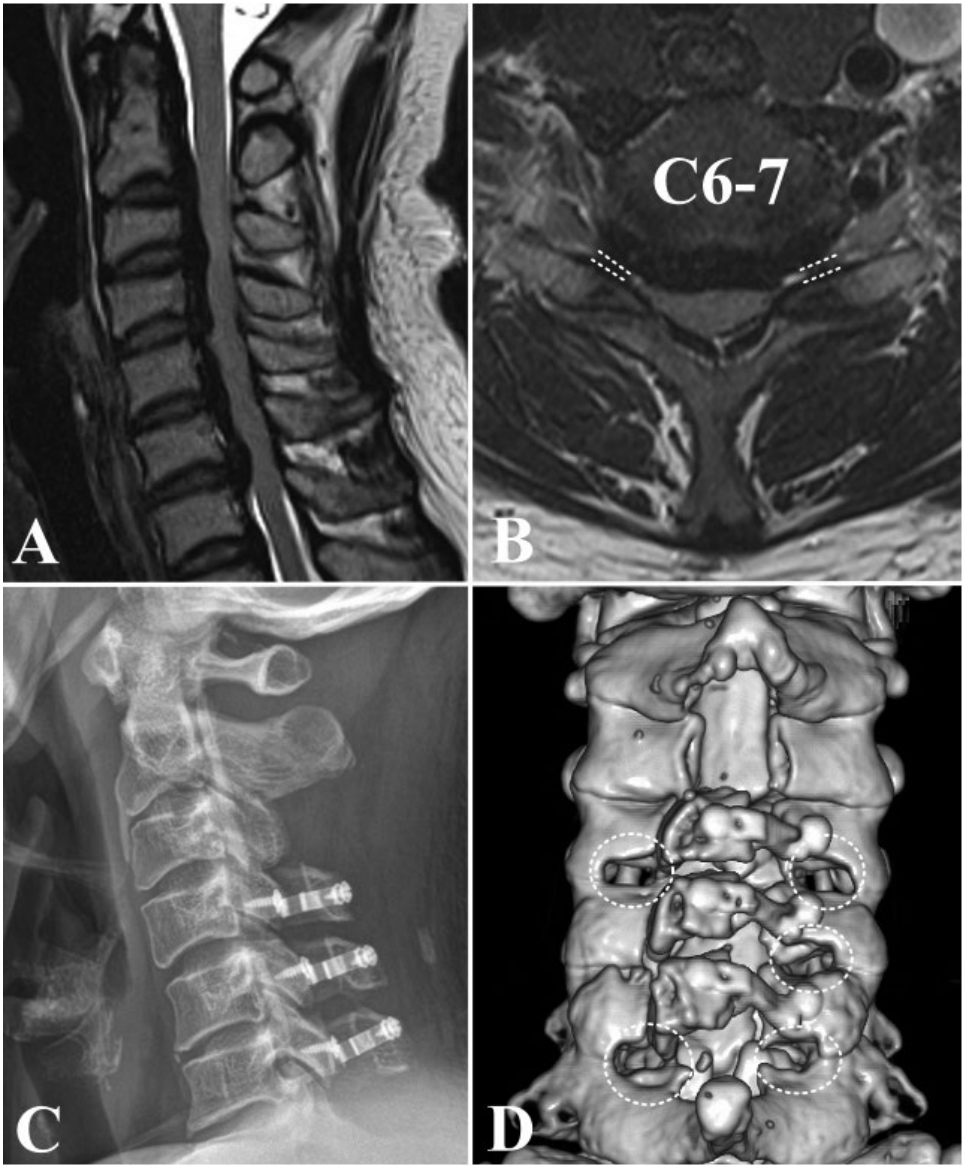

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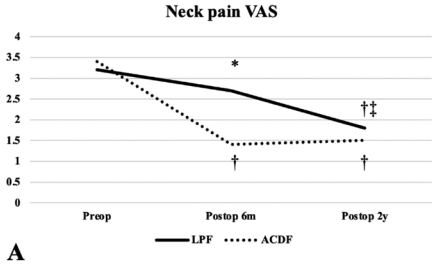

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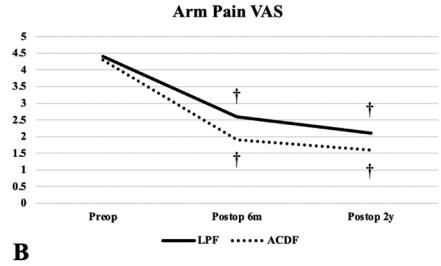

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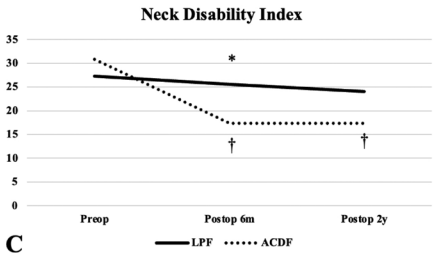

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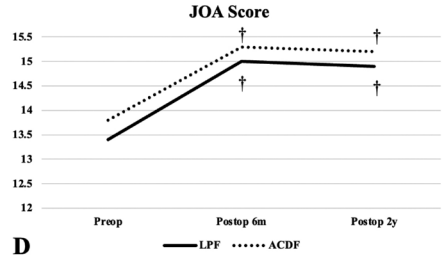

D

POSTER 25

Deep Sensory Disturbance is a Risk Factor for Post-laminoplasty Kyphosis in Patients with Cervical Posterior Longitudinal Ligament Ossification

Tomoya Kanto, MD[1], *Masahiko Takahata, MD[1], Hiroshi Taneichi, MD[1], Hidekazu Arai, MD[1], Satoshi Osuka, PT[2]*
Dokkyo medical university[1] Hokkaido University[2]

Introduction: Post-laminoplasty kyphosis is an undesirable sequelae in terms of reduced efficacy of spinal cord decompression as well as chronic neck pain, especially in patients with myelopathy caused by cervical posterior longitudinal ligament ossification (OPLL). Radiological parameters such as lower C2-7 extension range of motion (ROM) and sagittal imbalance have been reported as predictors of kyphosis deformity after laminoplasty (LAMP)[1,2,3] . However, our analysis of neck posture during daily activities using a wearable motion sensor demonstrated that many patients with cervical OPLL with impaired deep sensation are likely to flex their necks and gaze downward to watch their steps during walking and stair ascent. Therefore, we investigated whether deep sensory disturbance in the lower extremities contribute to the development of post-laminoplasty kyphosis.

Materials and Methods: A retrospective case-control study. A total of 119 patients with cervical OPLL who underwent LAMP for myelopathy were enrolled in this study. The mean age at surgery was 65 ± 10 years, 90 men and 29 women. Pre- and postoperative cervical spine alignment was measured, and cases with a decrease in C2-7 Cobb angle of 10 degrees or more were defined as cases with post-laminoplasty kyphosis. Deep sensory disturbance was defined as a impaired vibration sensation of the medial malleolus and/or a positive Romberg's sign. Preoperative cervical spine alignment and ROM, patient background, and degree of paralysis were compared.

Results: Post-laminoplasty kyphosis was observed in 29 patients (24%). The post-laminoplasty kyphosis group had a significantly smaller preoperative C2-7 extension ROM (7.5±5.7 vs. 11.7±7.9 degree), greater preoperative C2-7 flexion ROM (26.9±8.3 degree vs.20.7±10.2 degree), and higher prevalence of patients with deep sensory disturbance (55% vs. 21%) than the no post-laminoplasty kyphosis group. Patients with deep sensory disturbance had a significantly lower C2-7 Cobb angle at 2 years postoperatively (0.4±16.5 vs. 10.7±14.2) and a significantly greater ΔC2-7 angle (-10.7±10.9 vs. -2.5±7.1) compared to patients without deep sensory disturbance. Patients with deep sensory disturbance had significantly poorer Japanese Orthopaedic Association (JOA) scores both preoperatively (8.0±2.4 vs. 11.3±2.5) and postoperatively (11.6.±1.9 vs. 13.9±2.3) as well as poor neurological recovery (41.5±18.5 vs. 52.6±25.3) compared to patients without deep sensory disturbance.

Conclusion: While previous studies have focused on radiological parameters as predictors or causes of post-laminoplasty kyphosis, this study focused on the forward neck posture in activities of daily living and its causes. We found that deep sensory disturbance was associated with the development of post-laminoplasty kyphosis. The most likely mechanism is that patients with deep sensory disturbance have a habitual neck flexion posture to watch their feet when walking. Given that correcting this abnormal neck posture while walking could increase the risk of falling, the only solution would be to actively encourage the patient to improve forward neck posture while sitting and standing, and to perform neck extension exercises if the patients have deep sensory disturbance.

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POSTER 26

Grip Strength Changes Most in the Acute Postoperative Period Following Cervical Decompression and Fusion for Cervical Myelopathy

David Kim, MD[1], *Neil Shah, MD, MS[1], Carolyn Andrews, BS[1], Rachel Baum, BS, MPH[1], Alyssa Dempsey, BS[1], Carl Paulino, MD[1], Jad Bou Monsef, MD[1]*
SUNY Downstate Medical Center[1]

Introduction: Grip strength is an important tool in the diagnosis of cervical myelopathy. It can also serve to monitor functional changes in the postoperative period. However, the trajectory of grip strength recovery can vary from patient to patient. This retrospective cohort study compares preoperative and postoperative grip strength in patients undergoing cervical decompression and fusion for cervical myelopathy.

Materials and Methods: The outpatient orthopaedic electronic medical record was queried at a single academic center between 2020 and 2024 to identify both male and female patients (n=140) scheduled for cervical fusion for cervical myelopathy (anterior, posterior, or combined). Patients were assessed for both preoperative and postoperative grip strengths (measured in kg) with a hand dynamometer. This study excluded patients with missing data. The grip strength for right and left hands was individually recorded preoperatively and postoperatively at 15, 30, 60, 90, and >90 days. Paired t-tests were used to compare preoperative and postoperative grip strength within each time frame. Patients with postoperative days data recorded that was greater than the time period within 5 days were included in the preceding time category. For example, if the patient had a postoperative visit 63 days after, this grip strength was included as 60 days. Statistical significance was set at $p < 0.05$.

Results: Of the 140 patients who underwent cervical spine surgery and met the inclusion criteria, 25 had recorded preoperative and postoperative grip strengths. The mean difference in grip strength for every investigated postoperative time period increased for both right and left hands, however, only right-handed grip strength increased with statistical significance.

Grip strength in the right hand increased with statistical significance within 15, 60, 90, and >90 days after surgery (all $p < 0.05$) (Table 1). Strength did improve within the 30 day time window as well, but not significantly ($p = 0.06193$). The most significant increase in postoperative right hand grip strength occurred within the first 15 days with a mean difference of 8.54kg (95% CI [5.65, 11.42]).

Conclusion: The study showed that grip strength increases following cervical spine surgery, with the most significant changes observed within the first 15 days post-operation. Long-term recovery patterns differ between hands, with greater statistical significance noted among patients' right hands. Grip strength can be an objective tool to monitor postoperative progression.

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Table 1: Right and Left-Handed Postoperative Grip Strengths

Hand	Time Frame	Mean Difference (kg)	95% CI	p-value
Right	Within 15 days Post-Op	8.54	[5.65, 11.42]	**0.000005921**
Left	Within 15 days Post-Op	1.68	[1.36, 4.71]	0.2631
Right	Within 30 days Post-Op	7.75	[0.56, 16.06]	0.06193
Left	Within 30 days Post-Op	3.83	[3.24, 10.90]	0.2221
Right	Within 60 days Post-Op	7.04	[3.79, 10.29]	**0.0003345**
Left	Within 60 days Post-Op	1.44	[0.31, 3.18]	0.0991
Right	Within 90 days Post-Op	9.93	[6.12, 13.74]	**0.0001024**
Left	Within 90 days Post-Op	3.71	[2.47, 9.88]	0.2152
Right	Within >90 days Post-Op	7.48	[3.44, 11.53]	**0.001653**
Left	Within >90 days Post-Op	2.46	[1.91, 6.83]	0.243

POSTER 27

Hyperlipidemia Alters the Lipid Metabolism in Mouse Intervertebral Disc and Leads to Disc Degenerative Changes

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Introduction: Hyperlipidemia has been highlighted as a risk factor for disc degeneration, but the underlying mechanism remains elusive. Independent of obesity-related mechanical stress on the disc, an altered blood lipid profile per se has been suggested to correlate with disc degeneration. However, patients with hyperlipidemia are often obese. Therefore, it has been difficult to differentiate the effects of obesity-induced mechanical stress and hyperlipidemia on intervertebral discs. Our preliminary results showed that disc cells actively take up lipids from the circulation, suggesting that the altered blood lipid profile may affect lipid composition/metabolism in disc cells. In this study, we took advantage of a high-fat diet-induced hyperlipidemic mouse model to investigate the influence of altered blood lipids on disc lipid metabolism. This non-weight-bearing animal spine model allows us to study the direct causal relationship between hyperlipidemia and the intervertebral disc.

Materials and Methods: Male C57BL/6 mice were fed a 60% high-fat diet (HFD) or a calorie-matched low-fat diet (LFD) for 3 months starting at 8 weeks of age. At the endpoint, L4/5 discs were harvested for micro-CT scanning and histological analysis, and other lumbar discs and ~10 tail discs were homogenized and subjected to mass spectrometry-based lipidomics analysis. Plasma was also collected for lipidomics analysis.

Results: Mice in the HFD group had higher body weights and blood cholesterol and fatty acid concentrations (Fig. a). CT analysis showed decreased intervertebral disc height in the HFD group (Fig. b), and Safranin-O staining of the L4/5 disc consistently showed decreased proteoglycan content in the HFD group (Fig. c). PLIN2 (lipid droplet surface protein) staining revealed that the disc cells accumulated more lipid droplets in the HFD group (Fig. d). Lipidomics analysis further revealed that several types of lipids were significantly accumulated in HFD discs, including several saturated fatty acids.

Conclusion: Our data showed that hyperlipidemia could cause abnormal accumulation of lipids in the lumbar intervertebral discs of mice. In addition, it was suggested that the discs with this abnormal lipid accumulation had impaired proteoglycan turnover, resulting in early degenerative changes such as decreased Safranin-O staining area and disc height. Future molecular and biomechanical studies will investigate the underlying mechanism of this phenotype and its functional relevance in disc degeneration.

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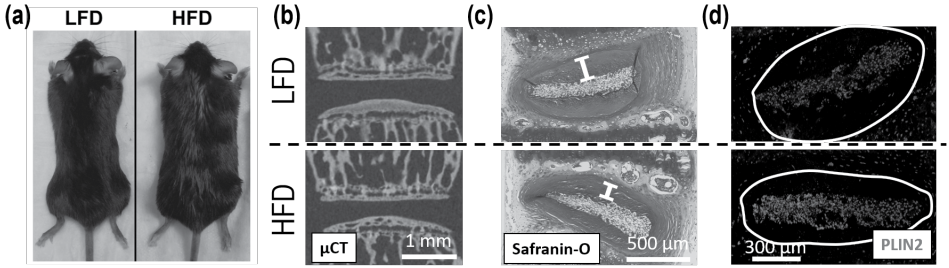

POSTER 28

How Common and Safe is Early Hospital Discharge After an Elective Single-Stage Front-Back Cervical Surgery?

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Introduction: A single-stage circumferential ("front-back") cervical fusion is advantageous for patients with cervical deformity, revision cases, trauma, tumor, multi-level and/or multi-column pathologies, and those at high risk for pseudarthrosis. However, a combined surgical approach can be technically demanding due to the increased operative time, greater intraoperative blood loss, and approach-related complications. Existing literature on anterior-alone and posterior-alone approaches suggest short-term complications may be mitigated through enhanced recovery pathways resulting in shorter hospital stays and avoiding potential hospital acquired complications. Currently, a paucity of literature exists on the impact of length of stay (LOS) on short-term complications after a single-stage front-back cervical surgery.

Materials and Methods: A single surgeon prospectively collected database (2020-2023) of consecutive adult (≥18 years-old) patients who underwent a single-stage front-back cervical fusion was reviewed. All patients underwent an enhanced recovery pathway per senior surgeon protocol. Patient demographics, comorbidities, indication for surgery, operative factors, LOS, and inpatient complications and 30-day postoperative outcomes were assessed and compared with a national database, National Surgical Quality Improvement Program (NSQIP). Propensity score matching was performed between databases to compare length of stay (LOS) and 30-day postoperative complications. Chi-square and t-tests were performed for categorical and continuous variables. Stepwise multivariate logistic regression was performed to identify independent associations for 30-day postoperative complications.

Results: In the single-surgeon series (N=109), the mean age was 59.3±10.7, mean ASA score 2.4, and most common indications for surgery were revision (50.5%), degenerative (28.4%), and deformity (15.6%). The majority required at least a 4-level fusion (63.3%) and mean operative time was 259 minutes. The mean LOS was 1.9 days with only 15.8% of patients with LOS≥3. No significant difference in LOS between in-tri-state (2.1 days) vs. out-of-tristate (1.8 days, P=0.133). The LOS was higher for international patients (3 days), but not significantly different for U.S. patients (1.9 days, P=0.08). For the propensity score matched national sample (N=499), the mean LOS was significantly higher (mean of 4.4 days with 57% of patients with LOS≥3) (P<0.001). The overall 30-day complication rate was 4% (vs. national 14.2%, P<0.001). The 30-day reoperation rate was 2.0% (vs. national: 4.4%, P=0.391), 30-day readmission rate was 4% (vs. national: 5.2%, P=0.783). In the national sample, the most common complications included wound infection (3.6%), pneumonia (2.4%), reintubation (1.8%), sepsis (1.2%) and urinary tract infection (1%).

Conclusion: In the largest single-surgeon series on circumferential cervical fusions, the majority were discharged by postoperative day 2 (84%, mean 1.9 days vs. national sample: 43%, mean 4.4 days) without an increased risk for 30-day reoperation or readmission. Early postoperative complications are significantly associated with prolonged LOS. In the national sample, infection was the most common short-term complication (wound infection,

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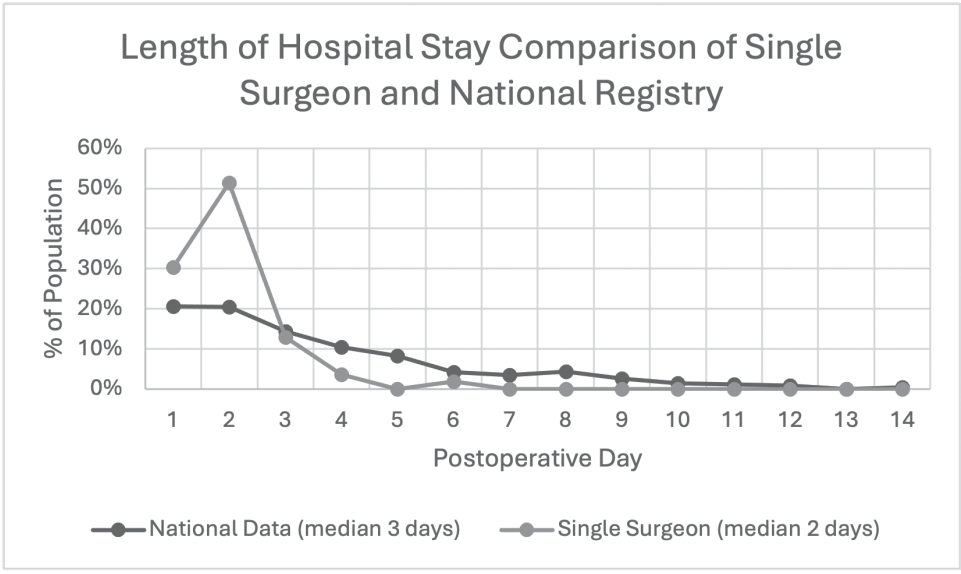
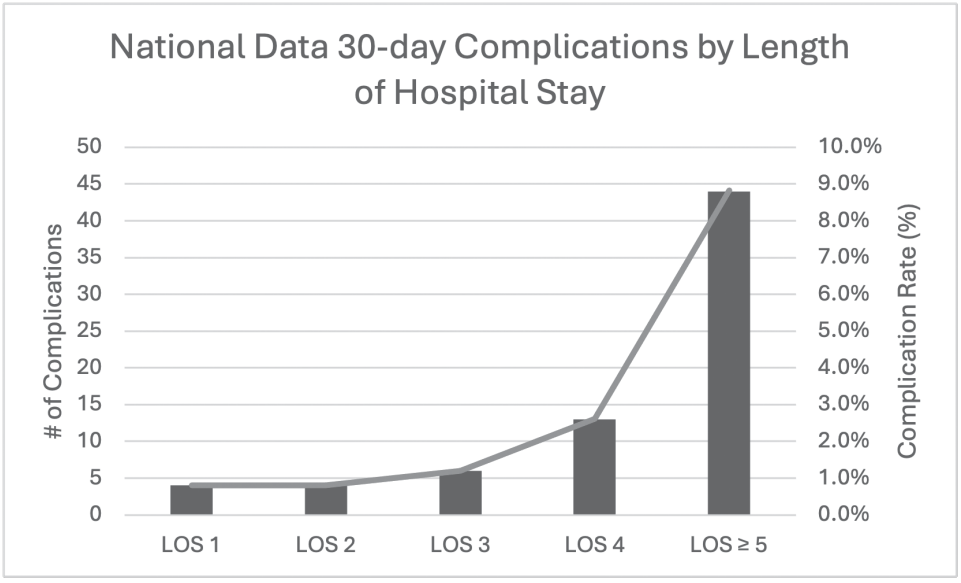
pneumonia, sepsis, urinary tract infection); whereas no infections were observed in the single-surgeon cohort. Through appropriate perioperative planning, surgical technique, and enhanced recovery pathways, early hospital discharge after circumferential cervical fusion can be safe and achieve excellent clinical outcomes.





POSTER 29

The Efficacy of Cervical Spinal Fusion in Patients with Parkinson's Disease

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Introduction: Parkinson's disease (PD) is a devastating neuromuscular disease that has several distinct spinal syndromes in addition to common degenerative spinal disorders. However, surgical management of PD patients remains challenging secondary to pre-existing myopathy, low bone mineral density, and multifactorial spinal and non-spinal etiologies of postural instability and impaired dexterity. Limited evidence in prior small cohort investigations has demonstrated that spinal fusion in PD is fraught with high rates of hardware failure, pseudoarthrosis, and reoperation. The current study compared the clinical and radiographic outcomes of PD patients undergoing cervical spinal fusion to a matched non-PD surgical population.

Materials and Methods: All adult PD patients who underwent anterior cervical discectomy and fusion (ACDF) or posterior cervical/ cervicothoracic decompression and fusion (PCDF) for myelopathy and/ or radiculopathy at an academic center between 2017-2022 were retrospectively identified. Patients were required to have a PD diagnosis by a neurologist within one year of spinal surgery. Preoperative medical comorbidities, PD metrics, bone and muscle quality, operative indication, and construct related factors were extracted. Fusion status was assessed via continuous osseous bridging on one-year postoperative CT scan and segmental mobility on long-term flexion/ extension x-rays. Pre- to post-operative changes in cervicothoracic alignment were determined from postoperative radiographs at short and long-term follow-up. One-to-one nearest neighbor matching of PD to non-PD surgical cohorts was performed to control for pertinent between group differences in demographic and operative variables. Univariate analysis compared patient/ surgical variables and postoperative outcomes across PD and non-PD ACDF and PCDF cohorts.

Results: A total of 47 PD patients were identified (27 patients with 1-3 level ACDF, 20 patients with >5 level PCDF). After matching, there were no significant differences in patient age, sex, smoking status, diabetes status, corticosteroid use, chronic kidney disease, surgery type (ACDF vs PCDF), and number of fusion levels between the PD and non-PD cohorts. Additionally, there were no significant differences in body mass index, cervical Hounsfield units, and long colli cross sectional area between PD and non-PD groups. In the PD cohort, the infection rate was 4.3% (0% ACDF, 10% PCDF), fusion rate was 75% (71% ACDF, 79% PCDF), the rate of new or progressive neuro deficit was 2.1% (0% ACDF, 5% PCDF), and the all-cause reoperation rate was 4.3% (0% ACDF, 10% PCDF), with no significant differences respective to the non-PD matched cohort. In the PCDF subgroup, the short-term (PD: -9.3, non-PD: -0.7, p=0.003) and long-term (PD: -10.2, non-PD: -0.3, p=0.034) change in C2-7 lordosis was significantly reduced in the PD relative to non-PD group. All other radiographic parameters did not differ significantly between PD and non-PD matched groups.

Conclusion: Although further controlled investigation is necessary, these results suggest that

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cervical spinal fusion in PD patients may be more efficacious than historical evidence suggests, without significant difference in postoperative clinical outcomes compared to matched non-PD patients. However, PD may predispose patients to cervical kyphotic changes after PCDF.

POSTER 30

The Superiority of Endplate Hounsfield Units Relative to Lumbar Vertebral Hounsfield Units in Predicting Subsidence After Anterior Cervical Discectomy and Fusion

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Introduction: Subsidence represents a well-known complication after anterior cervical discectomy and fusion (ACDF) that has been previously associated with segmental kyphosis, foraminal narrowing, pseudoarthrosis, recurrence of preoperative symptoms, and higher reoperation rates. Decreased bone quality is a known risk factors for interbody subsidence. CT vertebral Hounsfield Units (HUs) are often preferred relative to dual X-ray absorptiometry in assessment of bone quality because of increased regional specificity and less susceptibility to false elevations. However, HUs are a measure of only trabecular bone density and do not account for the strength of endplate cortical bone in contact with interbody surface. The present investigation developed a novel CT-based assessment of endplate bone density (EB-HU) and aimed to determine if EB-HU was a stronger predictor than trabecular HU for subsidence after ACDF.

Materials and Methods: All adult patients who underwent one-three level ACDF with a titanium interbody for radiculopathy and/ or myelopathy at an academic center between 2018-2020 were retrospectively identified. A 2mm superior and inferior endplate region was circumscribed on the preoperative left, right, and mid sagittal CT scans using the free draw function to account for endplate surface undulations (Figure 1). EP-HUs were calculated as the average HUs of the superior and inferior endplate regions on all views. Average standard lumbar vertebral HUs were determined from circumscribed trabecular bone within cranial, middle, and caudal axial CT cuts. Interbody subsidence at the superior and inferior endplate of each ACDF level was directly measured on the endplate-facing surface of both coronal and sagittal CT scans obtained at one year postoperatively to determine the maximum subsidence (subsidence defined as ≥2mm). Univariate and stepwise logistic regression analysis compared subsidence based on CT bone metrics. Receiver operating curve analyses determined the probability of subsidence based on EP-HUs and vertebral HUs.

Results: A total of 36 patients met the inclusion/exclusion criteria. Subsidence occurred at 34 of 70 unique fusion levels. Subsidence was associated with older age (p=0.012), male sex (p=0.043), and decreases interbody length (p=0.019). EP-HUs were moderately correlated with lumbar vertebral HUs (Pearson's ρ=0.63). Subsidence was significantly associated with decreased EP-HUs (Subsidence: 482 HU, No Subsidence: 547 HU, p=0.024) and decreased lumbar vertebral HUs (S: 293 HU, NS: 348 HU, p=0.005). ROC identified an optimal EP-HU cutoff of 512.30 (area under curve [AOC] =0.70) to predict subsidence. The AOC of the vertebral HUs with respect to subsidence was 0.66. EP-HU< 512.30 predicted subsidence (Odds Ratio: 5.62, p=0.008) independent of vertebral HUs and significant demographic and surgical factors.

Conclusion: CT endplate HUs rather than vertebral trabecular HUs may be more efficacious in predicting subsidence after ACDF.

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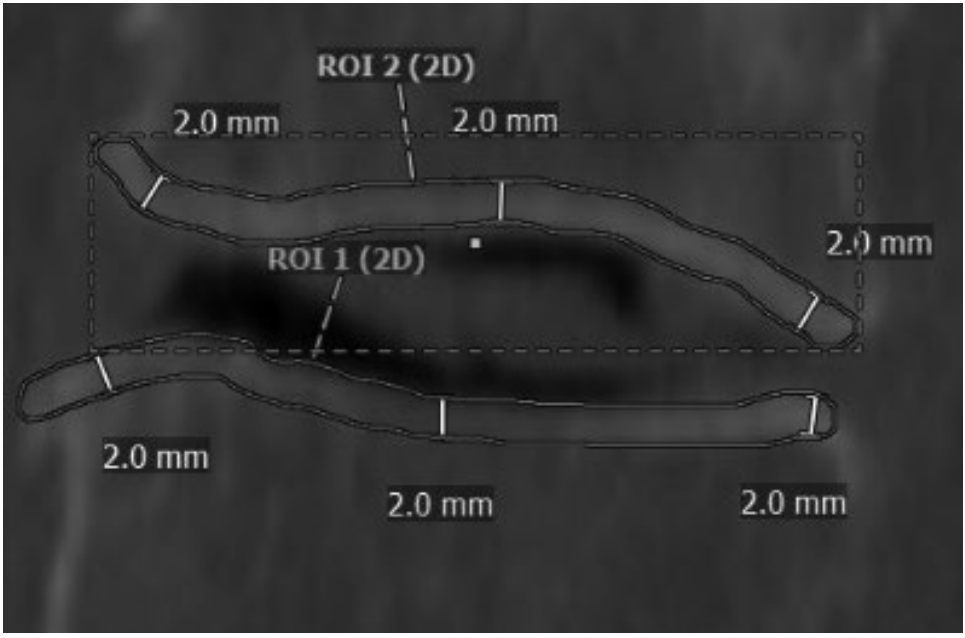

POSTER 31

Surgical Outcomes for Degenerative Cervical Myelopathy with Different Severities of Hand Dexterity Impairment: A Prospective Study with 1-year Follow-up

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Guangdong provincial people's hospital[1]

Introduction: Hand dexterity impairment is a common symptom in Degenerative Cervical Myelopathy (DCM) patients, and the 10-second Grip and Release (10s-G&R) test is widely accepted as a tool for evaluating hand function. However, the recovery capacity of patients with different severities of hand dexterity impairment has not been thoroughly studied. Our study aimed to elucidate the 1-year surgical outcomes of DCM patients with different severities of hand dexterity impairment, and to determine the cut-off value of 10-s G&R test to predict incomplete recovery.

Materials and Methods: Data were collected before surgery and at the 1-year follow-up. Hand functional outcome measures were compared across the three groups. Multivariate linear regression was conducted to explore predictive factors. Receiver Operating Characteristic (ROC) curve analysis was performed to assess the predictive efficacy of the preoperative 10s-G&R test and establish the cut-off value for incomplete recovery of hand dexterity.

Results: At the 1-year follow-up, substantial improvements were observed in the 10s-G&R test results as well as other parameters across all three groups. However, the incomplete recovery rates of the Mild/Moderate/Severe group were 26.67%, 46.88%, and 57.50%, respectively ($P<0.05$). Multivariate regression revealed that preoperative 10s-G&R test result, age, Hoffmann's sign, duration of symptom, and mJOA Upper score serve as significant predictors for postoperative 10s-G&R test outcomes. Patients with a preoperative 10s-G&R test < 15 cycles have a 1.9 times higher risk of incomplete recovery of hand function (95% CI = 1.217-3.026, P = 0.005).

Conclusion: Most of the patients, regardless of their preoperative hand function, exhibit potential for improvement in hand dexterity. However, almost half of the patients in the Moderate group, and even more in the Severe group, are unable to achieve complete recovery. A preoperative 10s-G&R test < 15 cycles predicts a higher risk of incomplete recovery of hand function, suggesting that surgical treatment is recommended before the 10s-G&R test drops below 15 cycles.

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Subsidence Following Anterior-Only Anterior Cervical Corpectomy Fusion for Cervical Spondylotic Myelopathy: Systematic Review and Meta-analysis.

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Introduction: Surgical interventions for cervical spondylotic myelopathy (CSM) frequently involve anterior approaches, such as anterior cervical discectomy/fusion (ACDF) or anterior cervical corpectomy/fusion (ACCF). Although graft subsidence is a well-established and described complication in ACDF procedures, much less has been published regarding factors related to subsidence in patients undergoing anterior-only ACCF for CSM. This systematic review aimed to address this gap by examining the occurrence and potential contributing factors of interbody subsidence following anterior-only ACCF performed for CSM.

Materials and Methods: A systematic literature search was conducted using PubMed, Embase, and COCHRANE to gather English-language studies relevant to the subject. The study's inclusion criteria encompassed anterior-only anterior cervical corpectomy and fusion (ACCF), surgery for the primary diagnosis of cervical spondylotic myelopathy (CSM), evaluation of subsidence and detailed descriptions of implant characteristics. Subsidence definition and published rates were collected and organized by the type of graft used. Qualitative analysis was performed for complications and revision rates. The data was subjected to meta-analysis to evaluate subsidence incidence rates, and meta-regression analysis was employed to assess variations between different graft types.

Results: A total of 245 abstracts were evaluated, of which 34 papers met the inclusion criteria. In total, 2005 patients were evaluated over a mean period of 31 months (range 6-56 months). Pooled subsidence rates expressed as incidence per person-years based on graft type were as follows: 2% (carbon fiber), 27% (fibular strut allograft), 2% (nHAPA composite strut), 5% (PEEK), 10% (static titanium), and 2% (expandable titanium cages). The combined subsidence rate for all grafts was 7%. Notably, the expandable titanium cohort demonstrated a lower subsidence rate (2%) compared to the overall pooled cohort (7%), while other graft types showed no significant difference.

Conclusion: In conclusion, subsidence occurred in approximately 7% of patients undergoing anterior-only ACCF procedures for CSM. Notably, the use of expandable metal cages resulted in a lower rate of subsidence compared with the broader cohort. The lower subsidence rates observed in ACCFs utilizing carbon fiber or expandable titanium interbody implants are consistent with those observed in anterior cervical discectomy and fusion (ACDF) procedures. This finding suggests that these implant options may be preferable to reduce the risk of subsidence when corpectomy is necessary for cervical spinal decompression without supplemental posterior fixation.

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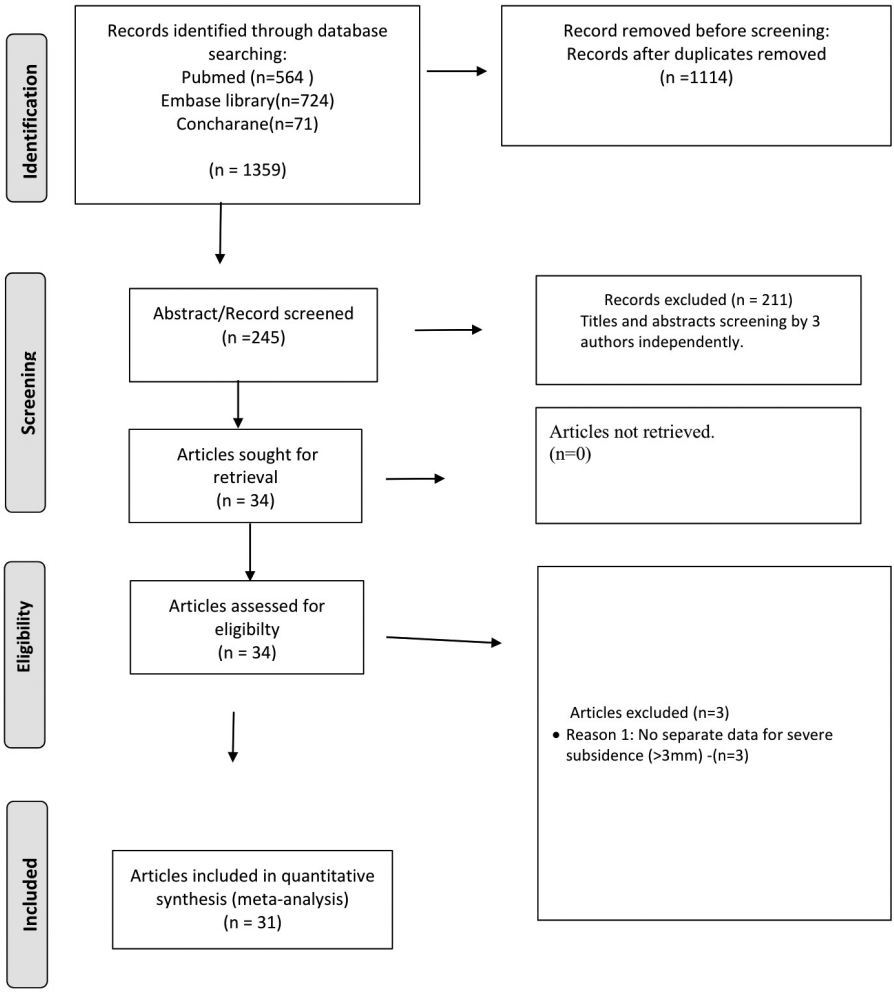

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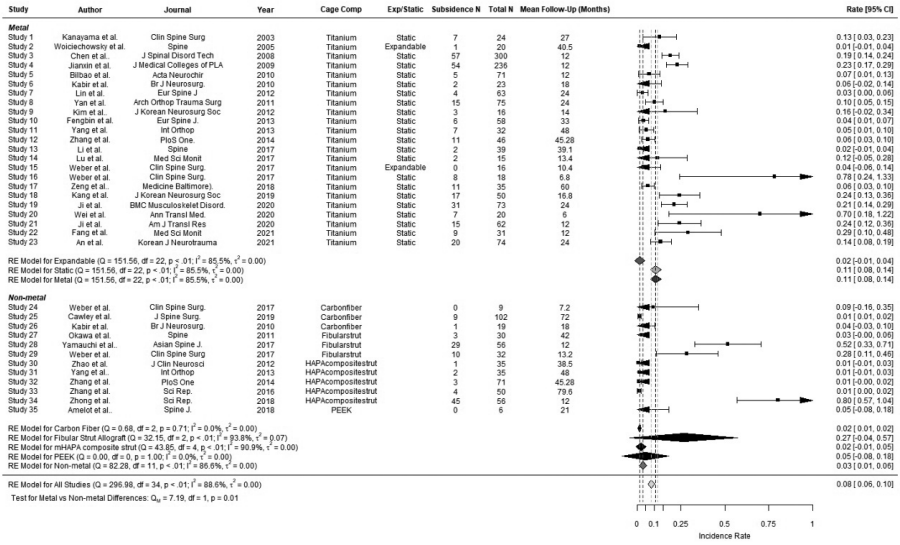

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WITHDRAWN

POSTER 34

How Reliable Is the Assessment of Fusion Status Following ACDF Using Dynamic Flexion-Extension Radiographs?

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Introduction: The radiographic diagnosis of non-union is not standardized. Prior authors have suggested using a cutoff of <1mm interspinous process motion (ISPM) on flexion-extension radiographs [1-3], but the ability of practicing surgeons to make these measurements reliably is not clear.

Materials and Methods: 29 practicing spine surgeons measured ISPM on 19 levels of ACDF from 9 patients. Surgeons relied on these measurements to report on fusion status. Inter-observer correlation co-efficients (ICC), standard error (SEM) and the minimum detectable difference (MD) of these measurements were calculated. We screened for clerical errors by checking measurements more than one standard deviation from the group mean.

Results: The ICC for ISPM was 0.77 (0.65; 0.88) with a SEM of 0.97mm and a MD of 2.69mm. Agreement on fusion status was moderate, with an ICC of 0.6 (0.44; 0.76). After screening for and removing clerical errors, the ICC improved to 0.82 (0.71; 0.91), SEM improved to 0.83mm, and MD improved to 2.29mm. Six reviewers had an ICC >0.9. The ICC from these high performing reviewers was 0.94 (0.9; 0.97), SEM was 0.45mm, and MD was 1.26mm.

Conclusion: The MD of 2.29mm in our study group was not precise enough to support a cutoff of <1mm ISPM as the sole measurement technique in screening for non-union after ACDF, and there was only moderate agreement amongst surgeons on fusion status based on dynamic radiographs. More stringent techniques are necessary to avoid mis-diagnosing

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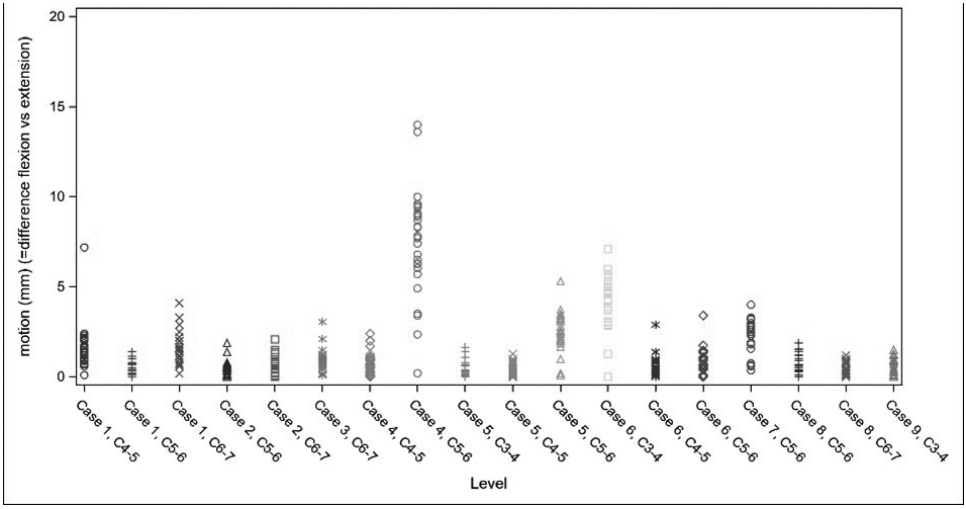
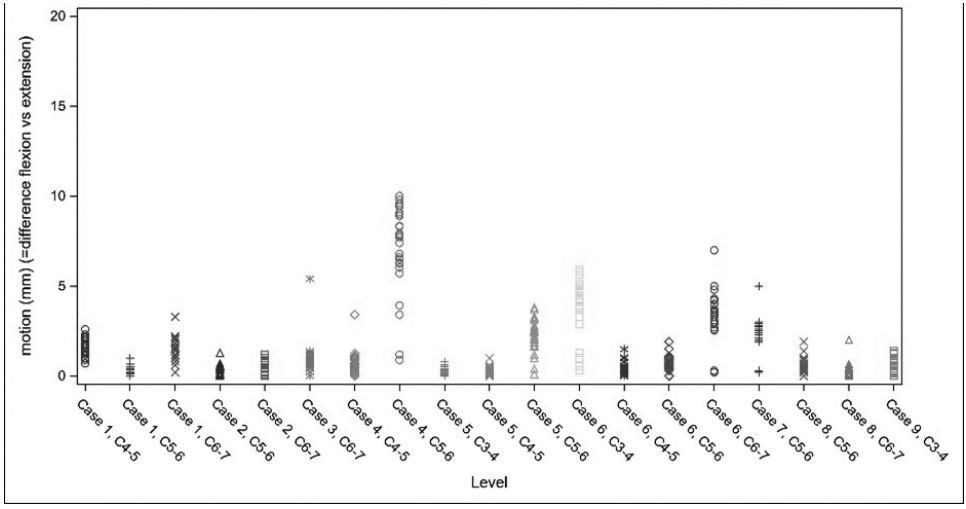
non-union in clinical studies. Future studies should consider auditing measurements to identify clerical errors.





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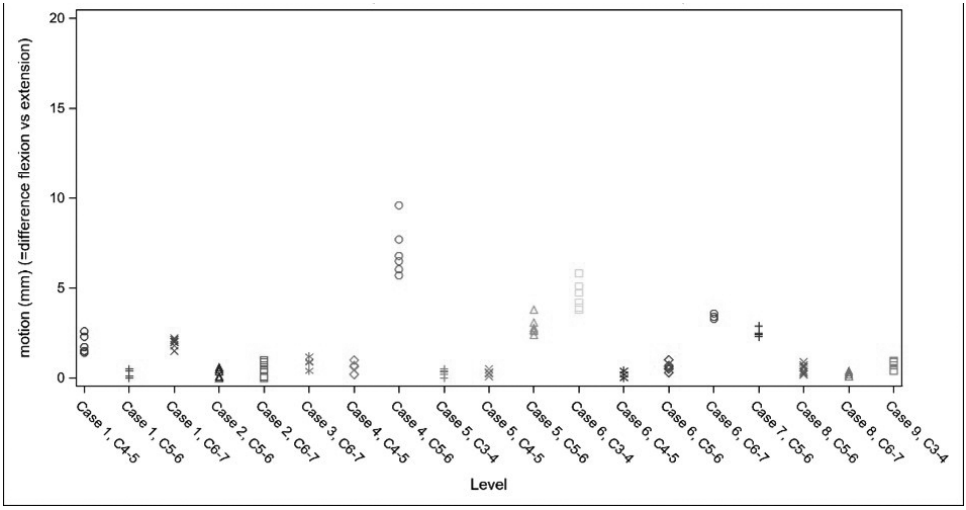

POSTER 35

Odontoid Fractures Portend Higher Mortality Risk Compared to Hip Fractures: A Matched Cohort Analysis

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Introduction: Both odontoid and hip fractures are common fragility fractures in the elderly population. While mortality risk is often discussed with hip fractures, the risk of mortality following odontoid fractures has received less attention. Therefore, the purpose of this study was to compare mortality rates between odontoid and hip fractures.

Materials and Methods: The California State database was queried for all patients who had a diagnosis of a hip or odontoid fracture from 2016 to 2020. Patients who had a diagnosis of a hip fracture were matched on a 10:1 basis on age, gender, and race to patients with a diagnosis of an odontoid fracture. After matching, multivariate analysis was performed with significant comorbidities as covariates. Mortality at 30 days, 60 days, 90 days, 6 months, 1 year, 2 years, 3 years, and 4 years was analyzed for both cohorts.

Results: After matching, 21,994 patients comprised the hip fracture cohort and 2,217 patients comprised the odontoid fracture cohort. The odontoid fracture cohort had a significantly higher length of stay, were more likely to be discharged to home, have paralysis, and a neurologic disorder. After multivariate analysis controlling for all significant comorbidities, patients with odontoid fractures had higher mortality at all time points studied (Figure 1). At two years after index injury, survival for the hip fracture cohort was 90.0% compared to 75.9% for the odontoid cohort ($p<0.001$). At 4 years after index injury, hip fracture survival was 81.0% and odontoid fracture survival was 67.8% ($p<0.001$) (Table 1).

Conclusion: Odontoid fractures portend a higher mortality risk than hip fractures. The two-year mortality rate for odontoid fractures was 24.1% compared to 10% for hip fractures in this matched cohort analysis. This high rate of mortality calls for increased attentiveness and improved management strategies for patients with odontoid fractures.

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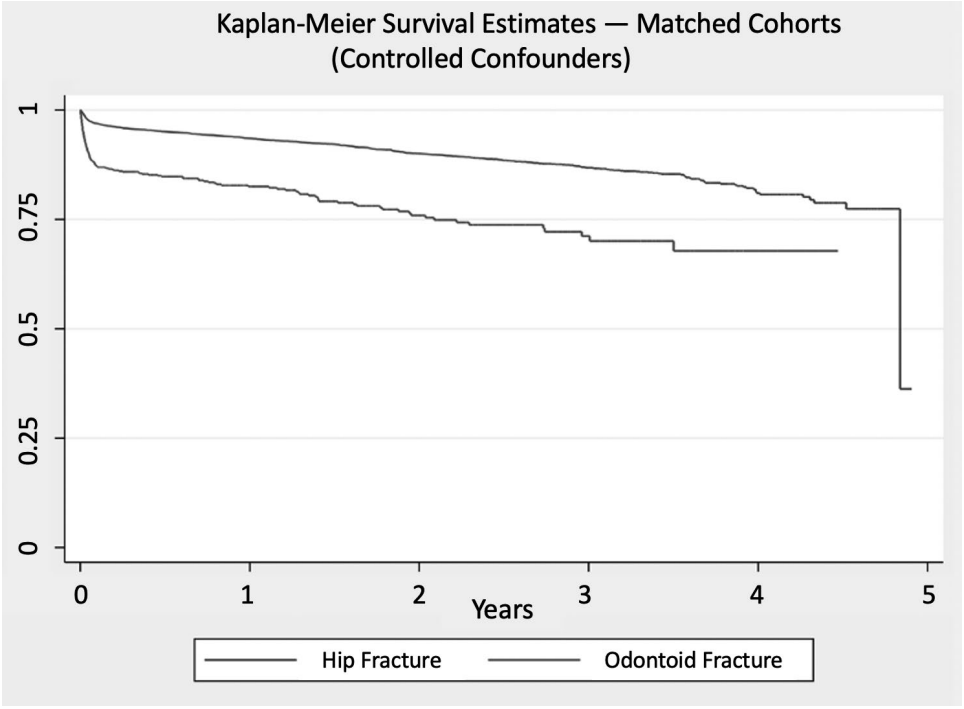

Table 1. Multivariate log-rank survivorship fractions between matched hip and odontoid fracture cohorts. A p-value <0.05 is considered significant.

Timepoint	Hip Fractures (n=21,994) Survivorship Fraction	Odontoid Fractures (n=2,217) Survivorship Fraction	p-value
30-Day	0.970	0.879	p<0.05
60-Day	0.964	0.867	p<0.05
90-Day	0.959	0.859	p<0.05
6-Month	0.951	0.848	p<0.05
1-Year	0.935	0.825	p<0.05
2-Year	0.900	0.759	p<0.05
3-Year	0.868	0.712	p<0.05
4-Year	0.810	0.678	p<0.05

POSTER 36

Safety and Efficacy of Same-day Discharge Following 3- and 4-level Anterior Cervical Spine Surgery: A Multicenter Study

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Introduction: Multi-level anterior cervical discectomy and fusion (ACDF) has been established as a safe procedure with favorable outcomes for degenerative disc disease of the cervical spine. However, there is limited evidence that patients who meet certain safety criteria may be safely discharged on the same day following these procedures. The purpose of this study was to determine factors associated with safe same-day discharge following 3- and 4-level anterior cervical spine surgery.

Materials and Methods: Patients who underwent 3- and 4- level ACDF or hybrid construct involving ACDF with 1-level cervical disc replacement for cervical radiculopathy and/or myelopathy at one of two academic centers between 2018 and 2023 were retrospectively identified. Data collected included demographic data, body mass index (BMI), Charlson Comorbidity Index (CCI), nicotine use, insurance type, preoperative work status, medical comorbidities, and facility type. Complication data including type of complication, time to complication from surgery, and reoperations were collected. Patient-reported outcome measures (PROMs) collected preoperatively (baseline) and postoperatively included Visual Analogue Neck (VAS Neck) and Arm (VAS Arm) scores. Hospital stay was determined by number of midnights stayed following surgery. A stay less than one midnight was categorized as "outpatient." A stay greater than one midnight was categorized as "inpatient." Logistic regression analysis was performed to determine factors associated with same-day discharge and risk factors for complications at three months postoperatively. Multivariate analysis was performed to determine differences in VAS Neck and Arm scores between inpatient and outpatient cohorts.

Results: A total of 160 patients were identified. The outpatient cohort was significantly younger ($p<0.001$), had a lower CCI ($p<0.001$), had more current nicotine users ($p=0.028$), was more likely to be covered by commercial insurance ($p<0.001$), and was more likely to be working at the time of surgery ($p=0.004$) compared to the inpatient cohort. There were significantly fewer patients with psychiatric comorbidities ($p=0.010$) and osteopenia or osteoporosis ($p=0.006$) in the outpatient cohort. There were no significant differences in the number of complications or type of complication between inpatient and outpatient cohorts acutely or at 6 week, 3 month, 6 month, or 1 year follow-up between cohorts. On logistic regression analysis, age ($p=0.001$), a psychiatric comorbidity ($p=0.003$), and Medicare/Medicaid coverage ($p=0.014$) were independently associated with a decreased likelihood of same-day discharge. A diagnosis of myeloradiculopathy was independently associated with a complication at 3 months postoperatively ($p=0.038$). On multivariate analysis, there was no independent association between inpatient/outpatient surgery and improvement in VAS Neck or Arm scores.

Conclusion: The current study demonstrates that carefully selected patients undergoing 3- or 4-level anterior cervical spine surgery for radiculopathy and/or myelopathy may be safely

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discharged on the same day of surgery. Factors that may influence the decision to consider same-day discharge include psychiatric comorbidities, insurance status, and diagnosis. These findings are important given the evidence that outpatient spine surgery leads to similar symptomatic improvement and patient satisfaction while simultaneously decreasing healthcare costs compared with inpatient surgery. Additionally, the findings in the present study emphasize the importance of psychiatric comorbidities as well as setting patient expectations with regard to safe, successful outpatient surgery.

Baseline Demographics

	Inpatient (n=71)	Outpatient (n=89)	p-value†
Age	61.6 ± 9.2	54.3 ± 8.5	**<0.001***
Sex			0.111
Male	28 (39.4%)	47 (52.8%)	
Female	43 (60.6%)	42 (47.2%)	
BMI	30.6 ± 7.6	30.8 ± 6.5	0.846
CCI	2.4 ± 1.6	1.4 ± 1.1	**<0.001***
Nicotine usage			**0.028***
Never	36 (50.7%)	46 (52.3%)	
Current	11 (15.5%)	26 (29.5%)	
Former	24 (33.8%)	16 (18.2%)	
Insurance			**<0.001***
Commercial	31 (43.7%)	69 (77.5%)	
Medicare/Medicaid	38 (53.5%)	18 (20.2%)	
Worker's compensation	2 (2.8%)	1 (1.1%)	
Self-pay	0 (0.0%)	1 (1.1%)	
Race			0.468
White	65 (91.5%)	84 (94.4%)	
Black or African American	4 (5.6%)	5 (5.6%)	
Asian	1 (1.4%)	0 (0.0%)	
More than one race	1 (1.4%)	0 (0.0%)	
Preoperative work status			**0.004***
Working	36 (54.5%)	68 (78.2%)	
Not working	11 (16.7%)	4 (4.6%)	
Retired	19 (28.8%)	15 (17.2%)	

† Pearson's χ^2 or Fisher's exact test for categorical data, and independent t-test for continuous data
*Indicates statistical significance ($p<0.05$).
Outpatient refers to patients discharged prior to midnight on day of surgery. Inpatient refers to patients discharged at least one midnight after day of surgery. Nicotine usage includes cigarette or vaporizer use within 30 days prior to evaluation.
Categories do not include patients who declined to answer or where no response was provided.

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Patient Comorbidities

	Inpatient (n=71)	Outpatient (n=89)	p-value[†]
Diabetes mellitus	18 (25.4%)	20 (22.5%)	0.711
Hypertension	41 (57.7%)	42 (47.2%)	0.205
Hyperlipidemia	28 (39.4%)	25 (28.1%)	0.176
Psychiatric	39 (54.9%)	30 (33.7%)	**0.010***
Osteopenia/osteoporosis	10 (14.1%)	2 (2.2%)	**0.006***
Autoimmune	7 (9.9%)	4 (4.5%)	0.218
Chronic steroid use	2 (2.8%)	0 (0.0%)	0.195
Cancer	6 (8.5%)	5 (5.6%)	0.540
MI/CAD	8 (11.3%)	4 (4.5%)	0.135
CVA	5 (7.0%)	2 (2.2%)	0.243
COPD	8 (11.3%)	4 (4.5%)	0.135
DVT	2 (2.8%)	5 (5.6%)	0.464

[†]Pearson's χ^2 test or Fisher's Exact test
*Indicates statistical significance, $p<0.05$.
Outpatient refers to patients discharged prior to midnight on day of surgery. Inpatient refers to patients discharged at least one midnight after day of surgery.
MI/CAD – myocardial infarction or coronary artery disease, CVA – cerebrovascular accident, COPD – chronic obstructive pulmonary disease; DVT – deep venous thrombosis.

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Independent Risk Factors for Short-term Complication

		95% Confidence Interval		
	OR	Lower Bound	Upper Bound	p-value[†]
Age	1.069	0.945	1.208	0.290
Sex				
Male		*ref*		
Female	1.088	0.331	3.584	0.889
BMI	0.925	0.847	1.010	0.80
CCI	0.904	0.590	1.386	0.644
Nicotine usage				
Never		*ref*		
Current	0.542	0.099	2.962	0.480
Former	2.717	0.868	8.508	0.086
Insurance				
Commercial		*ref*		
Medicare/Medicaid	1.842	0.460	7.372	0.388
Preoperative work status				
Not working		*ref*		
Working	0.511	0.062	4.228	0.533
Retired	0.488	0.047	5.113	0.550
Facility type				
Tertiary care facility		*ref*		
ASC	0.865	0.122	6.151	0.885
Diagnosis				
Radiculopathy		*ref*		
Myelopathy	3.778	0.566	25.200	0.170
Myeloradiculopathy	3.486	1.071	11.350	**0.038***
Admission				
Inpatient		*ref*		
Outpatient	2.373	0.748	7.532	0.143

[†]Backwards logistic regression model initially performed including all variables to determine factors associated with any complication at three month follow-up. Variables subsequently removed in a stepwise fashion using a value of $p>0.05$ as a threshold until the final model was achieved. Self-pay and worker's compensation were excluded from analysis given minimal number of patients.
Outpatient refers to patients discharged prior to midnight on day of surgery. Inpatient refers to patients discharged at least one midnight after day of surgery.
OR – odds ratio, BMI – body mass index, CCI – Charlson comorbidity index, ASC – ambulatory surgery center.

POSTER 37

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

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Introduction: Cervical total disc replacement (TDR) is now recognized as an effective treatment for symptomatic disc degeneration associated with radiculopathy and/or myelopathy symptoms. Clinical studies have consistently shown that the outcomes of cervical TDR are comparable or superior to those of anterior cervical discectomy and fusion.

Materials and Methods: The purpose of this study was to evaluate the results during 6-year follow-up of single-level PEEK-on-ceramic cervical TDR used in the treatment of single-level cervical disc disease.

Data were obtained from the prospective Food and Drug Administration (FDA) Investigational Device Exemption (IDE) trial for a PEEK-on-ceramic cervical TDR.

The study included 150 patients, of which 125 completed 5-year follow-up. To date, 50 (33% of the original cohort) have completed 6-year follow-up, which is ongoing. 12% of the 150 patients were excluded. Reasons for exclusion include repeat operations (6), loss to follow-up (10), death (1), and withdraw of consent (1). Radiographic analysis was available for 34 patients (23%). All patients were treated for single-level cervical disc degeneration with symptoms of radiculopathy and/or myelopathy.

Clinical outcomes consisted of 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.

The study included 16 sites in the United States. 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.

Results: More than 90% of patients reached NDI success (defined as at least 15-point improvement from baseline) at the 3-month follow-up and remained greater than 90% throughout 6-year follow-up. The mean pre-op NDI score was 63.3. It reduced significantly to 23.1 at 6-week follow-up and remained below 20 for the 6-year follow-up duration. VAS pain scores followed a similar trend with significant improvement from baseline of 81.6 to 22.9 at 6 weeks post-operative and remained below 20 through 6-year follow-up. More than 90% of patients reported to be very satisfied or satisfied throughout follow-up. On radiographic parameters, mean ROM was 7.3° prior to surgery and increased to 8.5° at latest follow-up. Mean disc height increased from 3.3 mm pre-operatively to at least 4 mm at latest follow-up. There were 6 (4%) re-operations in the series including 2 revisions, 2 removals, and 2 patients received supplemental fixation.

Conclusion: This study found that PEEK-on-ceramic TDR produced significantly improved

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clinical and radiographic outcomes, sustained over a 6-year follow-up period. The re-operation rate was comparable to other published studies. These outcomes provide additional endorsement for the utilization of cervical TDR in appropriately selected patients.

POSTER 38

How Does 2 Level Cervical Disc Replacement compare to Single Level?

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Introduction: Anterior Cervical Discectomy and Fusion (ACDF) is highly successful at a single level with greater than 90% fusion rates and high patient satisfaction. However, multi-level ACDF surgery, though still successful, has diminishing results with increasing levels. With many Investigational Device Exemption (IDE) clinical trials for the treatment of Symptomatic Cervical Disc Disease (SCDD) at a single level and recent IDE clinical trials for two contiguous levels, these trials offer the opportunity to compare clinical outcomes utilizing the same motion sparing technology mechanisms of action (MOA). The hypothesis is that cervical total disc replacement (cTDR) maintains its clinical benefits from single to multi-level procedures.

Materials and Methods: As part of prospective, randomized, multi-center, controlled IDE clinical trials, 103 patients received cTDR at a single level (Murrey et al.) and 133 patients received two-level cTDR. In both trials, the MOA was a semi-constrained ball-in-socket design. Under IRB approval, patients met similar inclusion/exclusion criteria and were consented. All patients were seen for follow-up at 6 weeks, 3 months, 6 months, 12 months, and 24 months. Patient-reported outcome measures and radiographs were collected at each in-office follow up. The primary endpoint was composite clinical success (CCS) at 24 months where a patient must be a success in all 4 criteria, defined as: ≥ 15 point improvement in Neck Disability Index (NDI) Score (out of 100) in subjects at 24 months compared with baseline, maintenance or improvement in neurological status at 24 months compared to baseline, no secondary surgical interventions at the index levels, and absence of major device-related adverse events. Secondary endpoints such as Visual Analog Score (VAS) neck pain, VAS arm pain, and VAS satisfaction were collected at each in-office time point.

Results: At 24 months, CCS was achieved in 72.3% of the single-level patients and 88.2% of the two-level patients. There was 1 major device-related adverse event in the single-level and none in the two-level study. There was no difference in the incidence of secondary surgical interventions between groups. Similar NDI scores over time were seen between groups showing statistically significant improvement from pre-operative (single-level: 53.9±15.0: two-level: 58.8±15.8) to 24 month (single level: 21.4±20.2; two level: 14.2±16.7). At 24 month, the mean difference between groups was statistically significant ($p \leq 0.05$). In addition, there was a statistically significant difference in patients achieving NDI success which was achieved in 79.8% of single level and 95.3% of two level patients. All secondary endpoints consistently showed similar improvement from baseline for both groups but none of the measures showed a statistically significant difference between treatments.

Conclusion: The comparison of these two IDE clinical trials for the treatment of Symptomatic Cervical Disc Disease (SCDD) at a single or two levels is counterintuitive and profound. Unlike what is classically seen in ACDF surgery, the two level cTDR patients had greater clinical success. This could be a consequence of almost two decades of greater experience in the spine community. However, with greater understanding of the degenerative cascade, possibly what we once considered a single level patient was truly a two level patient.

POSTER 39

Forty-eight-month Clinical Outcomes of Patients Over 60 Years Old in a Prospective, Controlled, Multicenter Study Evaluating Two-level Cervical Disc Arthroplasty with a PEEK-on-ceramic Artificial Disc

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Introduction: Cervical total disc replacement (cTDR) has gained acceptance as a treatment for symptomatic disc degeneration with symptoms of radiculopathy with/without myelopathy. While clinical outcomes of cTDR have consistently been reported to be similar or superior to those of cervical discectomy and fusion, there are limited reports addressing differences related to patient age. The purpose of this study was to compare the 4-year results of two-level PEEK-on-ceramic cervical TDR for patients ≥60 years old to those <60.

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 included 145 patients who completed 4-year follow-up, of which 124 were <60 years old at the time of surgery and 21 were ≥60 years. All patients were treated for two-level cervical disc degeneration with radiculopathy and/or myelopathy.

Clinical outcome was based on the Neck Disability Index (NDI), neck pain and arm pain intensity scores (10-point scale), and neurologic status. Radiographic measures included flexion/extension (F/E) range of motion (ROM), disc space height, heterotopic ossification, and adjacent-level degeneration based on Kellgren-Lawrence grading.

Mean 48-month outcomes for patients ≥60 years old were compared to those of patients <60. Radiographs were evaluated by an independent lab specializing in image assessment.

Results: Of the outcomes reviewed, only one statistically significant difference was detected based on age group. The mean change in F/E ROM from baseline to 48 months at the inferior index level was 3.33° (<60) and -0.19° (≥60) (p=0.01). At the superior index level, the difference was not significant (1.80° (<60) vs. 0.12° (≥60); p=0.20). The difference in change in global ROM was also not significant (5.67° (<60) vs. 0.77° (≥60); p=0.07). Statistically significant differences were not seen for the other outcomes assessed: mean change in NDI, mean change in neck pain, mean change in arm pain. Neurologic status was normal in 93.6% of the <60 age group and 100.0% of the ≥60 group (p=0.24). The mean change in average disc height from baseline to 48 months was similar in both groups. The distribution of Kellgren-Lawrence grades (none, doubtful, minimal, moderate, and severe) was also similar for each age group for the level above and below the surgical levels (p=0.88 above, p=0.49 below) and the rate of radiographically relevant HO (grade 3 or 4) was comparable between age groups (superior level (p=0.49); inferior level (p=0.20)). Through latest follow-up, there were zero secondary surgical interventions in the ≥60 cohort and 9 in the <60 cohort.

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Conclusion: This study found that patients ≥60 years of age who were treated with PEEK-on-ceramic TDR at two levels had comparable clinical and radiographic outcomes to patients <60 years of age through 4-year follow-up. These results affirm that cervical TDR performs similarly in patients ≥60 versus those <60, although the small sample size of patients ≥60 years of age is a limitation.

Clinical Outcomes by Age Group – Month 48

	Age < 60 Years		Age >= 60 Years		
Characteristic	N	Mean (SD)	N	Mean (SD)	P-value*
NDI - Change from Baseline	124	-44.32 (18.938)	21	-42.29 (12.574)	0.6357
Neck Pain Intensity - Change from Baseline	117	-5.99 (2.571)	20	-5.70 (1.780)	0.6273
Arm Pain Intensity - Change from Baseline	117	-5.93 (2.731)	20	-5.50 (2.259)	0.5052
Intervertebral Angle (Superior Index Level) - Change from Baseline	104	1.80 (5.353)	19	0.12 (4.517)	0.2004
Intervertebral Angle (Inferior Index Level) - Change from Baseline	91	3.33 (5.055)	19	-0.19 (4.138)	0.0054
Average Disc Height (Superior Index level) - Change from Baseline	107	1.05 (0.831)	19	1.11 (0.726)	0.7823
Average Disc Height (Inferior Index level) - Change from Baseline	101	0.81 (1.022)	19	0.64 (0.879)	0.4788
Global Range of Motion - Change from Baseline	103	5.67 (11.209)	19	0.77 (8.038)	0.0719

Abbreviation: NDI = neck disability index,
Subjects censored at Index level secondary surgical interventions.
* P-value calculated using a T-test
Source: t-age.sas; Analyzed 22JAN2024

POSTER 40

Does Posterior Cord Compression by Ligamentum Flavum Adversely Affect Clinical Outcome of Anterior Cervical Discectomy and Fusion?

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Introduction: Anterior cervical discectomy and fusion (ACDF) effectively relieves cord compression by removing anterior compressive lesions such as discs, bone spurs, and ossification of the posterior longitudinal ligament. However, combined posterior compressive lesions like ligamentum flavum buckling or hypertrophy cannot be addressed with the anterior approach. While ACDF generally yields favorable outcomes for cervical myelopathy treatment, it remains unclear whether posterior cord compression by the ligamentum flavum may adversely affect ACDF's clinical outcomes. If remaining posterior compression impedes clinical improvement post-ACDF, a combined posterior approach or single-stage posterior operation should be considered. Therefore, this study aimed to demonstrate the clinical implications of posterior cord compression by the ligamentum flavum in ACDF.

Materials and Methods: A total of 195 consecutive patients who underwent ACDF and were followed up for over 2 years were retrospectively reviewed. Ligamentum flavum cord compression (LFC) was graded on a 0-2 scale (see Figure 1). Patients with LFC grade 2 were classified into the LFC group, while those with LFC grade 0-1 were classified into the no-LFC group. Patient characteristics, cervical sagittal parameters, neck pain visual analogue scale (VAS), arm pain VAS, and Japanese Orthopedic Association (JOA) score were assessed.

Results: One hundred sixty-seven patients (85.6%) were included in the no-LFC group, while the remaining 28 patients (14.4%) were included in the LFC group. Among patients in the LFC group, 14 (50.0%) achieved clinical improvement, while the other 14 (50.0%) did not. Patient baseline characteristics and sagittal parameters did not show significant differences between the two groups. Spondylolisthesis was significantly more frequently detected in the LFC group ($p=0.001$). The JOA score significantly improved in the no-LFC group postoperatively ($p<0.001$), while it did not demonstrate improvement in the LFC group ($p=0.642$). JOA scores at postoperative 3 months ($p=0.037$) and 2 years ($p=0.001$) were significantly higher in the no-LFC group. Furthermore, the JOA recovery rate at postoperative 2 years was significantly higher in the no-LFC group ($p=0.042$) (Table 1). Multiple regression analysis showed that LFC was significantly associated with the JOA recovery rate at postoperative 2 years ($p=0.045$), while spondylolisthesis did not show significant results ($p=0.482$).

Conclusion: Previous case reports have suggested that aggravation of ligamentum flavum buckling after ACDF occasionally necessitates early posterior revision. However, the clinical impact of cord compression by the ligamentum flavum has not been thoroughly studied. This study demonstrated that posterior cord compression by the ligamentum flavum adversely affects the clinical outcomes of ACDF. Furthermore, multiple regression analysis confirmed that LFC is associated with the JOA recovery rate. While ACDF effectively addresses anterior compressive pathologies, the amount of canal widening achievable is limited when combined posterior compression exists. Additional posterior decompression with laminoplasty or laminectomy might yield better results, requiring further investigation. In conclusion, when

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preoperative MRI indicates spinal cord indentation due to ligamentum flavum hypertrophy or buckling, anterior decompression by ACDF alone may not provide sufficient decompression and clinical improvement. Therefore, alternative surgical strategies such as an anterior-posterior combined approach or posterior approach should be considered.

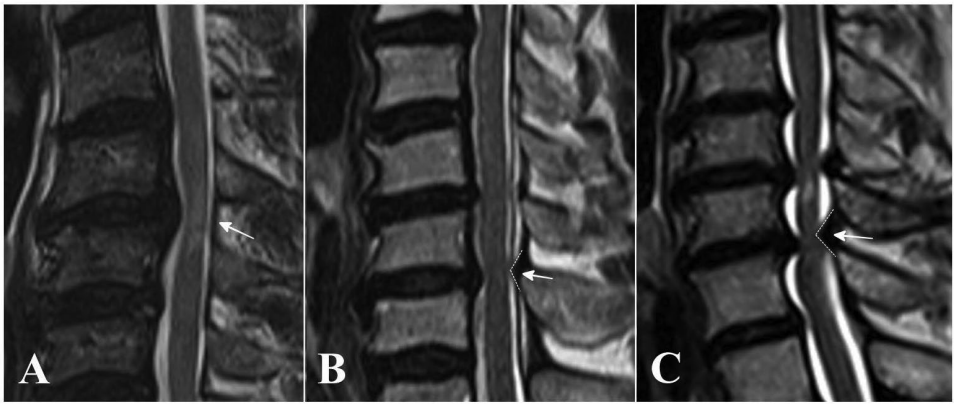

Figure 1. Ligamentum flavum cord compression grade (A) Grade 0, no ligamentum flavum buckling or hypertrophy. Despite cord compression, cerebrospinal fluid (CSF) space can be seen at the posterior aspect of spinal cord. **(B)** Grade 1, mild ligamentum flavum buckling. CSF space posterior to spinal cord is obliterated. However, posterior line of spinal cord can be seen as a smooth line. **(C)** Grade 2, ligamentum flavum buckling and hypertrophy. Spinal cord is compressed by ligamentum flavum and indentation of posterior margin of cord is identified.

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Table 1. Patient baseline characteristics and patient reported outcome measures.

Variables			No LFC group (n = 167)	LFC group (n = 28)	P value
Baseline characteristics	Demographics	Age	62.2±10.5	63.4±8.1	0.534
		Sex (M:F)	96:71	16:12	1.000
		BMI	25.0±2.4	25.3±4.6	0.709
		HTN	53 (31.7%)	15 (53.6%)	0.281
		DM	22 (13.2%)	6 (21.4%)	0.250
		Smoking status	35 (21.0%)	4 (14.3%)	0.610
		Number of levels fused	1.9±0.8	2.0±0.7	0.634
		Follow-up period	57.5±33.5	64.6±33.4	0.298
	Radiographic parameters	C2-C7 lordosis	9.5±0.1	11.0±10.3	0.415
		C2-C7 SVA	20.6±11.1	24.5±13.1	0.097
		Segmental lordosis	2.0±3.6	3.4±5.0	0.087
		Canal width	9.8±1.1	9.6±1.2	0.456
		Spondylolisthesis	9 (5.4%)	8 (28.6%)	0.001*
Patient reported outcome measures	Neck pain VAS	Preop	4.0±2.5	4.1±2.4	0.435
		Postop 3M	1.8±2.0	1.7±2.4	0.883
		Postop 2Y	1.9±2.2	2.2±2.9	0.556
	Arm pain VAS	Preop	4.7±2.7	5.2±1.8	0.521
		Postop 3M	2.5±2.7	2.3±2.6	0.691
		Postop 2Y	2.8±2.8	3.5±3.3	0.087
	JOA	Preop	14.1±2.3	14.0±1.9	0.822
		Postop 3M	15.2±2.0	14.3±2.4	0.037*
		Postop 2Y	15.2±2.0	13.8±2.6	0.001*
	JOA recovery rate	Postop 3M	52.6±80.5	34.9±62.1	0.287
		Postop 2Y	56.4±71.4	25.6±86.9	0.042*

LFC, ligamentum flavum cord compression; BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; SVA, sagittal vertical axis; M, months; Y, years; VAS, visual analogue scale; JOA, Japanese Orthopedic Association.

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Late to Extubate? Risk Factors and Associations for Delayed Extubation after Adult Cervical Deformity

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Introduction: Due to the proximity of the surgical site to important respiratory and oropharyngeal structures, patients may undergo delayed extubation after adult cervical deformity (ACD) surgery to manage postoperative airway edema/obstruction and reduce the likelihood of reintubation and other respiratory, medical, and surgical complications. Herein, we evaluate the relevant predictors and relationships with delayed extubation.

Materials and Methods: In a retrospective cohort study of a prospectively continuously enrolled database, operative ACD patients with baseline (BL) and peri-operative data (6W) were analyzed via descriptive statistics and means comparison analyses. Patients were grouped based on whether they experienced delayed extubation (DE), as defined by leaving the OR while still intubated, versus those who were extubated successfully in the OR (non-DE). Regression analyses identified predictors of delayed extubation and associations with peri-operative complications and outcomes.

Results: 82 patients met inclusion criteria(mean age 62.4±13.0 years, 52.4% female, mean Edmonton frailty score: 5.10±2.97, mean ACFI score: 0.30±0.16, mean CCI: 1.41±1.73). The mean operative time was 393.80±170.90 minutes, mean EBL 435.0±306.0 mL, and mean length of stay was 10.9±42.3 days. 30(36.6%) patients had a previous history of cervical surgery. 14 patients left the OR intubated, 11(13.4%) had complete 6W, and 1(1.2%) required reintubation. There were no differences between the DE cohort and non-DE cohort in terms of baseline cervical radiographic parameters or pre-operative cSVA, C2-C7, or TS-CL alignment goals. The DE cohort demonstrated greater Edmonton frailty scores at baseline(p=0.017) as well as significantly greater EBL (p=0.021). There was a significantly greater proportion of patients with congenital scoliosis amongst those with delayed extubation(p=0.016). Smoking history also demonstrated a considerably higher rate of delayed extubation (27.3% v 6.5%, p=0.031). Additionally, kidney disease at baseline was a significant predictor of delayed extubation (OR 35.5, p=0.029). During surgery, there was a significant difference in the rate of blood transfusions (DE: 27.3% v non-DE: 4.8%, p=0.12), although operative time and levels fused did not appear to significantly different or serve as predictors. Post-operatively, there was as expected a significant difference in the rate of SICU admission (DE: 90.9% v. non-DE: 49.2%, p=0.01), although there were no significant differences in LOS. When considering the impact of degree of correction, those with increased cSVA and MGS correction postoperatively from baseline were more likely to experience delayed extubation (OR 1.1, CI 95% 1.05-1.17, p<.001; OR 1.14, CI 95% 1.05-1.24, p=0.003). Furthermore, delayed extubation was a significant

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predictor of increased VR-Physical Component Scores (p=0.013) at 6W, and the DE cohort demonstrated significantly higher VR-PCS and VR-MCS Scores at 6W (p=0.01, both).

Conclusion: Delayed extubation may hinder the reclamation of quality of life perioperatively, and certain considerations such as minimizing intraoperative blood loss and transfusions required and also the degree of correction could minimize the occurrence of delayed extubation.

POSTER 42

What is the Difference of a Decade of Experience? Comparing Two Multi-center, Prospective, Randomized Clinical Investigational Device Exemption Trials of An Approved TDR at two contiguous levels of the Cervical Spine.

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Introduction: In 2013, the first Investigational Device Exemption (IDE) clinical trial for the treatment of Symptomatic Cervical Disc Disease (SCDD) at two contiguous levels was approved for an unconstrained Total Disc Replacement (cTDR). A decade later, this same device was the control arm of a new IDE trial at 2 levels. Although different investigators, the objective of this analysis was to explore if a decade of knowledge demonstrated a significant improvement in patient outcomes compared to the original trial.

Materials and Methods: Both studies were prospective, randomized, multi-center, controlled IDE clinical trials with similar inclusion/exclusion criteria and study designs. The original IDE trial had 148 cTDR patients and the new IDE trial had 140 cTDR patients treated at 2 levels with the same unconstrained device. Patients were seen at the same intervals of follow-up at 6 weeks, 3 months, 6 months, 12 months, and 24 months. Patient-reported outcome measures and radiographs were collected at follow up. Both studies were based on non-inferiority models with a primary endpoint. The composite clinical success (CCS) at 24 months was defined as a patient must be a success in all 4 criteria, defined as: ≥ 15 point improvement in Neck Disability Index (NDI) Score (out of 100) in subjects at 24 months compared with baseline, maintenance or improvement in neurological status at 24 months compared to baseline, no secondary surgical interventions at the index levels, and absence of major device-related adverse events (AEs). Secondary endpoints such as Visual Analog Score (VAS) neck pain, VAS arm pain, Short-Form-12 (SF-12) and patient satisfaction were collected at each time point in both studies.

Results: At 24 months, the original trial with neurologic status added CCS was achieved in 76.3% (Hisey et al, 2014) compared to a CCS success of 86.1% in the new trial demonstrating a statistically significant difference ($p < 0.05$). There was a lower incidence of secondary surgical interventions in the original study (98.8% success) compared to new study (96.4% success), however not statistically different. The original study reported 8 patients with AEs and 1 patient with neurologic deterioration (ND). In comparison, the new study had 0 AEs and 2 patients with NDs demonstrating a statistically significant difference favoring the new study. All secondary endpoints consistently showed similar improvement from baseline in both studies but none of the measures showed a statistically significant difference between studies.

Conclusion: This is truly a unique opportunity to compare data from 2 IDE trials with the same treatment group. This ad hoc analysis shows that the advancement of knowledge over a decade in spinal surgery has reduced major device-related adverse events. However, secondary surgical interventions remains low in both trials and patient reported outcomes show high success in both trials with a statistical difference between the trials. In summary, this comparison shows an improvement in surgical expertise and planning over a decade while

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patient overall success remains extremely high. This validates the reproducibility of clinical outcomes over many surgeons and centers.

POSTER 43

Is the Atlantoaxial Level Overlooked in the Radiologic Interpretation of Cervical Magnetic Resonance Imaging?

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Introduction: In the absence of trauma or obvious pathology, it has been our experience that the atlantoaxial level of the cervical spine is often overlooked in magnetic resonance imaging (MRI) radiologic reports. The presence of radiographic changes at this level of the spine has the potential to induce significant clinical symptoms and it warrants diligent scrutinization equal to the remainder of the examination. Therefore, the purpose of this study is to quantify the rate at which the atlantoaxial level is omitted from official cervical MRI radiologic reports and to identify potential missed pathology through these omissions to underscore the need for improved standardization of evaluation.

Materials and Methods: The preoperative MRIs and associated radiologic reports of 219 patients undergoing anterior or combined anterior/posterior cervical decompression and fusion in a single year were collected. The inclusion or omission of distinct evaluation at the atlantoaxial level within each radiologic report was recorded. All imaging was then reviewed by a musculoskeletal/neuroradiology fellow with the oversight of a fellowship-trained musculoskeletal radiologist. The atlantoaxial level was specifically evaluated, and any pathology was noted and compared to the official radiologic reports. The rates of atlantoaxial evaluation omission from the radiologic reports and missed pathology at this level were primarily and secondarily reported.

Results: MRI studies were performed at 101 different institutions. The total number of radiologists who signed reports based on these studies was 126. Specific documentation of atlantoaxial evaluation was noted in 32 (14.6%) radiologic reports, with the remaining 187 reports (85.4%) documenting no specific evaluation of the atlantoaxial level. On independent review of the imaging, pathology was noted at the atlantoaxial level in 18 patients (8.2%), with 19 total abnormal findings. The encountered pathologies were absent from the official reports in 13 of these cases (5.9% of the total study population). Degenerative changes, including transverse ligament hypertrophy and facet arthritis, were most common.

Conclusion: Documented interpretation of the atlantoaxial level is often omitted from official cervical spine MRI reports. In our study, formal documentation was omitted from 85% of reports, resulting in missed pathology in nearly 6% of cases. This study underscores the importance of thorough imaging interpretation and clinical correlation to a patient's symptoms. In addition, it highlights the need for standardized reporting of these studies to avoid any potential morbidity associated with a missed diagnosis.

POSTER 44

Machine Learning-based Cluster Analysis Identifies Four Unique Phenotypes of Degenerative Cervical Myelopathy Patients with Distinct Clinical Profiles and Long-term Functional Outcomes

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Introduction: Degenerative cervical myelopathy (DCM) is the leading cause of nontraumatic spinal cord disability worldwide, affecting approximately 1.6 to 7.88 per 100,000 individuals annually.[1] This highly prevalent condition significantly impacts the physical and functional well-being of middle-aged and older adults, often surpassing the effects of conditions like cancer or diabetes on their overall quality of life (QoL).[2]

DCM, which is an overarching term which includes multiple benign, non-traumatic entities including cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament, causes a diverse spectrum of signs and symptoms.[3] Its insidious onset, varying progression and response to treatment, and potential for presentation with concurrent clinical findings highlight the complexity of its diagnosis.

Two widely employed unsupervised machine-learning models, latent profile analysis (LPA) and k-means clustering, present valuable avenues for identifying clinically relevant patient subgroups. LPA, a person-centered analytical clustering technique, identifies groups based on responses to manifest clinical variables using maximum likelihood estimation. Conversely, k-means clustering, a non-model-based grouping technique, relies on the pairwise Euclidean distance between data points to minimize within-cluster variances. Considering the principal differences between these two methods, but with similar objectives, leveraging their combined application can yield a more robust analytical tool, particularly if their results exhibit high consistency.[4,5] This study aims to apply these clustering algorithms using a large trial-based DCM database, seeking to elucidate relevant disease phenotypes and exploring the existence of symptom clusters and their impact on quality of life after surgery.

Materials and Methods: We implemented both latent profile analysis and k-means clustering on aggregated data from three large DCM trials. Key covariates, including the Nurick score, NDI (neck disability index), neck pain, and motor and sensory scores, were employed for clustering. Outcome differences among identified phenotypes were assessed using ANOVA, followed by posthoc Tukey test.

Results: A total of 1,047 DCM patients (mean [SD] age: 56.80 [11.39] years) had complete one year outcome assessment. Both LPA and k-means clustering identified four DCM patient phenotypes: "severe multimodal impairment" (n=286), "minimal impairment" (n=116), motor-dominant" (n=88) and "pain-dominant" (n=557) groups. The "severe multimodal impairment group", comprising of frail elderly patients, demonstrated the worst overall 1-year outcomes (SF-36 PCS mean [SD]: 40.01 [9.75]; SF-36 MCS mean [SD]: 46.08 [11.50]), but exhibited the most substantial neurological recovery after surgery (DmJOA mean [SD]: 3.83 [2.98]). A higher frailty score and a positive smoking status predicted membership in phenotype 1 ("severe multimodal impairment" group).

Conclusion: A patient-centered cluster analysis facilitated the identification of four novel

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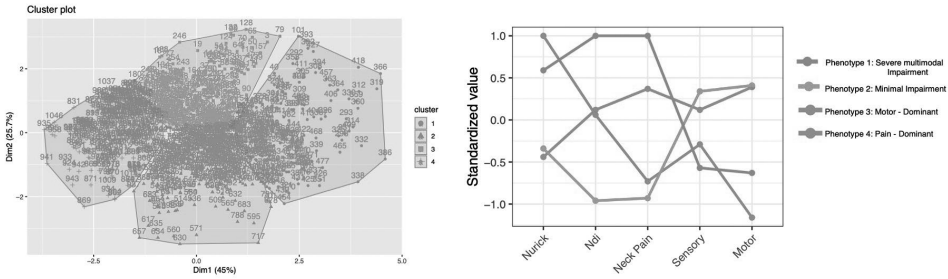
phenotypes of DCM, underscoring the interrelatedness of patients' symptoms rather than their occurrence in isolation. Our results provide empirical data that may inform conceptual models of symptom clustering in DCM, suggesting the potential existence of subgroups characterized as "severe multimodal impairment", "minimal impairment", "pain-dominant", and "motor-dominant" dysfunction. By identifying key variables that uniquely distinguish and predict membership in different phenotypes, our study offers guidance in classifying patients beyond the conventional mJOA framework. Accurate patient selection, grounded in a heuristic and multifaceted symptom assessment, is a crucial step in developing personalized management strategies for individuals with DCM.



A B

A. Cluster analysis showing 4 classes using k-means algorithm. B. Four patient phenotypes identified using LPA analysis with x-axis showing the symptom scales and the y-axis showing the standardized mean values

Table 1. Mean comparison of baseline symptom scores and one-year outcomes across the four clinical phenotypes

	Phenotype 1 Mean ± SD (n= 286)	Phenotype 2 Mean ± SD (n = 116)	Phenotype 3 Mean ± SD (n= 88)	Phenotype 4 Mean ± SD (n = 557)	ANOVA F Statistic	ANOVA p value	Posthoc pairwise comparison* 1 vs 2	1 vs 3	1 vs 4	2 vs 3	2 vs 4	3 vs 4
Baseline Scores												
Ndi	36.73 ± 16.40	26.36 ± 14.81	18.89 ± 13.59	30.84 ± 15.01	35.48	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nurick	3.58 ± 1.08	3.09 ± 1.15	3.60 ± 1.08	3.09 ± 1.00	18.01	<0.05	<0.05	1	<0.05	<0.05	1	<0.05
Neck Pain	2.27 ± 1.35	1.51 ± 1.20	0	2.08 ± 1.12	98.39	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05
Sensory	0.98 ± 0.14	3.0 ± 0	2.0 ± 0	2.0 ± 0	22,759.51	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1
Motor	7.07 ± 1.99	8.90 ± 2.23	8.28 ± 2.24	8.24 ± 1.82	33.24	<0.05	<0.05	<0.05	<0.05	0.12	<0.05	1
One-Year Outcomes												
SF-36 PCS	40.01 ± 9.75	43.68 ± 9.84	42.37 ± 10.73	41.86 ± 10.21	4.31	<0.05	<0.05	0.22	0.06	0.80	0.29	0.97
SF-36 MCS	46.08 ± 11.50	44.00 ± 13.52	47.33 ± 11.93	47.72 ± 10.74	3.98	<0.05	0.34	0.80	0.20	0.16	<0.05	0.99
mJOA	14.30 ± 2.68	15.51 ± 2.16	15.23 ± 2.47	15.30 ± 2.51	11.75	<0.05	<0.05	<0.05	<0.05	0.86	0.86	0.99
ΔmJOA	3.83 ± 2.98	0.92± 2.51	2.31 ± 2.64	2.47 ± 2.62	35.03	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.95

*post hoc comparison using Tukey HSD

POSTER 45

Specific Cervical Spine Surgical Constructs can be Accurately Identified with Deep Learning Algorithms

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Introduction: Automatic categorical labeling of large image datasets could assist in cohort building for research by reducing the time and variability associated with manual data entry. Both prospectively maintained registries and retrospective studies require substantial manual work to assemble patient cohorts, perform radiographic measurements, and surveille for postoperative radiographic complications. The purpose of this study is to develop deep learning algorithmic pipelines for the automatic classification of common cervical spine surgical constructs to facilitate efficient cohort assembly and production of spine radiography registries.

Materials and Methods: DICOM files of instrumented cervical spine radiographs were extracted from the institutional PACS system. These DICOM images were then manually labeled according to the type of instrumentation present, including the following categories: (1) ACDF, (2) anterior cervical corpectomy and fusion (ACCF), (3) dens screw, (4) ACDF and ACCF, (5) posterior cervical fusion, (6) anterior-posterior cervical fusion, (7) laminoplasty, (8), Laminoplasty and ACDF or ACCF, (9) cervical total disc replacement, and (10) hybrid constructs (cervical total disc replacement and adjacent fusion). A 70:15:15 split was used to organize the images into training, validation, and testing sets. A deep learning classifiers with the ImageNet-pretrained EfficientNet architecture were trained over 60 epochs on images from the training set. Hyperparameters were tuned against the performance of the models in the validation set. Final performance metrics for the model were calculated on the held-out test set.

Results: 6000 instrumented cervical spine DICOM images were identified and manually labeled according to the type of instrumentation present. The deep learning algorithm differentiated the various cervical spine constructs with excellent accuracy (range 86.4-99.0%) (Figure 1). The deep learning model demonstrated lower accuracy when few images were available for any given construct, including identifying images containing a dens screw for which there were only 17 images (86.4% accuracy). The model was even able to correctly differentiate subtle differences with high accuracy, including ACDF (90.4% accuracy) versus ACCF (96.7% accuracy) versus concomitant ACDF and ACCF (91.1% accuracy).

Conclusion: Utilizing a deep learning classifier, an algorithm was trained to correctly label instrumented cervical spine radiographs according to the type of surgical construct present in the radiograph. This model can be used in an efficient data ingestion pipeline for large imaging datasets to facilitate research and in the creation of spine radiography registries.

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Full Categories

Category	N	P	R	MAP-50
All	1855	0.774	0.671	0.765
ACDF	214	0.853	0.855	0.904
ACCF	490	0.943	0.953	0.967
Dens Screw	17	0.847	0.824	0.864
ACDF + ACCF	107	0.783	0.944	0.911
Cervical Posterior Fusion	262	0.797	0.836	0.904
Cervical Ant-Post Fusion	207	0.962	0.967	0.990
Laminoplasty + ACDF or ACCF	15	0.819	1.000	0.886
Cervical TDR + ACDF	20	0.943	0.825	0.945

POSTER 46

Respiratory Comorbidities Increase Risk for Postoperative Hematoma Requiring Reoperation Following Anterior Cervical Discectomy and Fusion

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Introduction: Prior studies have identified general risk factors for postoperative hematoma requiring reoperation after anterior cervical discectomy and fusion (ACDF), such as multilevel fusion and coagulopathy. However, specific coughing-related factors like chronic obstructive pulmonary disease (COPD), asthma, and tobacco use have yet to be extensively investigated. The purpose of this study was to assess the correlation between these respiratory comorbidities and the incidence of postoperative hematoma requiring reoperation following ACDF.

Materials and Methods: Patients who underwent single or multi-level ACDF between 2011 and 2021 were identified using Current Procedural Terminology (CPT) codes in the PearlDiver database. The primary outcome was the occurrence of postoperative hematoma requiring reoperation within 30 days. Chi-square tests and t-tests compared groups, and multivariable logistic regression identified predictors for postoperative hematoma.

Results: Among 399,900 ACDF patients, 901 (0.2%) developed postoperative hematoma requiring reoperation within 30 days. Patients with postoperative hematoma were older (58 vs 55, $p < 0.001$) and predominantly male (62.5% vs 44.9%, $p < 0.001$). After adjustment, tobacco use and comorbid COPD were associated with postoperative hematoma (Odds Ratio [OR], 1.27; 95% Confidence Interval [CI], 1.10-1.47; p. < 0.001 and OR, 1:41; 95% CI, 1.21-1.64; $p < 0.001$, respectively). Comorbid asthma was not a significant risk factor. Additional risk factors included comorbid hypertension (OR, 1.46; 95% CI, 1.18-1.82; $p < 0.001$), coagulopathy (OR, 1.50; 95% CI, 1.24-1.81; $p < 0.001$), anemia (OR, 1.38; 95% CI, 1.17-1.62; $p < 0.05$), and history of deep vein thrombosis (OR, 1.93; 95% CI, 1.44-2.54; $p < 0.001$).

Conclusion: Tobacco use and COPD were identified as novel risk factors for postoperative hematoma formation requiring reoperation after ACDF. Recognizing these modifiable factors, providers may consider postponing non-emergent ACDFs until patients undergo smoking cessation programs or receive optimal COPD management.

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Table 2: Risk factors Postoperative Hematoma Requiring Reoperation within 30 Days of Anterior Cervical Discectomy and Fusion

Variable	Odds-Ratio	95% CI	*p* value
Age	1.01	1.00 – 1.02	**0.0022**
Gender			
Male	1.95	1.69 – 2.26	**< 0.001**
Mean Family Income	1.00	1.00 – 1.00	0.42
Multilevel Procedure	0.45	0.36 – 0.57	**< 0.001**
Comorbidities			
Anemia	1.38	1.17 – 1.62	**< 0.001**
Asthma	1.00	0.83 – 1.19	0.97
Cancer	0.89	0.74 – 1.07	0.22
CVD	1.21	1.03 – 1.41	**0.017**
Coagulopathy	1.50	1.24 – 1.81	**< 0.001**
COPD	1.41	1.21 – 1.64	**< 0.001**
CAD	0.96	0.82 – 1.13	0.62
Diabetes	1.04	0.89 – 1.20	0.63
Hx DVT	1.93	1.44 – 2.54	**< 0.001**
Hx PE	0.72	0.45 – 1.11	0.16
Hypertension	1.46	1.18 – 1.82	**< 0.001**
Liver Disease	0.97	0.83 – 1.14	0.75
Obesity	1.07	0.92 – 1.24	0.38
Sleep Apnea	0.98	0.85 – 1.14	0.84
Tobacco Use	1.27	1.10 – 1.47	**< 0.001**
Valvular Disease	1.17	0.99 – 1.37	0.067

POSTER 47

Therapeutic Time Window of Intravenous Muse Cell Administration for Spinal Cord Injury in Mice

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Introduction: Muse cells, discovered by Dezawa et al., are non-tumogenic pluripotent-like stem cells found in bone marrow, peripheral blood, and connective tissues expressing pluripotent stem markers (SSEA-3) and mesenchymal markers (CD-105) [1, 2]. They can differentiate into cells of all 3 germ layers from a single cell [1]. Circulating Muse cells administered exogenously home to damaged sites by detecting sphingosine-1-phosphate, a key inflammatory mediator produced by damaged cells [3]. They replace apoptotic and damaged cells by spontaneously differentiating into various cell types, facilitating tissue repair. Thus, intravenous administration was the main route for Muse cell therapy, eliminating the need for surgery. Furthermore, pre-treatment pluripotency or differentiation induction via gene or cytokine introduction is unnecessary. Remarkably, allogenic and xenogenic Muse cells escape host immune rejection post-injection without immunosuppression. Due to these unique characteristics, Muse cell stockpiling is feasible. Muse cell administration via intravenous infusion in clinical trials for various conditions, including stroke, acute myocardial infarction, and spinal cord injury (SCI), proceeds without HLA-matching or immunosuppression [4, 5]. Despite the established safety in SCI clinical trials, the therapeutic time window of administration of Muse cells remains undetermined. Elucidating the optimal therapeutic time window of Muse cell therapy is crucial, as it provides foundational data for designing protocols in future clinical trials.

Materials and Methods: Using severe SCI mice, cells were administered at four different times: 2, 8, 14, and 28 days post-injury (DPI). PBS (control), mesenchymal stem cells (MSC: $1.0x10^5$ cells), or Muse cells ($1.0x10^5$ cells) were intravenously administered (n=10). Hindlimb paralysis was assessed using the Basso mouse scale (BMS) score. Histological evaluation and immunofluorescence imaging were conducted.

Results: Behavioral improvement was significant exclusively in the 2-DPI Muse cell group compared with the control 6 weeks after SCI (BMS score: control 2.8±1.0, MSC 3.6±1.2, Muse cell 5.2±1.4; two-way ANOVA followed by Bonferroni post hoc test: $P<0.01$). Histological evaluation revealed significantly smaller scar tissue areas in hematoxylin-eosin staining and larger preserved myelinated tissue areas in Luxor-fast blue staining in the 2- and 8-DPI Muse cell groups compared with the control. Muse cells spontaneously differentiated into cells positive for neural, glial, and oligodendrocyte markers among all Muse cell groups in immunofluorescence imaging (Figure 1). Furthermore, Figure 2 demonstrated that Muse cells differentiated into motor neurons and the synaptic connections were formed, indicating the possibility of functioning motor neurons derived from Muse cells. The number of synapses touching a motor neuron in the lumbar enlargement was greater in the 2- and 8-DPI Muse cell group compared with MSC group (each $P<0.01$) (Figure 3).

Conclusion: The treatment efficacy between acute and subacute phase administrations

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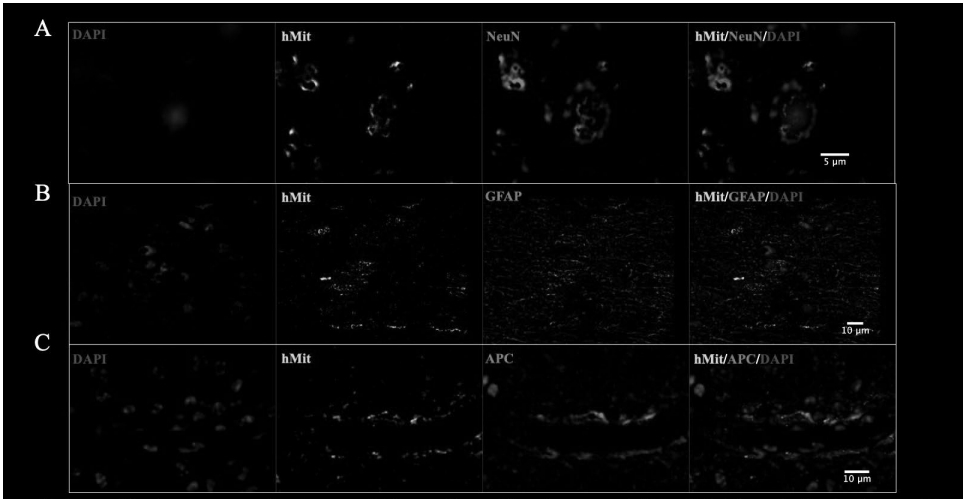
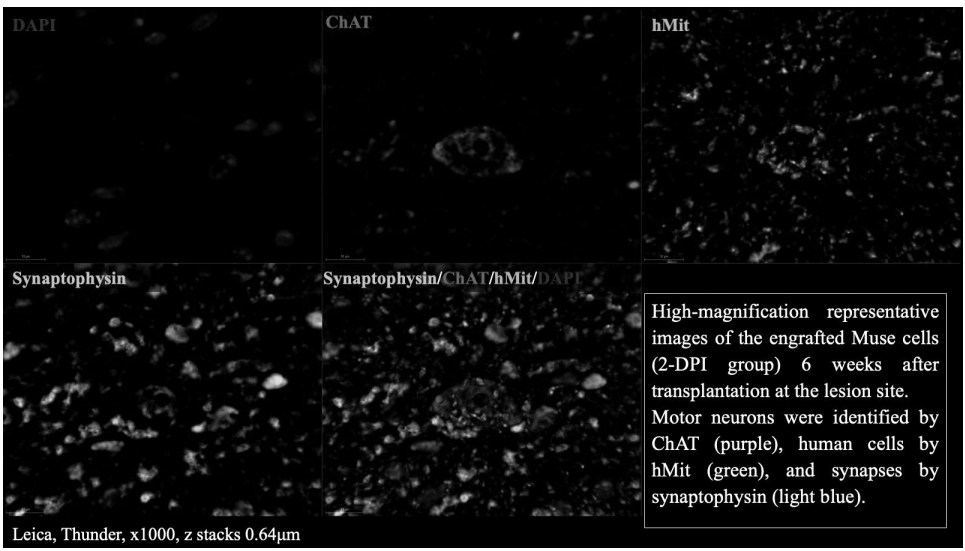
shows differences when compared to MSC, suggesting that the optimal administration timing for Muse cell therapy in SCI is before the subacute phase. Despite 28 days post-SCI, homing and differentiation of the Muse cells at the lesion site were confirmed.



High-magnification representative images of Muse cells positive for neuronal (A), glial (B), and oligodendrocyte (C) markers at the lesion site in 28-DPI group administered Muse cells.



High-magnification representative images of the engrafted Muse cells (2-DPI group) 6 weeks after transplantation at the lesion site. Motor neurons were identified by ChAT (purple), human cells by hMit (green), and synapses by synaptophysin (light blue).

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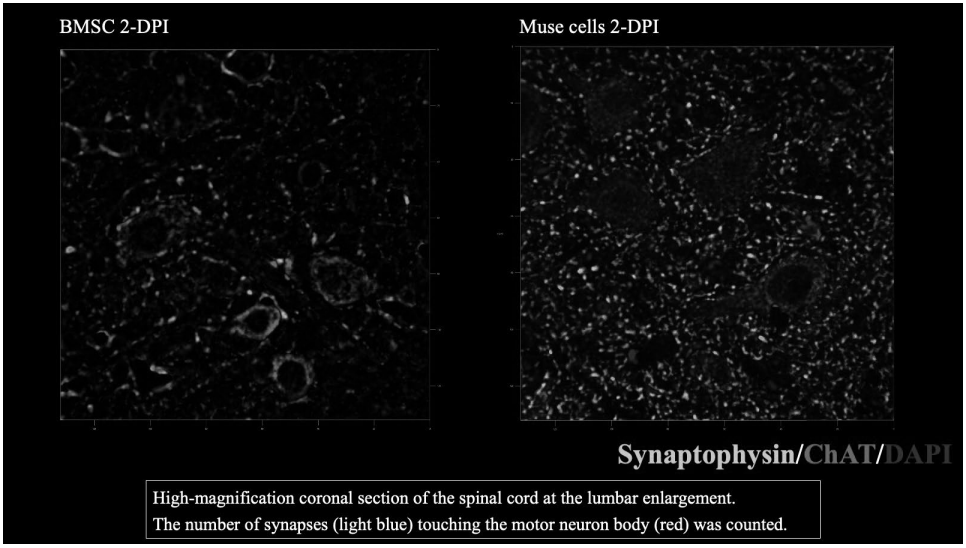

High-magnification coronal section of the spinal cord at the lumbar enlargement.
The number of synapses (light blue) touching the motor neuron body (red) was counted.

POSTER 48

Clinical and Radiographic Outcomes of Cervical Disc Replacement for Treatment of Adjacent Segment Disease: A Case Series

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Introduction: Cervical disc replacement (CDR) is not currently approved for the treatment of adjacent segment disease (ASD) but may be a promising intervention due to its superior motion preservation relative to anterior cervical discectomy and fusion (ACDF). This case series aims to evaluate clinical outcomes and radiographic measurements following treatment of ASD with CDR.

Materials and Methods: Patients who underwent CDR for ASD were retrospectively identified from a surgical database for a single spine surgeon. Demographic, perioperative, patient-reported and radiographic data were obtained. Patient-reported outcomes (PROs) included Patient-Reported Outcome Measure Information System- Physical Function (PROMIS-PF), Neck Disability Index (NDI), Visual Analog Scale (VAS)-Neck, VAS-Arm, 12-Item Veterans Rand (VR-12) Physical Component Score (PCS), VR-12 Mental Component Score (VR-12 MCS), and 9-Item Patient Health Questionnaire (PHQ-9). PROs were obtained preoperatively, and six weeks postoperatively and at final follow-up. The average follow-up time was 8.9 months±6.3 months. Radiographic measurements included baseline disc height, and baseline and postoperative segmental angle, segmental range of motion (ROM), and C2-C7 ROM.

Results: Twelve patients met inclusion criteria. The operated levels ranged from C3-C4 to C6-C7, with C5-C6 being the most frequently operated level (5/12). Three inpatient surgeries were included, with the rest being performed outpatient. Operative time ranged from 37 to 71 minutes. Eleven patients were discharged on postoperative day 0, and one patient was discharged on day 1. By final postoperative follow-up, patients on average reported the following improvements in PROs: 3.0 for PROMIS-PF, 20.9 for NDI, 2.6 for VAS-N, 4.7 for VAS-A, 13.6 for VR-12 PCS, 8.1 for VR-12 MCS, and 4.6 for PHQ-9. At least 75% of patients achieved MCID for PROMIS-PF, NDI, VAS-N, VAS-A, VR-12 PCS, and PHQ-9. Only 28.6% achieved MCID for VR-12 MCS. Radiographically, the average baseline disc height of 5.2. On average, patients had a 2.7 degree increase in segmental angle, 1.2 degree increase in segmental ROM, and 0.3 degree increase in C2-C7 ROM.

Conclusion: Though not currently approved for treatment of adjacent segment disease, CDR can help patients to achieve clinically significant improvements in physical function, disability, neck and arm pain, and depressive burden. On average, patients may have increases in segmental angle and segmental ROM, and similar C2-C7 ROM compared to baseline. Longer term follow-up studies should be conducted to evaluate how patient-reported and radiographic outcomes may change over time.

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Table 1. Perioperative Characteristics

Characteristic	Total (n= 12)
Spinal Pathology	
Herniated Nucleus Pulposus	100.0% (12)
Central Stenosis	66.7% (8)
Foraminal Stenosis	16.7% (2)
Operated Level	
C3-C4	8.3% (1)
C4-C5	16.7% (2)
C5-C6	41.7% (5)
C5-C7	16.7% (2)
C6-C7	16.7% (2)
Number of Levels	
One	83.3% (10)
Two	16.7% (2)
Operative Time (Mean ± SD; min)	50.8±11.9
Estimated Blood Loss (Mean ± SD; mL)	30.6±11.0
Length of Stay (Mean ± SD; hours)	7.9±8.0
Postoperative Day of Discharge	
POD 0	91.7% (11)
POD 1	8.3% (1)
POD 0 VAS pain	4.2±2.4
POD 0 OME	25.3±22.8

ACDF = Anterior Cervical Discectomy and Fusion; CDR = Cervical Disc Replacement; POD = postoperative day; mL = milliliters; SD = standard deviation; OME = oral morphine equivalents

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Table 2. Patient-reported outcomes and minimum clinically important difference

	Total (n=12) (mean±SD)
Pre-Op	
PROMIS-PF	42.3±8.7
NDI	44.8±21.5
VAS-N	6.7±2.9
VAS-A	6.9±2.9
VR-12 PCS	34.0±9.0
VR-12 MCS	45.0±14.4
PHQ-9	10.1±6.3
6-week Post-Op	
PROMIS-PF	41.3±16.4
NDI	22.4±21.0
VAS-N	2.8±3.3
VAS-A	1.7±3.5
VR-12 PCS	48.1±10.0
VR-12 MCS	59.0±10.0
PHQ-9	5.1±6.2
Final Post-Op	
PROMIS-PF	47.8±12.0
NDI	23.5±20.9
VAS-N	4.2±3.5
VAS-A	2.6±3.3
VR-12 PCS	46.0±12.7
VR-12 MCS	56.5±11.8
PHQ-9	5.0±5.9
Δ Pre-Op to 6-week Post-Op	
PROMIS-PF	3.0±26.0
NDI	21.0±12.6
VAS-N	4.0±2.6
VAS-A	5.0±5.1
VR-12 PCS	12.7±9.4
VR-12 MCS	9.6±10.2
PHQ-9	3.4±3.9
Δ Pre-Op to Final Post-Op	
PROMIS-PF	3.0±26.0
NDI	20.9±17.2
VAS-N	2.6±2.8
VAS-A	4.7±3.6
VR-12 PCS	13.6±10.7
VR-12 MCS	8.1±9.7
PHQ-9	4.6±4.7
MCID Achievement	
PROMIS-PF	85.7% (6)
NDI	77.8% (7)
VAS-N	77.8% (7)
VAS-A	75.0% (6)
VR-12 PCS	85.7% (6)
VR-12 MCS	28.6% (2)
PHQ-9	75.0% (6)

PROMIS-PF=Patient-Reported Outcome Measure Information System-Physical Function; NDI=Neck Disability Index; VAS-N=Visual Analog Scale-Neck; VAS-A=Visual Analog Scale-Arm; VR-12 PCS=Veterans RAND-12 Item Health Survey Physical Component Score; VR-12 MCS=Veterans RAND-12 Item Health Survey Mental Component Score; PHQ-9=9-Item Patient Health Questionnaire; MCID=Minimal Clinically Important Difference

Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

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Table 3. Radiographic outcomes

	All Levels (n=14)
Preoperative	
Disc Height	5.2±1.5
Segmental Angle	2.8±3.0
Segmental ROM	0.8±1.7
C2-C7 ROM	7.8±13.6
Final Postoperative	
Segmental Angle	4.6±8.8
Segmental ROM	1.8±4.9
C2-C7 ROM	8.1±14.4
Δ Preoperative to Final Postoperative	
Segmental Angle	2.7±10.3
Segmental ROM	1.2±3.6
C2-C7 ROM	0.3±0.9

SD: Standard Deviation; ROM: Range of Motion

POSTER 49

Temporal Trends of Improvement in Patients With Cervical Radiculopathy After Anterior Cervical Surgery

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Introduction: Although several studies have shown that patients with radiculopathy and/or neck pain due to degenerative conditions of the cervical spine improve significantly after anterior cervical surgery, evidence regarding the temporal trends and course of improvement is still largely lacking. Spine surgeons lack clarity on these frequently asked questions in preoperative and postoperative visits – How much time will it take for my pain to go away? How much time will it take for my physical function to improve? I have had some improvement, but when can I expect a full recovery? Is there a likelihood that I may not improve further? The objective of this study was to analyze temporal trends of improvement in non-myelopathic patients after anterior cervical surgery for degenerative pathology.

Materials and Methods: This was a retrospective review of prospectively collected data. Patients who underwent primary single-level anterior cervical discectomy and fusion (ACDF) or cervical disc replacement (CDR) for cervical radiculopathy and/or neck pain due to degenerative pathology and had a minimum of 1-year follow-up were included. Patients with myelopathy were excluded. Outcome measures were: 1) patient-reported outcome measures (PROMs) (Neck Disability Index, NDI; Visual Analog Scale, VAS neck and arm; 12-Item Short Form Survey Physical Component Score, SF-12 PCS); 2) global rating change (GRC); 3) minimal clinically important difference (MCID) achievement rates; and 4) return to activities. The points analyzed were preoperative, 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and 2 years. Improvement trends across these time points were plotted on graphs. All analyses were done separately for ACDF and CDR cohorts.

Results: 284 patients (163 ACDF, 121 CDR) were included. VAS neck and arm were found to have statistically significant improvement compared to the previous timepoint ($p<0.05$) up to 6 weeks following both ACDF and CDR. NDI and SF-12 PCS were found to have statistically significant improvement compared to the previous timepoint ($p<0.05$) up to 3 months after both ACDF and CDR. Beyond these timepoints, there was no significant improvement in PROMs in both cohorts and the plotted graphs of improvement showed a plateau. >80% of patients reported feeling better compared to preoperative on the GRC scale by 6 weeks following both ACDF and CDR. >50% of patients in both cohorts achieved MCID in PROMs by 6 weeks. 91%, 77%, and 94% of ACDF patients returned to driving (average 14 days), returned to work (average 12 days), and discontinued narcotics (average 7 days), respectively, after surgery. 100%, 88%, and 98% of CDR patients returned to driving (average 15 days), returned to work (average 6 days), and discontinued narcotics (average 5 days) after surgery.

Conclusion: Patients with cervical radiculopathy and/or neck pain due to degenerative conditions are expected to improve up to 3 months after both ACDF and CDR. Neck pain and

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arm pain improve up to 6 weeks and disability and physical function improve up to 3 months. Beyond these timepoints, the trends in improvement tend to reach a plateau. >80% of patients feel better compared to preoperative by 6 weeks after both ACDF and CDR.

POSTER 50

Both Terminal E-beam and Gamma Irradiation Negatively Impact Biological Properties of Demineralized Bone Matrices

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Introduction: Non-terminally irradiated, aseptically processed, bone allografts have previously been shown to better maintain structural and biological properties compared to terminally irradiated counterparts.[1,2] It is also well-established that the osteoinductive properties of demineralized bone matrices (DBMs) can vary between manufacturers due to various factors including processing methods and terminal sterilization.[3,4] Despite the evidence that it adversely impacts tissue quality, γ-irradiation is still commonly used to sterilize DBMs in the marketplace. More recently, E-beam irradiation has emerged as an alternative to γ-irradiation sterilization for allograft tissues with the potential of causing less degradation due to a faster dose rate. However, the effects of terminal E-beam on DBM properties have not been well-characterized and directly compared to those caused by terminal γ-irradiation.

Materials and Methods: Commercial aseptically processed DBM fibers (control) were donor-matched (N=3 lots) and optionally treated with 25kGy of γ/E-beam irradiation. Changes to collagen matrix structure were investigated by scanning electron micrography (SEM). Matrix stability was assessed by evaluating the susceptibility of irradiated samples to enzyme degradation by measuring the percentage of tissue remaining following collagenase digestion. Matrix stability was secondarily assessed by measuring total protein loss and remaining collagen protein using a BCA Protein Assay and a Sirius Red collagen staining kit. The proportion of BMP-2 retention was also measured using ELISA. One-way ANOVA with Dunnett's post-hoc test was used to compare the differences between treatments.

Results: Structural changes to gamma and E-beam irradiated DBM fibers compared to non-irradiated samples were observed by SEM (**Figure 1A-C**). Both terminal irradiation methods resulted in altered matrix stability, with increased susceptibility to enzyme degradation and protein loss over time. Gamma-irradiated DBMs samples trended ($p=0.0752$) towards less residual tissue following enzyme treatment, while the E-beam irradiated samples showed significantly less tissue ($p<0.05$) compared to non-irradiated ones (**Figure 1D&E**). Protein loss and remaining collagen further corroborated these results whereby total protein released rapidly from and E-beam irradiated samples ($p<0.05$) (**Figure 1F**), and the remaining collagen was significantly retained in the non-irradiated samples compared to both irradiation modalities ($p<0.05$) (**Figure 1G**). Preliminary results indicated that BMP-2 elution at 24 hr was also undesirably rapid for all irradiated samples (**Figure 1H**).

Conclusion: This study suggests that terminal E-beam irradiation may change collagen structure and matrix stability compared to non-irradiated controls and may not offer any significant benefit compared to terminal gamma irradiation. Optimal biologic performance of DBMs requires maintenance of the extracellular matrix, which not only provides a structural role supporting cell adhesion, but also plays an essential role in retaining and providing osteoinductive growth factors such as BMPs. This work indicates that terminal irradiation may impact the ability of DBMs to retain critical bone-forming proteins throughout the bone

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healing process, which may ultimately affect their ability to lead to new bone formation and successful fusion.

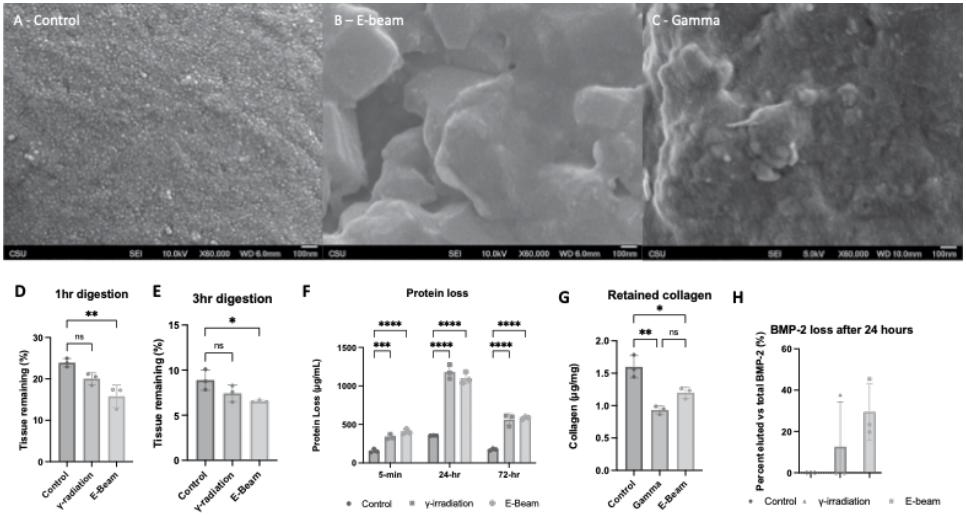

Figure 1: SEM images of (A) control (non-irradiated), (B) E-beam irradiated, and (C) γ-irradiated DBM, (D) quantification of enzyme degradation after 1hr, (E) after 3hr, (F) quantification of total protein eluted, (G) quantification of total retained collagen following elution and (H) percent of released BMP-2 to total BMP-2 extracted. Significance assessed at *p<0.05, **p<0.01, ***p<0.001, ****p<0.0001.

POSTER 51

Effect of Thoracic Inlet Angle on Cervicothoracic Parameters and Patient Reported Outcomes in Posterior Multi-Cervicothoracic Fusion

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Introduction: Thoracic Inlet Angle (TIA) is created by the intersection of a line from the tip of the sternum to the midpoint of the superior T1 endplate and a line perpendicular to the superior T1 endplate . This radiographic parameter is constant and independent of posture and has been significantly correlated with cervical sagittal balance. The purpose of this study was to investigate the effect of TIA on other cervicothoracic parameters and patient reported outcomes (PROs) in patients undergoing multi-level posterior cervicothoracic fusions with a caudal end of C7, T1 or T2.

Materials and Methods: Retrospective, multi-center analysis of patients undergoing multilevel posterior cervicothoracic fusions terminating at C7, T1 or T2. Basic demographic data was collected, along with PROs (Oswestry Disability Index [ODI] and pain Visual Analog Scale [VAS] at intermittent intervals from preoperative to two years postoperative. Radiographic parameters (TIA, Cervical Lordosis, T1 Slope, Cervical Sagittal Vertical Alignment [cSVA]) were also measured at these intervals.

Results: 257 patients were included in this analysis. Mean age was 62.6 ± 13.4 years with a mean BMI of 28.5 ± 6.6 and 68.5% female. 57% were never smokers, 32.1% were former smokers and 10.9% were current smokers. From preop to 2years postop, there was a 2.3% change in TIA, 17.2% change in cervical lordosis, 14.1% change in T1 slope and 34.9% change in cSVA. VAS and ODI saw 31.2% and 17.2% improvement, respectively, over this time frame. There was a strong positive correlation between TIA and T1 slope at both pre (r^2=56.4) and 2 years postop (r^2=58.4). Similar findings were observed between TIA and cSVA at pre (r^2=58.3) and 2 years postop (r^2=63.4). Weak positive correlations were observed between TIA and cervical lordosis, and PROs (VAS and ODI) and TIA at pre and 2 years post.

Conclusion: As expected, TIA remained essentially unchanged from pre- to post-op. That said, strong positive correlations were found between TIA and T1 slope and TIA and cSVA at preoperative and 2 years postoperative. The findings of this analysis support the relationship of TIA and cervical sagittal alignment demonstrated in previous studies. Additionally, weak positive correlations between TIA and cervical lordosis and TIA and patient reported outcomes were also found. Current data suggest that surgical goals include achievement of reasonable sagittal balance. More static measures such as TIA and more potentially variable measures such as T1 slope should be considered when planning a posterior cervical reconstruction.

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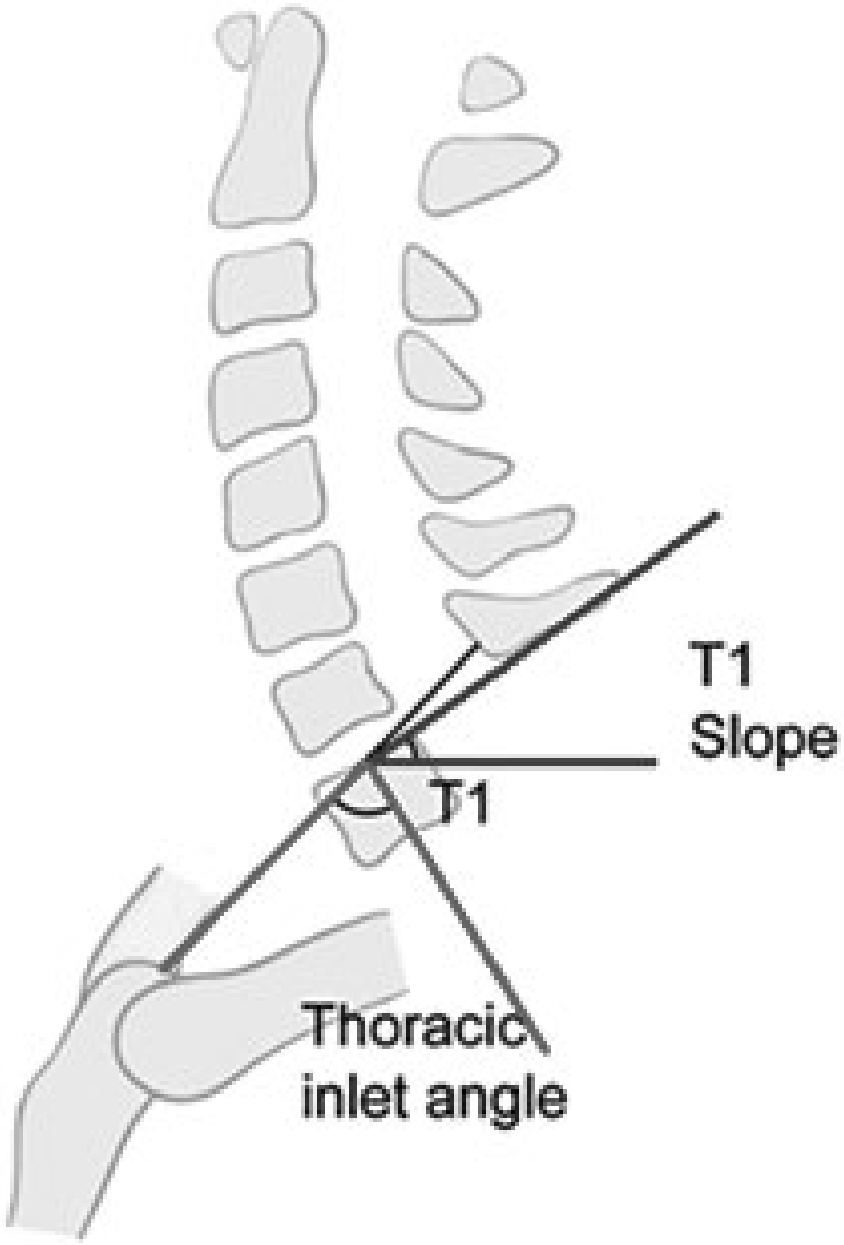

POSTER 52

Comparison of Outcomes of Ambulatory versus In-Hospital Cervical Disc Replacement

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Introduction: Cervical disc replacement (CDR) is being increasingly performed at ambulatory surgical centers (ASCs), but a comparison of outcomes of inpatient and ambulatory CDR has not been studied. The objective of this study is to evaluate perioperative, complication, and clinical outcome data for patients undergoing elective CDR in the ambulatory versus inpatient setting.

Materials and Methods: A retrospective chart review was performed to identify patients undergoing elective CDR and patients were grouped into ASC or In-Hospital groups. Data regarding patient background and comorbidities, surgical data, and clinical outcome data were obtained. Specific outcomes of interest included Visual Analog Scale-Neck Pain (VAS-NP), VAS-Arm Pain (VAS-AP), Neck Disability Index (NDI), 12-Item Veterans Rand Health Survey Physical and Mental Composite Score (VR-12 PCS/MCS), Patient-Reported Outcome Measurement Information System-Physical Function (PROMIS-PF), and the Patient-Health Questionnaire-9 (PHQ-9). Outcome surveys were completed as standard of care preoperatively and up to two years postoperatively (average follow-up: 14.7 ± 8.9 months). Rates of minimum clinically important difference (MCID) rates were determined by group. Postoperative clinical outcomes and MCID achievement rates were compared between groups using multivariate regression to account for baseline differences in comorbidity burden between groups.

Results: The chart review yielded 293 patients meeting inclusion criteria, with 262 in the ASC group. Patients in the In-Hospital group had higher average body mass indices (BMIs) and were more likely to have an American Society of Anesthesiologist score >2 ($p \leq 0.010$, both). The estimated blood loss and postoperative day 0 narcotic consumption were greater for the In-Hospital group ($p \leq 0.001$, both). There was a higher rate of postoperative urinary retention in the In-Hospital group ($p=0.004$), but no difference in other post-surgical complication rates. Two patients in the ASC group required subsequent hospitalization; one had seizure-like symptoms likely secondary to preoperative illicit substance use, and one patient developed aphasia, likely due to a medication side effect. There was no difference in preoperative patient-reported outcomes ($p \geq 0.105$, all). The ASC group reported lower VAS-AP six weeks postoperatively ($p=0.002$). By final follow-up, the ASC group reported inferior VR-12 PCS, but superior NDI and VAS-AP scores relative to the In-Hospital group ($p \leq 0.043$, all). The In-Hospital group reported significantly greater improvement in PHQ-9 scores by six weeks postoperatively ($p<0.001$). However, there was no difference in magnitude of improvement by final follow-up or in MCID achievement rates between groups ($p \geq 0.135$, all).

Conclusion: Patients undergoing inpatient CDR tended to have higher BMIs and comorbidity burdens. The complication rates in different surgical settings were largely similar. When controlling for differences in baseline health, patients undergoing ambulatory CDR reported superior postoperative arm pain scores, better disability, but worse physical health by final follow-up. The In-Hospital group reported greater early mental health improvements postoperatively.

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Table 1. Demographic and perioperative characteristics

Characteristic	Total (n = 293)	In-Hospital (n = 31)	ASC (n = 262)	*p-value
Age (years)	47.9±10.4	49.2±9.7	47.7±10.5	0.422
Male	62.4% (183)	61.3% (19)	62.6% (164)	0.887
BMI (kg/m^2)	28.9±5.8	31.6±8.1	28.6±5.4	**0.008**
Ethnicity				0.748
Black	9.2% (26)	10.0% (3)	9.1% (23)	
Asian	2.8% (8)	3.3% (1)	2.8% (7)	
Hispanic	8.8% (25)	13.3% (4)	8.3% (21)	
White	76.1% (216)	73.3% (22)	76.4% (194)	
Other	3.2% (9)	0.0% (0)	3.5% (9)	
Comorbidities				
Smoker	8.2% (24)	12.9% (4)	7.7% (20)	0.315
Hypertension	17.5% (51)	22.6% (7)	16.9% (44)	0.434
Diabetes	6.5% (19)	12.9% (4)	5.7% (15)	0.125
ASA Classification				**0.010**
≤2	85.6% (232)	70.0% (21)	87.6% (211)	
>2	14.4% (39)	30.0% (9)	12.5% (30)	
Insurance Type				0.771
Medicare/Medicaid	2.4% (7)	3.2% (1)	2.3% (6)	
Workers' Comp	24.2% (71)	19.4% (6)	24.8% (65)	
Private	73.4% (215)	77.4% (24)	72.9% (191)	
Number of instrumented levels				0.232
One	80.1% (222)	70.8% (17)	81.0% (205)	
Two	19.9% (55)	29.2% (7)	19.0% (253)	
Operative Time (min.)	52.0±19.6	55.1±38.0	51.6±16.0	0.358
Estimated Blood Loss (mL)	26.1±5.5	33.5±13.6	25.4±3.2	**<0.001**
Length of Stay (hours)	7.3±4.8	14.6±9.5	6.4±2.8	**<0.001**
POD 0 VAS Pain	4.8±2.1	4.8±1.8	4.8±2.2	0.981
POD 0 Narcotic Consumption (OME)	20.8±15.1	38.6±22.8	18.7±12.3	**<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

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

Boldface indicates significance ($p<0.05$).

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Table 2. Post-Surgical Complications

Complication	Total (n = 293)	In-Hospital (n = 31)	ASC (n = 262)	*p-value
Acute Renal Failure	–	–	–	
Altered Mental Status	–	–	–	
Anemia, postoperative	–	–	–	
Arrhythmia	–	–	–	
Aspiration/Re-intubation	–	–	–	
Atelectasis	–	–	–	
Dysphagia	0.4% (1)	0.0% (0)	0.4% (1)	0.730
Epidural Hematoma	–	–	–	
Fever of Unknown Origin	–	–	–	
Ileus	–	–	–	
Incontinence, urinary	–	–	–	
Nausea/Vomiting	1.4% (4)	0.0% (0)	1.6% (4)	0.487
Pleural effusion	–	–	–	
Pneumonia	–	–	–	
Pulmonary Embolism	–	–	–	
Respiratory Distress	–	–	–	
Urinary Retention	0.4% (1)	3.3% (1)	0.0% (0)	**0.004**
Urinary Tract Infection	–	–	–	
Venous Thromboembolism	–	–	–	

Boldface indicates significance

*p-value determined through Chi-square analysis

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

	Total (n = 293)	In-Hospital (n = 31)	ASC (n = 262)	*p-value
Pre-Op				
VR-12 MCS	51.4±11.8	47.5±13.4	52.1±11.5	0.113
VR-12 PCS	36.1±9.8	32.9±10.3	36.6±9.7	0.118
PROMIS-PF	40.4±7.1	38.6±6.2	40.6±7.2	0.301
PHQ-9	6.2±5.5	7.8±6.3	6.0±5.3	0.140
VAS-NP	6.2±2.3	6.9±2.2	6.1±2.3	0.118
VAS-AP	5.7±2.5	6.3±2.3	5.6±2.6	0.245
NDI	37.8±18.5	43.7±18.7	36.9±18.4	0.105
6-week Post-Op				
VR-12 MCS	55.6±10.3	57.6±5.1	55.4±10.7	0.401
VR-12 PCS	42.4±10.3	43.7±8.8	42.2±10.5	0.452
PROMIS-PF	45.7±8.0	45.1±5.1	45.8±8.3	0.965
PHQ-9	4.2±5.0	3.3±6.4	4.3±4.8	0.378
VAS-NP	2.9±2.5	4.0±3.5	2.7±2.4	0.154
VAS-AP	2.4±2.8	4.7±3.7	2.1±2.5	**0.002**
NDI	24.3±19.6	32.0±28.5	23.4±18.2	0.171
Final Post-Op				
VR-12 MCS	55.4±11.4	50.6±13.2	56.1±11.0	0.131
VR-12 PCS	46.8±19,2	49.9±12.3	47.8±9.5	**0.041**
PROMIS-PF	49.5±9.4	44.1±8.2	50.3±9.3	0.058
PHQ-9	3.8±5.0	5.5±6.3	3.5±4.7	0.140
VAS-NP	2.5±2.4	3.3±2.4	2.2±2.4	0.071
VAS-AP	2.0±2.6	3.3±2.9	1.8±2.5	**0.043**
NDI	16.9±17.4	29.0±21.7	15.1±16.0	**0.002**
Δ Pre-Op to 6-week Post-Op				
VR-12 MCS	11.1±5.2	8.5±12.6	11.4±9.8	0.752
VR-12 PCS	5.5±10.3	8.9±9.6	5.1±10.4	0.423
PROMIS-PF	4.7±8.0	6.5±4.4	4.4±8.4	0.397
PHQ-9	2.0±4.8	6.5±6.3	1.4±4.3	**<0.001**
VAS-NP	3.0±2.8	3.2±3.0	3.0±2.8	0.693
VAS-AP	3.0±3.4	2.1±4.2	3.1±3.3	0.318
NDI	12.1±16.1	17.3±17.9	11.5±15.9	0.244
Δ Pre-Op to Final Post-Op				
VR-12 MCS	3.9±11.5	4.4±14.2	3.8±11.1	0.747
VR-12 PCS	9.7±10.7	7.5±12.8	10.0±10.4	0.617
PROMIS-PF	9.5±9.4	8.3±6.4	9.7±9.7	0.814
PHQ-9	2.4±4.9	3.1±8.3	2.3±4.1	0.546
VAS-NP	3.6±2.9	3.6±2.6	3.6±3.0	0.868
VAS-AP	3.3±3.4	2.9±3.8	3.4±3.4	0.852
NDI	20.2±17.8	17.1±21.6	20.7±17.3	0.585
MCID Achievement				
VR-12 MCS	30.4% (34)	35.7% (5)	29.6% (29)	0.641
VR-12 PCS	75.9% (85)	78.6% (11)	75.5% (74)	0.802
PROMIS-PF	78.8% (93)	78.6% (11)	78.9% (82)	0.981
PHQ-9	18.2% (24)	5.6% (1)	20.2% (23)	0.135
VAS-NP	73.5% (100)	77.8% (14)	72.9% (86)	0.661
VAS-AP	45.0% (58)	38.9% (7)	46.0% (51)	0.577
NDI	77.6% (104)	72.2% (13)	78.5% (91)	0.555

*p-value calculated using Student's t-test 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 medical device he or she wishes to use in clinical practice.

POSTER 53

Twenty-four-month Assessment of Arthrodesis in a Prospectively Enrolled Cohort of 50 Subjects Treated with ACDF at 3 Levels

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Strenge Spine Center[1] Pinehurst Surgical Clinic[2] Spine Institute of Louisiana[3] Inspira Health Network[4] Thomas Jefferson University[5] Providence Medical Technology[6] UCSF[7]

Introduction: When performing an anterior cervical discectomy and fusion (ACDF), achieving solid arthrodesis helps ensure sustained relief of symptoms from disc degeneration. The rate of successful arthrodesis has been well established in 1- and 2-level ACDF[1], however, no level-1 evidence describing outcomes following 3-level treatment has yet been published. The purpose of this analysis is to describe comprehensive radiographic outcomes derived from both dynamic x-ray and thin slice CT in a cohort of prospectively enrolled subjects treated with ACDF at 3 levels as part of the control arm for an IDE clinical trial.

Materials and Methods: Subjects were recruited from 19 sites with enrollment beginning in May 2020 and concluding in June 2023. All subjects had myeloradicular symptoms from degenerated discs at 3 contiguous levels between C3 and C7 surgically treated with ACDF. Fusion success was dependent on all treated levels exhibiting both segmental range of motion (ROM) <2º and contiguous interbody bridging bone (IBB). Radiographic outcomes were determined by an independent lab at 12 and 24 months following treatment. Subjects requiring surgical re-intervention prior to the month 24 visit were considered a fusion failure, however they did not contribute to the summaries of component outcomes (ROM and IBB).

Results: Outcomes were available for 50 of the 57 treated subjects (age=58.6 years, BMI=31.3kg/m^2, 56% female). Fusion across all three segments was achieved in 18 subjects (36%). Thirteen (13) subjects (26%) required surgical re-intervention prior to study conclusion with 11 for treatment of symptomatic pseudarthrosis. Of the 37 subjects not requiring re-intervention, 15 (41%) failed at one level and 4 (11%) failed at two levels. No subjects had failure at all three levels. A segmental ROM of ≥2º for at least one level was observed in 15 subjects (37% of subjects not revised), where IBB was absent for at least one level in 19 subjects (49% of subjects not revised). Of the subjects with complete fusion assessed at month 24, 7 (39%) had achieved success by the earlier month 12 visit. There was one subject deemed a fusion success at month 12, that failed month 24 (IBB across all three levels, ROM <2º at two levels).

Conclusion: To the authors' knowledge, this study is the first level 1 evidence assessing radiographic outcomes in patients treated with 3-level ACDF. When followed through 24 months, subjects treated with ACDF had a high incidence of revision. Less than half of the subjects treated achieved complete fusion, with most of those subjects only reaching that status between 12 and 24 months after treatment. Further analyses need to be done to understand how these radiographic outcomes manifest in clinical relief of initial complaints.

POSTER 54

Severe Paresthesia at 1-year After Surgery for Degenerative Cervical Myelopathy Could Relate with the Significantly Lower Treatment Satisfaction Independent from the Improvement of Myelopathy

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Osaka Metropolitan University[1]

Introduction: Surgery for degenerative cervical myelopathy (DCM) aims to improve and/or prevent further deterioration of the patient's myelopathy, physical function and quality-of-life (QOL) [1, 2]. However, patients seem to be not satisfied with their treatment for myelopathy when they have severe residual paresthesia, even when their myelopathy and QOL are improved after surgery. Current study aimed to identify the incidence of residual paresthesia after surgery for DCM, and to demonstrate the impact of these symptoms on clinical outcomes and patient's satisfaction.

Materials and Methods: This is multi-center, retrospective cohort study in Japan. In total, 290 patients who underwent laminoplasty for DCM were included. Patients were divided into two groups based on their Visual analog scale (VAS) score for paresthesia of the upper extremities at 1 year postoperatively: the severe paresthesia group and no/mild paresthesia group. The severe paresthesia group included patients with a VAS score for paresthesia of >40 mm, and the no/mild paresthesia group included patients with a VAS score of ≤40 mm. Preoperative factors, change in clinical scores (JOA scores, VAS of upper extremity paresthesia, VAS of neck pain, NDI, EQ-5D-5l, SF-36 and JOACMEQ) , radiographic factors (cervical sagittal vertical axis, C2-C7 angle, and C2-7 range of motion), and 5 graded satisfaction scales at 1 year postoperatively were compared between groups.

Results: Overall, 128 of 290 patients had severe residual paresthesia at 1 year postoperatively. Preoperative patient-oriented pain scale scores were significantly associated with postoperative residual paresthesia, independently from age, severity of preoperative paresthesia and other preoperative clinical scores (p=0.032). Mixed-effect model demonstrated that patients with severe postoperative residual paresthesia showed significantly smaller improvements in JOACMEQ QOL (p=0.046), PCS of SF-36 (p=0.041) and JOA score (p=0.037) than patients with no/mild residual paresthesia. In terms of the treatment satisfaction, there was significant difference in treatment satisfaction between the two groups; 76.2% and 54.7% of patients in the no/mild paresthesia and severe paresthesia groups, respectively, were satisfied with the treatment (p=0.002). Logistic regression analysis identified that residual paresthesia was significantly correlated with the lower treatment satisfaction, independently from improvements in JOA score and JOACMEQ QOL (adjusted odds ratio: 2.5, p=0.010).

Conclusion: Surprisingly, 44% of patients with DCM showed severe residual paresthesia at 1 year postoperatively. These patients showed significantly worse treatment satisfaction, even after adjusting for improvements in myelopathy and QOL. As such patients were demonstrated higher preoperative pain, multidisciplinary approach for residual paresthesia including medications for neuropathic pain might be important to tackling this situation.

POSTER 55

Changes in Fat Infiltration of Cervical Paraspinal Muscles after Anterior Cervical Discectomy and Fusion

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Hospital for Special Surgery[1]

Introduction: Increasing research is being conducted on how cervical foraminal stenosis affects cervical paraspinal muscles, which are clinically important. It has been shown that increased severity of this condition is associated with higher fat infiltration (FI) of the cervical multifidus and rotatores. Loss of motor innervation of these muscles in foraminal stenosis can trigger physiologic changes leading to muscle atrophy and FI. Increased FI is associated with sensorimotor deficits, clinical disability, and lower scores on health-related quality of indices. Anterior cervical discectomy and fusion (ACDF) is used to treat foraminal stenosis. It is hypothesized that this procedure's restoration of spinal nerve function could also contribute to reversal of paraspinal muscle atrophy. Therefore, this study investigated how FI of the multifidus and rotatores changes after ACDF surgery.

Materials and Methods: We reviewed patients who underwent ACDF between 2015 and 2018 and had preoperative and postoperative cervical imaging performed (postoperative period being 1-5 years after surgery). For each patient, the upper level was defined as the most superior segment that was fused in their ACDF surgery and the lower level was defined as the most inferior segment that was fused. The muscles were segmented bilaterally at the midvertebral points of the upper and lower levels using axial T2-weighted MRI scans. A custom software calculated the area above and below a certain pixel intensity threshold for each segmentation. The area above was considered fat (intramuscular fat = FAT) and the area below was considered muscle (functional cross-sectional area = fCSA). The software also calculated the total muscle area (cross-sectional area = CSA = fCSA + FAT). The FI was then determined using the formula FI = (FAT/CSA)*100. Preoperative FI was compared with the postoperative FI at the upper and lower levels using paired t-test or Wilcoxon signed rank test dependent on distribution. A significance level of 0.05 was used.

Results: A total of 36 patients (median age 57 years; 40.0% females) met inclusion criteria. There was a significant decrease (52.1% vs 45.0%, $p = 0.013$) in FI at the lower level and no significant change (36.7% vs 36.2%, $p = 0.858$) at the upper level from the preoperative to the postoperative period.

Conclusion: Results showed a significant decrease in FI of the multifidus and rotatores at the lower level and no significant change at the upper level. FI in cervical foraminal stenosis is hypothesized to occur secondary to nerve compression and resulting muscle denervation. ACDF surgery alleviates nerve compression, potentially reversing FI and muscle atrophy at the lower level, suggesting it addresses both pathological changes in the cervical spine and in cervical paraspinal muscles that can contribute to clinical disability. Follow-up studies can assess whether there is a more prominent change in FI after a longer postoperative period.

POSTER 56

Anterior Cervical Discectomy and Fusion: Incidence and Outcomes in Ehlers-Danlos Syndrome

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Oregon Health and Science University[1]

Introduction: Ehlers Danlos syndrome (EDS) is an inherited connective tissue disorder that often manifests with tissue hypermobility. Weakened tissue integrity seen in EDS heightens the risk of joint and soft tissue injuries, potentially increasing the need for cervical spine surgery and affecting surgical results. Additionally, EDS is often linked to chronic pain, which may complicate post-operative pain management.

This study seeks to evaluate the frequency and outcomes of anterior cervical discectomy and fusion (ACDF) in patients with EDS compared to the general population, focusing specifically on post-operative opioid use and revision rates. Determining the impact of EDS on surgical outcomes has potential to lead to more efficacious, risk-stratified spine care in these patients.

Materials and Methods: A retrospective review was conducted using the PearlDiver database for the years 2016-2020 on adults aged 25-75 who underwent ACDF. Patients were stratified into two groups: those with EDS and those without EDS. Primary outcomes were post-operative opioid use and revision rates. Opioid use metrics were 1) average MME (Morphine Milligram Equivalents) within the 90-day postoperative period and 2) percentage of patients belonging to either low- or high-opioid use groups. Low opioid use was defined as no use or discontinuation within 90 days post-ACDF, while high opioid use was defined as continued use beyond 365 days.

ACDF incidence and mean age at surgery were compared between EDS and control groups. Outcome analysis was conducted on propensity score-matched groups (3:1 ratio of controls to EDS patients), adjusting for variables including age, gender, osteoporosis, diabetes, and tobacco use. Revisions were tracked using CPT codes to identify any cervical surgery performed ≥30 days post-initial ACDF. T-tests were employed to analyze continuous variables (age and MME), while contingency table analysis was used to examine the outcome rates. Additionally, a 5-year Kaplan-Meier Survival Analysis was conducted to compare the revision-free survival rates between the two groups.

Results: Demographics: ACDF incidence was higher in EDS patients compared to controls (RR = 4.25, CI = 3.77-4.78, $p<0.01$). Age at ACDF was younger in EDS patients (54.3±8.2 vs 60.7±9.1, $p<0.01$) and a higher proportion of EDS patients requiring ACDF were female compared to controls (89.6% vs 52.6%, $p < 0.01$).

Outcomes: EDS patients required greater amounts of opioids within 90 days post-ACDF compared to controls (921.5±1160.2 vs 778.6±976.9, $p<0.01$). EDS patients were more likely than controls to demonstrate high-opioid-use (RR = 1.2, 1.07-1.36, $p<0.01$), and less likely to demonstrate low-opioid-use (RR = 0.79, CI = 0.66-0.95, $p<0.05$). EDS patients also had a higher rate of revision fusions (RR = 1.84, CI = 1.22-2.78, $p<0.01$). The Kaplan-Meier Survival Analysis demonstrated a significantly higher 5-year probability of revision fusions post-ACDF in EDS (8.9%) versus controls (4.9%, $p<0.05$).

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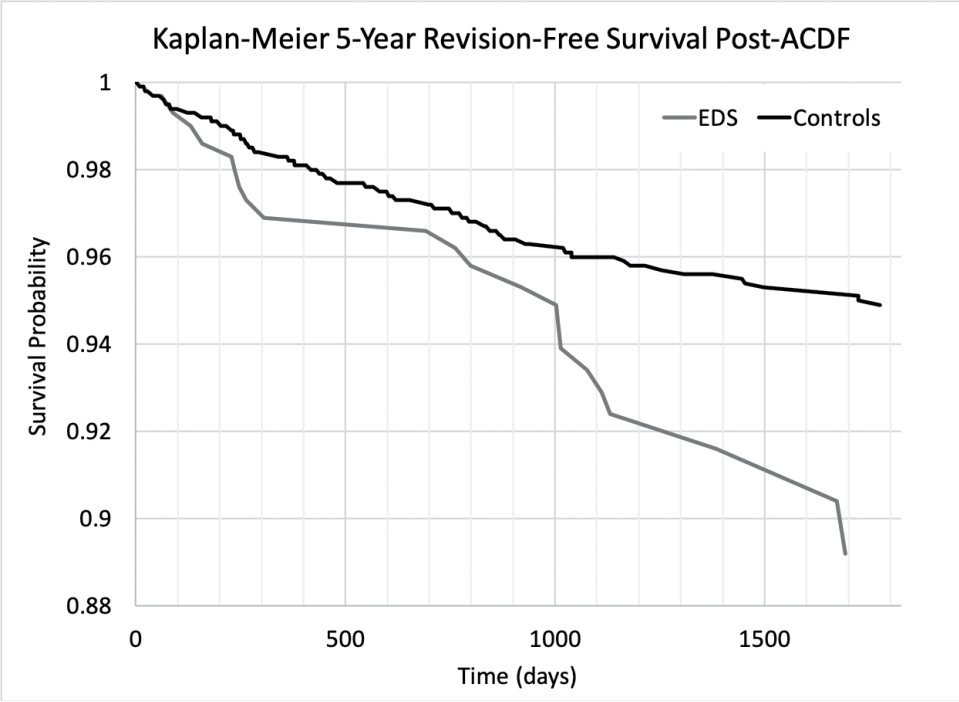
Conclusion: Patients with EDS have a higher risk of requiring ACDF and may experience less favorable outcomes, evidenced by higher rates of opioid use and revision surgeries. These results emphasize the need for the development of risk-stratified guidelines tailored for the spinal care of EDS patients, as well as the importance of thorough discussions regarding post-operative expectations and outcomes.



POSTER 57

The Effect of Hybrid Cervical Disc Arthroplasty and Anterior Cervical Fusion Constructs on Adjacent Level Intradiscal Pressures: A Biomechanical Study

***Anthony Viola, DO*[1]**, *Raghunandan Nayak, BS*[1], *Elifho Obopilwe, MS*[1], *Ajitha Chivukula, BS*[1], *Scott Mallozzi, MD*[1], *Isaac Mossimoss, MD*[1], *Hardeep Singh, MD*[1]
University of Connecticut[1]

Introduction: Anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA) are commonly performed to address various cervical pathologies including cervical radiculopathy and/or myelopathy. Biomechanical studies have demonstrated increased disc pressures in levels adjacent to ACDF and linked this to the development of adjacent segment degeneration (ASD). There is a paucity of research focusing on investigating the effects of hybrid CDA and ACDF constructs on adjacent discs. The goal of this study was to assess the effects of a hybrid construct (CDA with 1-, 2-, or 3-level ACDF) on the intradiscal pressures immediately adjacent to the construct during cervical range of motion.

Materials and Methods: Six fresh-frozen cervical spine specimens, stabilized at T1 and loaded at C2, were utilized. The specimens were tested in the native condition, with CDA at C6-7, and 3 subsequent conditions consisting of a hybrid construct of CDA at C6-7 and ACDF at C5-6, C4-6, and C3-6. Intradiscal pressure sensors were inserted into the disc above and below the construct. Peak pressures were measured at 15 degrees of flexion, extension, and lateral bending for three cycles. Changes in intradiscal pressure are reported as percent change compared to the baseline intradiscal pressures of the native spine. The testing protocol was repeated for each condition. Statistically significant differences in pressures were calculated using analysis of variance with post-hoc Tukey analysis ($p < 0.05$).

Results: The intradiscal pressure immediately above the construct including CDA with a 2- and 3- level ACDF was significantly increased during flexion (249%, 572%, $p < 0.05$). The intradiscal pressure immediately above the construct including CDA with a 3-level ACDF was significantly increased during left and right lateral bending (268% and 284%, $p < 0.05$). No significant change in the intradiscal pressure in the disc above was noted during extension in any of the constructs. The intradiscal pressures in the disc above the construct did not change significantly in the CDA alone or CDA with adjacent 1-level fusion during motion in any direction.

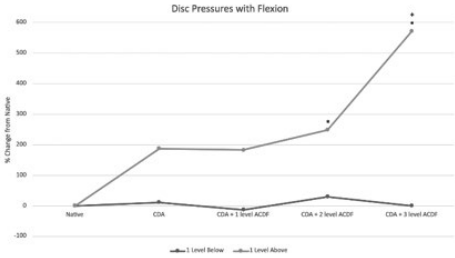
The intradiscal pressure did not significantly increase in the disc below in any of the hybrid constructs. The intradiscal pressure significantly decreased in the disc below the constructs including CDA and 1- and 3-level ACDFs (-53%, –58%, $p < 0.05$) during extension. The intradiscal pressure significantly decreased in the disc below the construct including CDA with 2-level ACDF (-61%, $p < 0.05$) during left lateral bending.

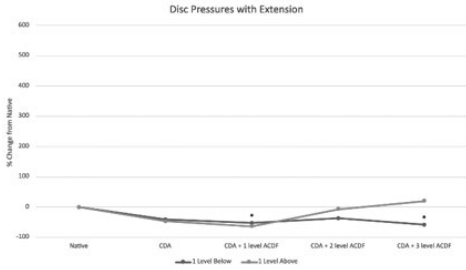
Conclusion: Biomechanical studies have demonstrated increased intradiscal pressures adjacent to ACDF during flexion. This study showed increased intradiscal pressures in levels adjacent to hybrid CDA and ACDF constructs during flexion above a 2- or 3-level fusion and above a 3- level fusion in lateral bending. Intradiscal pressures above CDA alone or CDA with 1-level fusion did not significantly increase. The pressures in the level below the CDA did not significantly increase in any condition. These findings suggest that the addition of a CDA below a fusion construct may reduce ASD by protecting adjacent levels from increased intradiscal pressures during normal motion.

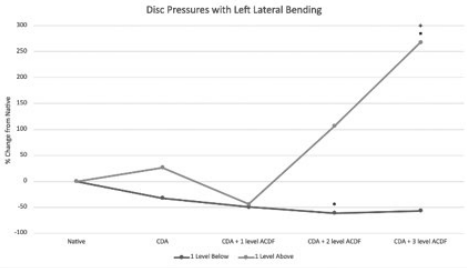
POSTER 57 continued

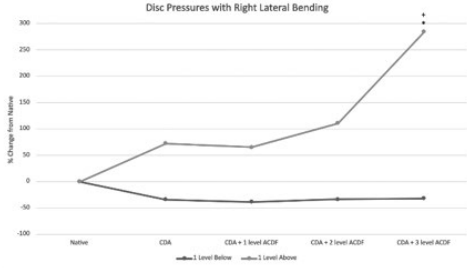
Individual Disclosures can be found in the Disclosure Index pages 16-24.
Papers are numbered based on their presentation date and time, which may be found on pages 9-15. Virtual Posters are listed after podium presentations

POSTER 57 continued









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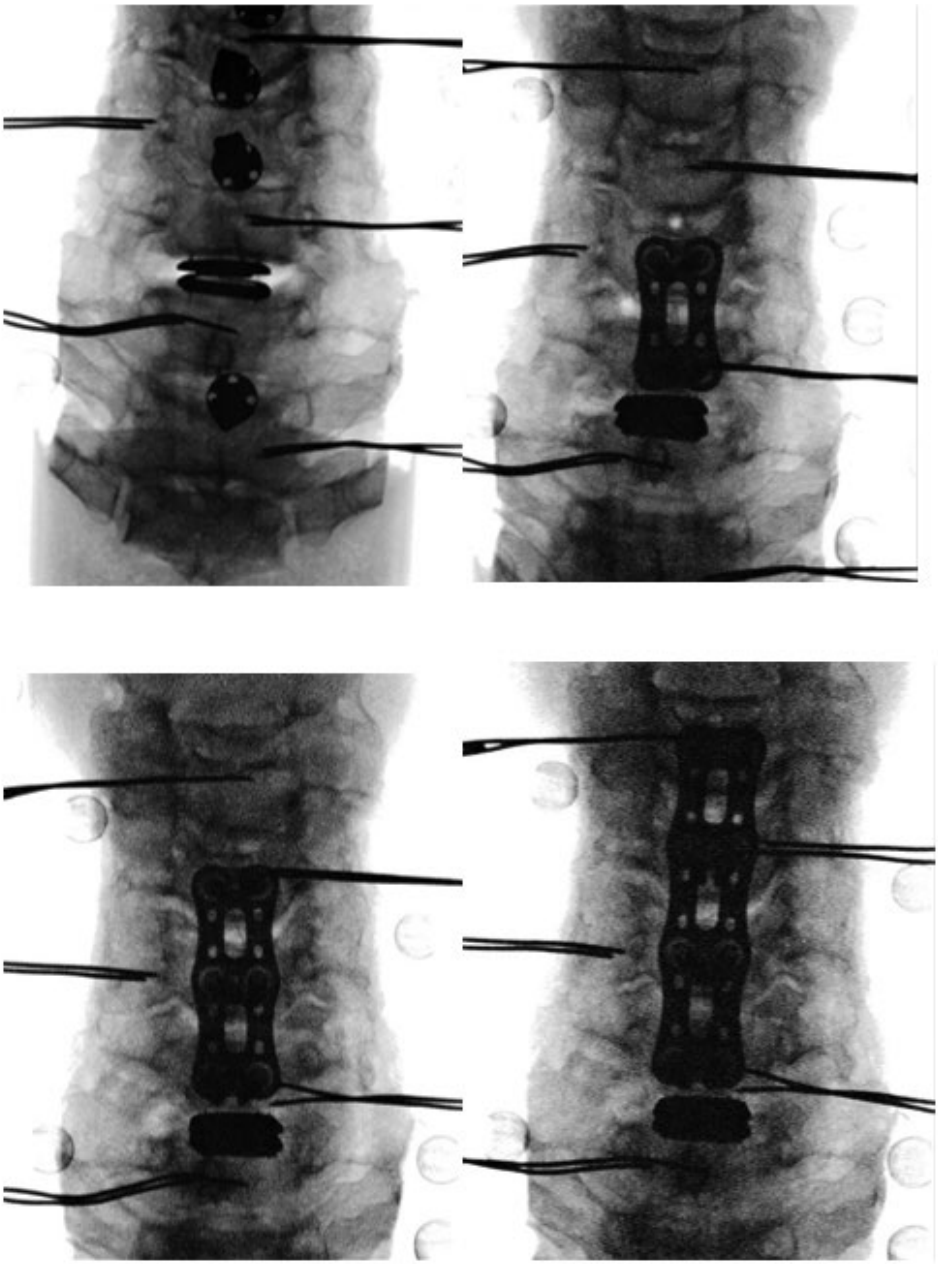

POSTER 58

Sarcopenia and Cage Subsidence after Single Level Anterior Cervical Discectomy and Fusion

Jesse Wang, MD[1], *Jasraj Raghuwanshi, BS*[1], *Kamran Arastu, BS*[1], *Lawal Labaran, MD*[1], *Jialun Chi, BS*[1], *Stephen Lockey, MD*[1], *Xudong Li, MD, PhD*[1]
University of Virginia[1]

Introduction: Sarcopenia is an age-related progressive loss of skeletal muscle mass and function and has been associated with increased complication rate, length of stay and mortality after spine surgeries (1). Anterior Cervical Discectomy and Fusion (ACDF) is a commonly performed procedure for cervical disc degeneration. A major potential complication of ACDF is cage subsidence, which is the loss of intervertebral height. This can potentially result in sagittal malalignment, pseudoarthrosis, and restenosis of the cervical foramina. A number of factors, including bone mineral density, cage material, and cage placement, are known to influence the risk of subsidence (2), but the role of sarcopenia is unknown. This study aims to investigate the relationship between sarcopenia and incidence of cage subsidence following single level ACDF surgery.

Materials and Methods: A retrospective review of patients undergoing single-level ACDF between 2017-2023 was performed. Exclusion criteria include revision surgeries, surgeries with additional procedures, or surgeries with indications involving infection, neoplasm or metabolic bone diseases. Sarcopenia was defined by evaluating fatty infiltration of the axial cuts of T2-weighted MRI images of the multifidus muscle at C5-6 using the modified Goutallier classification. Sarcopenia was graded as mild (Goutallier 0,1), moderate (Goutallier 2), or severe (Goutallier 3,4). Cage subsidence was calculated by first measuring intervertebral body height (IVH) represented as an average of anterior, middle and posterior IVH normalized to vertebral body length (VBL) **Figure 1**. The difference between IVH on postoperative day 0 and most recent follow up was then calculated and represented as a percentage height loss. Three independent reviewers performed blinded assessment of sarcopenia grading and measurement of cage subsidence, and the results were aggregated. Other variables including cage material, patient demographics and comorbidities were also collected from the electronic medical record.

Results: 50 patients met inclusion criteria during the study period. The average time for follow-up was 358 days. Sarcopenia was grouped into mild (36 patients), moderate (8 patients), and severe (6 patients). Patients with mild sarcopenia noted 5.9% reduction in IVH, compared to 15% in moderate and 19.8% in severe group **Figure 2**. There was no statistically significant difference in cage subsidence between the mild and moderate sarcopenic group ($p = 0.73$), however, there was statistically significant increase in subsidence between the mild and severe group ($p = 0.004$). Regarding cage material, 42% used PEEK cages, 32% used titanium, and 26% used allograft. No difference was noted between the degree of height loss in terms of cage material (PEEK 10.7%, titanium 10.8%, allograft 7.07%; $p = 0.69$). Smokers had average 13.4% subsidence compared to nonsmokers at 8.9%, though this did not reach statistical significance ($p = 0.12$). When comparing comorbidities, there was no difference in rate of hypertension, sleep apnea, coronary artery disease or chronic kidney disease between the three sarcopenia groups.

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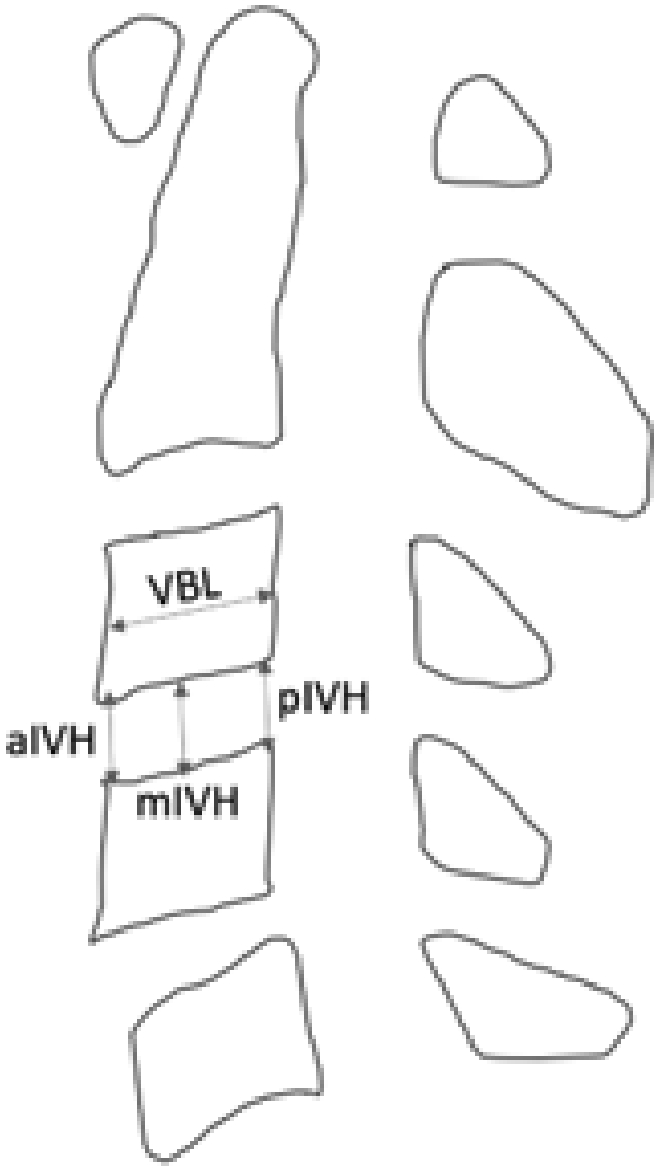
Conclusion: Patients with severe sarcopenia demonstrated higher degree of cage subsidence following single level ACDF. No difference was noted for cage material regarding subsidence. Spine surgeons should consider screening patients for sarcopenia preoperatively and counsel them regarding their increased risk of postoperative complications following ACDF.



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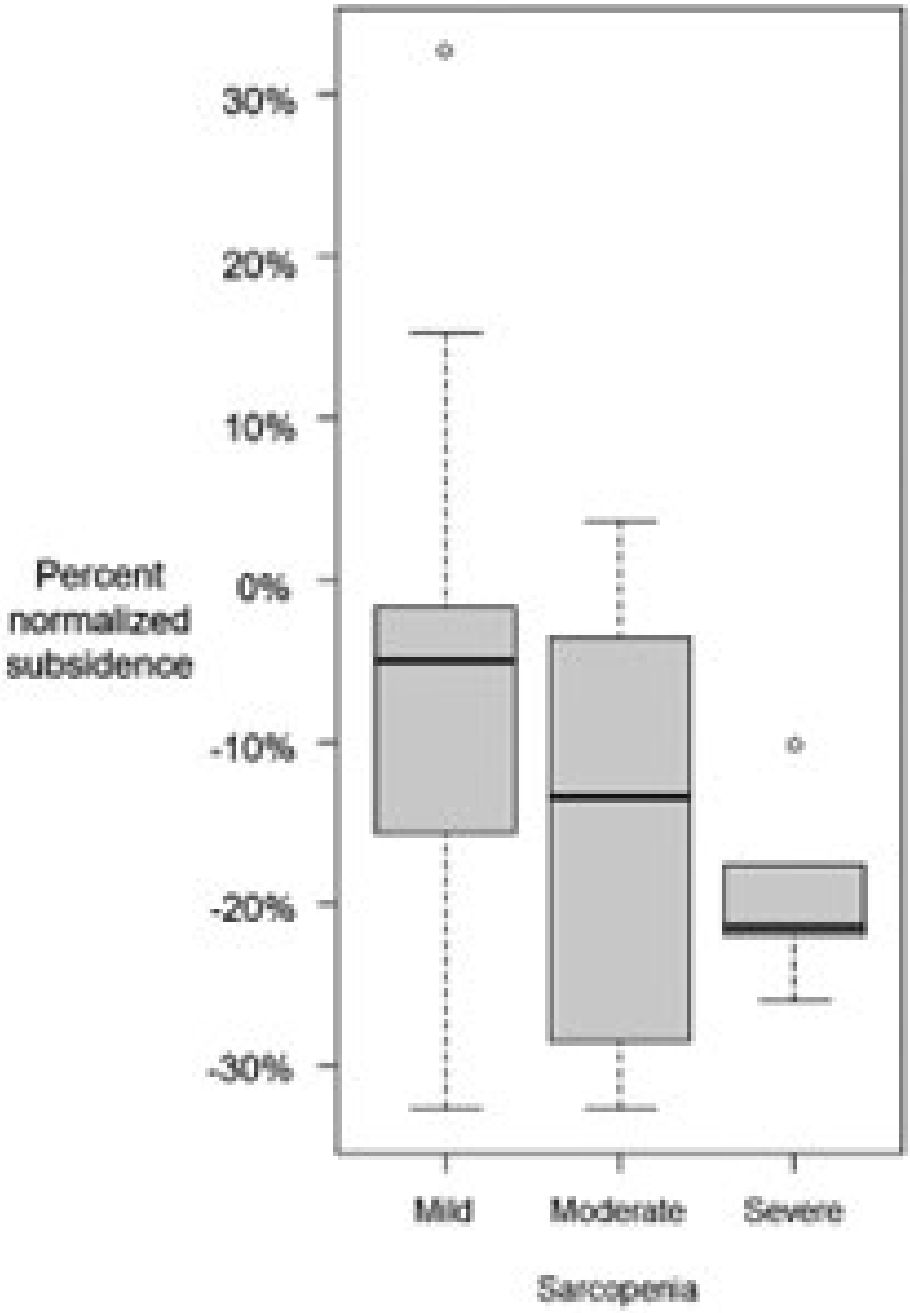

The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or medical device he or she wishes to use in clinical practice.

POSTER 59

Patient Perceptions of Same Day versus Overnight Stay for Cervical Surgery

Spencer Neaville, DO[1], Jaynie Criscione, BS[2], Caitlin Dobson, FNP[3], ***Marc Weinstein, MD[3]***
Foundation for Orthopaedic Research and Education[1] USF Morsani College of Medicine[2] Florida Orthopaedic Institute[3]

Introduction: Traditionally inpatient surgeries are shifting toward being performed outpatient due to recent developments in surgical technique, advances in anesthesia and pain management, and changes to reimbursement structures by payers. This shift raises important questions regarding patient preferences and perceptions of inpatient (over-night stay) versus outpatient (same-day surgery) experiences. Our study aims to explore patient perspectives to inform shared decision-making and optimize patient-centered care when determining operative setting and post-operative care.

Materials and Methods: After receiving approval from our Institutional Review Board (IRB), we administered a cross-sectional phone call survey to patients over 18 years of age. Patients who underwent one or two-level cervical spine surgery by five fellowship-trained spine surgeons at our institution from January 1 to December 31, 2023 were included. The surgeries included were anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA). Our initial sample size included 123 patients, and after applying exclusion criteria, 96 patients consented to participate. Nine patients were excluded because their surgery included a corpectomy, three patients declined participation, three patients had surgery indicated due to trauma, and twelve patients could not be reached. We assessed individual patient perceptions of their surgery and perioperative experience and compared inpatient to outpatient surgery groups. We also gathered demographic information and patient outcome measures using our EMR.

Results: Of the 96 patients who consented to participate in the study, 68 (70.8%) stayed at least one night after surgery, and 28 (29.2%) were same-day surgeries. The average age of the overnight group was 57 (SD = 11.9), and the average age of the same-day group was 55 (SD = 10.5, p = .50). Fourteen (14.5%) of patients felt they were allowed a preference in determining the length of post-operative stay. Utilizing a 5-point Likert scale, patients were asked how satisfied they were with the setting where they received surgery, and 88.2% of overnight patients reported being very satisfied or satisfied compared to 85.7% of same-day patients (NS). When asked which setting they would prefer if they needed a similar surgery in the future, 80.9% of overnight patients would choose to stay overnight again, and 75% of same-day patients would choose to have same-day surgery again. Including both groups, 29.2% of patients would prefer to go home the same day if they had another neck surgery, while just 19.8% would recommend similar same-day surgery to a family member. In patients who were married, 32.8% preferred same-day surgery compared to 20.7% of single patients. Patients in the overnight group had an average improvement in NDI of 15 compared to 13.9 (NS) in the outpatient group.

Conclusion: Understanding patient preferences for inpatient versus outpatient surgery is essential in delivering patient-centered care and optimizing resource allocation in healthcare facilities. We hope that the findings from this survey-based study will aid healthcare providers in tailoring surgical options to better align with patient preferences, potentially improving patient satisfaction and overall healthcare outcomes. Further research should be performed to study the importance of preference for healthcare delivery setting.

POSTER 60

High Preoperative Expectations May Not Need to be Feared

Joseph Wick[1], *Preston Jelen, BA*[1], *John Dawson, PhD*[1], *Berit Swanberg, BA*[1], *Benjamin Mueller, MD/PhD*[1], *Omar Ramos, MD*[1], *James Schwender, MD*[1], *Eiman Shafa, MD*[1], *Amir Mehbod, MD*[1], *Eduardo Beauchamp, MD*[1], *Kevin Mullaney, MD*[1], *Manuel Pinto, MD*[1], *Joseph Perra, MD*[1], *Bayard Carlson, MD*[1], *Timothy Garvey, MD*[1]
Twin Cities Spine Center[1]

Introduction: Most surgeons are apprehensive about patients with high expectations. Limited data exists evaluating correlations between patients' preoperative expectations for pain relief and subsequent functional and satisfaction outcomes following primary anterior cervical surgery. Understanding correlations between expectations and outcomes may help identify patients most likely to benefit from surgery. We sought to specifically evaluate correlations between preoperative expectations for pain improvement and 12-month functional outcomes and satisfaction following 1-2 level primary anterior cervical discectomy and fusion (ACDF) and/or cervical disc arthroplasty (CDA).

Materials and Methods: Patients who underwent 1-2 level primary ACDF or CDA between 2016-2021 were identified from a single-center prospective outcomes database. All patients had 12-month follow-up NDI data. Patients were excluded for indications including trauma, tumor, or infection. Preoperative expectations for achievement of moderate and complete pain relief were collected at the initial clinic visit using 5-point Likert scales. Preoperative and 12-month postoperative satisfaction were recorded using 7-point Likert scales. Covariates were collected from the electronic medical record, including age, gender, procedure type (ACDF or CDA; number of operative levels), preoperative tobacco and opioid use, worker's compensation/litigation, BMI, and indication (radiculopathy versus myelopathy). Linear regression models were constructed to assess 12-month NDI change score from baseline NDI versus expectations of achieving complete pain relief, moderate pain relief, and a composite of either moderate or complete pain relief ("at least moderate" relief). Additional linear regression models were developed to assess expectations versus patients' achievement of the minimum clinically important difference (MCID) at the 3- and 12-month postoperative timepoints and satisfaction at the 12-month postoperative timepoint.

Results: A total of 198 ACDF (56.1% female, median age 57) and 52 CDR patients (55.8% female, median age 51) met inclusion criteria. In linear regression models, no significant correlations were found between patients expecting complete pain relief, moderate pain relief, or a composite of "at least" moderate pain relief and degree of NDI score improvement at the 12-month postoperative timepoint or MCID achievement at the 3- and 12-month postoperative timepoints. There was no association between preoperative expectations and 12-month satisfaction. However, higher degrees of preoperative dissatisfaction were significantly associated with greater 12-month improvement in NDI score.

Conclusion: Preoperative pain relief expectations were not associated with functional outcomes or satisfaction following 1-2 level primary ACDF or CDR at 12-month follow-up. Patients' dissatisfaction with their preoperative spinal condition was significantly associated with greater 12-month NDI improvement. While setting appropriate expectations is important, assessing baseline satisfaction may help identify those most likely to benefit from surgery.

POSTER 61

Can C2 Dome-like Expansive Laminoplasty Provide Better Clinical Outcomes than Laminectomy and Posterior Instrumented Fusion in Severe JOA Patients with OPLL Involving C2?

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Introduction: Ossification of longitudinal ligament (OPLL) including C2 is usually of continuous and mixed type, and surgery using an anterior approach is often difficult. Accordingly, posterior approach surgery is the main surgery, but depending on the type of surgery, there is a possibility of insufficient decompression. There have been several studies on this, but there has not yet been a comparative study on C2 dome-like expansive laminoplasty and laminectomy and posterior instrumented fusion.

Materials and Methods: This study performed a retrospective cohort analysis on 40 patients with compressive symptoms caused by OPLL up to C2 level. 21 patients underwent C2 dome-like expansive laminoplasty with C3-7 expansive open-door laminoplasty (Group C2-Dom) and 19 underwent C2-7 laminectomy and posterior instrumented fusion (Group C2-PS). The Japanese orthopedic association (JOA) score was divided into mild-moderate and severe (JOA < 9), and each group were compared. The types, longitudinal extent, K-line classification of OPLL, and the preoperative and postoperative differences in C2-7 angle on flexion, neutral, extension x-ray were analyzed to evaluate the radiological characteristics. JOA score, visual analog scale (VAS) score, and recovery rate (RR) were used to evaluate clinical outcomes and statistically analyzed.

Results: The JOA score, VAS score and recovery rate were significantly improved at the final follow-up in both groups with no significant intergroup differences. At the final follow-up, ROM was significantly greater in the C2-Dom group than in the C2-PS group (1.11 vs 21.51, $P < 0.05$). There were no radiological or clinical differences between the two groups in mild-moderate JOA. In patients with severe JOA, pre- and postoperative ROM change was less in the C2-Dom group than in the C2-PS group (2.5 vs. 22.2, $P = 0.01$), and postoperative JOA(12.75 vs. 6.89, $P < 0.01$), change of VAS(19.42 vs. -14.44, $P < 0.1$), and recovery rate (49.95 vs. -2.46, $P < 0.01$) improved more in the C2-Dom group.

Conclusion: The C2 dome-like expansive laminoplasty can preserve the patient's neck motion after surgery. When patients with severe JOA, C2 dome-like expansive laminoplasty could achieve favorable clinical outcomes compared C2 laminectomy and posterior instrumented fusion. Further research and long-term clinical follow-up are needed to better appreciate the OPLL involving C2 level.

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Table 1. Demographic and baseline data

Characteristcis	Total	C2-Dom	C2-PS	p-value
No.of patients	40	21	19	
Sex (n)				
Female	7	2	5	
Male	33	19	14	
Age at surgery (yrs)	58.90 ± 10.31	61.48 ± 10.97	56.05 ± 8.98	0.097*
BMI (kg/m2)	26.26 ± 3.44	26.35 ± 4.30	26.17 ± 2.26	0.872*
Duration of initial symptoms (months)	36.73 ± 63.34	49.29 ± 69.63	22.86 ± 54.03	0.191*
Follow up periods (months)	47.70 ± 28.05	61.00 ± 17.53	33.00 ± 30.48	**0.001***
Operation level (n)	4.50 ± 1.16	4.67 ± 0.58	4.32 ± 1.57	0.344*
Comorbid conditions				
Smoking status, % (n)	40.0 (16)	47.6 (10)	31.6 (6)	
HTN	22	9	13	
DM	9	3	6	

* Student t-test

Table 2. Radiographic data comparison between patients C2-Dom vs. C2-PS

Radiologic parameters		C2-Dom	C2-PS	p-value
Preoperative C2-7 angle				
	Flexion	-6.96 ± 10.85	-17.71± 12.55	**0.014***
	Neutral	13.01 ± 12.30	8.92 ± 10.42	0.266
	Extension	20.74 ± 11.90	19.31 ± 10.35	0.722
	Range of motion (ROM)	27.70 ± 14.43	37.02 ± 14.41	0.078
Postoperative C2-7 angle				
	Flexion	-7.01 ± 12.73	-7.63 ± 15.85	0.897
	Neutral	11.43 ± 11.47	2.68 ± 12.01	**0.028***
	Extension	16.54 ± 7.84	7.82 ± 11.55	**0.012***
	Range of motion (ROM)	23.55 ± 12.68	15.45 ± 11.97	0.057
ROM change (Post-Pre)		-1.11 ± 14.98	-21.51 ± 18.93	**0.002***
K-line classificaiton (+), % (n)		76.2 (16)	78.9 (15)	0.840
MRI high signal intensity, % (n)		38.1 (8)	68.4 (13)	0.057

*p<0.05, statistically significant difference

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Table 3. Surgical outcomes for the C2-Dom and C2-PS groups: Severe JOA (JOA < 9)

		C2-Dom groups (n=13)	C2-PS groups (n=9)	P-value
ROM change		1.2 ± 17.4	-22.2 ± 14.1	**0.010***
Preoperative				
	VAS	3.7 ± 2.8	1.1 ± 2.4	**0.034***
	JOA	8.3 ± 2.4	7.6 ± 3.1	0.332
2 years after surgery				
	VAS	2.3 ± 2.5	2.6 ± 3.5	0.834
	JOA	12.4 ± 4.3	6.9 ± 3.8	**0.006***
Differentiation of JOA score		3.08 ± 3.56	0.33 ± 4.74	0.136
Recovery rate		42.3 ± 48.3	-2.5 ± 41.2	**0.035***

*p<0.05, statistically significant difference

POSTER 62

Do Octogenarians Have Worse Outcomes Following Cervical Spine Surgery?

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Introduction: As the population ages, the demand for elective cervical spine surgery among older adults continues to increase. However, concerns remain regarding the optimal management of older patients undergoing cervical surgery, given the potential complexities associated with advanced age, comorbidities, and physiological decline. While the safety and efficacy of cervical spine surgery in younger cohorts have been extensively studied, there is a paucity of literature specifically addressing outcomes in octogenarians. Among a cohort of patients undergoing elective cervical spine surgery, we sought to investigate the disparities between octogenarians and non-octogenarians regarding: 1) patient characteristics, 2) perioperative variables, and 3) postoperative outcomes.

Materials and Methods: A single-institution, retrospective cohort study was conducted of patients between the ages of 80-89, undergoing elective cervical spine surgery for degenerative pathology from 2011-22. Octogenarians undergoing cervical spine elective surgery were propensity matched 3:1 by baseline neck and arm pain, surgical approach, and total levels involved. Patient demographics and perioperative variables were compared between the cohorts. Primary outcomes of interest were patient satisfaction, 12-month reoperation rate and postoperative complications including pneumonia, pulmonary embolism, urinary tract infection, hematoma formation, deep vein thrombosis and surgical site infection. Secondary outcomes were PROMs at 3 and 12 months, including quality of life (EQ5D), modified Japanese Orthopaedic Association, neck disability index, and visual analog scale for neck and arm pain. Achieving minimal clinically important difference (MCID) was also assessed for each PROM. A sub-analysis was conducted for new-onset dysphagia following anterior approach separately.

Results: Among 116 patients undergoing elective cervical spine surgery for degenerative pathology, the mean age was 57.3±9.8, and 67 (57.8%) were male. Of these, 29 (25.0%) were between the ages of 80 and 89. Patient demographics: Octogenarians were significantly older (82.4±2.2 vs. 59.1±11.1, p<.001), had smaller body mass index (26.2±4.1 vs. 30.0±6.3, p=.003), less private insurance (3.4% vs. 41.4%, p<.001), and fewer active smokers (3.4% vs. 30.0%, p=.018) than non-octogenarians, with no difference in sex (p=.668), comorbidities (p=.173), myelopathic symptoms (p=.369), or ASA grade (p=.090). Perioperative variables: there was no difference in estimated blood loss (p=.836), operative time (p=.864), total levels involved (p=.428), or length of hospital stay (p=.193) between octogenarians and non-octogenarians. Outcomes: There was no difference in 12-month patient satisfaction (65.2% vs. 55.3%, p=.393), reoperation (3.4% vs. 2.3%, p=.736), 90-day readmission (12.0% vs. 6.9%, p=.408) or postoperative complications (10.3% vs. 6.9%, p=.548) between octogenarians and non-octogenarians. Similarly, there was no difference in any 3- and 12-month PROMs or proportion achieving MCID between the cohorts. On sub-analysis of anterior approach, there was no difference in postoperative new-onset dysphagia (16.7% vs. 11.5%, p=.732) among octogenarians and non-octogenarians.

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Conclusion: Patient satisfaction, reoperation rate, readmission rate, postoperative complications and PROMs did not signficantly differ between octogenarians and non-octogenarians undergoing cervical spine surgery. These findings suggest that age alone should not be a determining factor in surgical decision-making for elective cervical spine procedures, as octogenarians can achieve comparable outcomes to their younger counterparts.

POSTER 63

Level Selection in Posterior Cervical Fusion: The Clinical Impact of Junctional Crossing

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Introduction: Level selection is a crucial step in planning posterior cervical fusion (PCF) surgeries. Current literature suggests that a construct with a lower instrumented vertebra caudal to the cervico-thoracic junction (CTJ) is protective against hardware failure. However, the impact of extending the fusion beyond the CTJ in combination with an upper instrumented vertebra extending to the upper cervical junction, is still unclear. Among a cohort of patients undergoing PCF, we sought to determine the impact of crossing neither, one or both junctions on: a) reoperation, b) hardware failure, and c) patient reported outcomes (PROs).

Materials and Methods: Patients from a single institution undergoing PCF for degenerative pathology from 2010-22 were identified. Fusions involving the occiput were excluded. The primary independent variable was PCF construct, regarding the upper (C2-C3 segment) and lower (C7-T1 segment) cervical junctions. Based on the biomechanical differences between the upper cervical and the subaxial cervical spine, we suggest the C2-C3 segment be considered a functional junction with potential clinical relevance. Patients were categorized into those with: 1) neither junction crossed (NJX), 2) one junction crossed (OJX), or 3) both junctions crossed (BJX). Outcomes included reoperations, hardware failure, and PROs, including neck disability index (NDI%), neck and arm pain visual analogue score (VAS), and quality of life (EQ5D) at 3, 12 and 24 months. Cox-proportional hazard and multivariable regression models were conducted controlling for age and BMI for reoperation and mechanical failure, respectively.

Results: Among 443 patients undergoing PCF for degenerative cervical pathology, the mean age was 62.32±10.12; 268 (60.8%) were male. Of these, 88 (19.9%) patients had BJX, 139 (31.4%) OJX, and 216 (48.8%) NJX. Preoperatively, there was no difference in age, gender, smoking status, BMI, prior spine surgery, or comorbidities between the groups (all p>0.05). Reoperation: OJX patients had significantly more reoperations (10.8%) than BJX (3.4%, p=.045) and NJX (4.2%, p=.015) patients, with no difference between BJX and NJX patients (p=.758). On cox-proportional hazard regression, OJX was associated with increased risk for reoperation versus NJX (HR=3.85, 95%CI=1.90-7.79, p<0.001) and BJX (HR=3.19, 95%CI=1.44-7.03, p=0.004). Hardware failure: NJX patients had significantly less hardware failure (6.5%) than BJX (17.2%, p=.004) and OJX (19.7%, p<.001) patients, with no difference between BJX and NJX patients (p=.645). On multivariable regression, OJX (OR=3.85, 95%CI=1.90-7.79,p=<.001) and BJX (OR=3.19, 95%CI=1.44-7.03,p=.004) increased the odds of hardware failure versus NJX. PROs: NJX reported less 3-month NDI% (29.36±17.93 vs. 34.16±15.08 vs. 35.07±18.61, p=.013) than BJX and OJX patients, with no difference in other PROs.

Conclusion: In our cohort of patients undergoing PCF, patients with OJX had greater rates of reoperation than patients with BJX and NJX. Patients with NJX had less hardware failure and 3 month NDI% than patients with BJX and NJX, with no difference in other PROs at any timepoint. The results of our study suggest avoiding junction crossing is beneficial in reducing

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hardware failure and improving short-term outcomes. Further, where clinically feasible, opting to cross both junctions during PCF may lead to better postoperative outcomes and a reduced need for subsequent surgeries when compared to crossing only one junction.

POSTER 64

Varenicline Reduces Delayed Union Rates in Nicotine-Dependent Adults with Cervical Fractures

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Introduction: High serum nicotine levels are associated with increased risk of delayed union and nonunion. Varenicline, a nicotinic receptor partial agonist used in smoking cessation, has been shown to mitigate the adverse effects of nicotine use in rodent models. However, its impact on human adult cervical fracture patients is not known.

Materials and Methods: The PearlDiver database was queried to identify nicotine-dependent adults with cervical fracture. Patients were stratified by preoperative varenicline use within one year of surgery and matched 1:1 by age, sex, and Charlson Comorbidity Index (CCI). Comparative analyses were performed on demographics, comorbidities, and medical and surgical complications up to two years postoperatively. Multivariate logistic regression analyses, accounting for significant variables, were utilized to further characterize the role of varenicline on fracture healing.

Results: In total, 1,883 non-varenicline and varenicline users were included. Mean age was 53.6 years, 47.0% were female, and mean CCI was 2.5. Varenicline users reported lower rates of blood loss anemia (Varenicline User = 5.4% vs Non-Varenicline User = 7.8%) but higher rates of chronic pulmonary disease (69.1% vs 55.7%), obesity (38.8% vs 34.2%), osteoarthritis (44.1% vs 39.3%), and depression (73.6% vs 67.7%), all $p<0.05$. At 90-day follow-up, varenicline users had lower rates of infection (0.3% vs 1.1%, $p=0.011$) and anterior (0.6% vs 1.6%, $p=0.003$) or posterior (0.5% vs 1.5%, $p=0.003$) fusion and but comparable rates of wound dehiscence (0.5% vs 0.7%, $p=0.403$) and hematoma (0.5% vs 0.3%, $p=0.422$). At 6-month follow-up, varenicline users had lower rates of delayed fracture union (0.4% vs 1.4%, $p=0.002$). Finally, at 2-year follow-up, varenicline users had lower rates of fracture sequelae (2.8% vs 4.3%, $p=0.013$) but comparable rates of pseudoarthrosis (1.2% vs 1.3%, $p=0.882$) as non-varenicline users. Multivariate regression analysis, accounting for age, gender, CCI, and significant comorbidities, revealed that varenicline users have lower odds of delayed union (OR=0.41, 95%CI=0.34-0.48, $p<0.001$) and pseudoarthrosis (OR=0.79, 95%CI=0.69-0.90, $p<0.001$).

Conclusion: In cervical fracture patients, varenicline use was associated with lower rates of infection, delayed fracture union, fracture sequelae, and subsequent anterior or posterior fusion. In addition, pseudoarthrosis and delayed fracture union patients were less likely to report varenicline use preoperatively. Pharmacotherapy may be beneficial in mitigating associated risks and optimizing outcomes in nicotine users with spinal pathologies.

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Variable	Non-Varenicline Users (N = 1,883)	Varenicline Users (N = 1,883)	P-value
Demographics			
Age	53.64 (12.21)	53.64 (12.21)	1.000
Female Sex	889 (47.21)	889 (47.21)	1.000
CCI	2.52 (2.30)	2.52 (2.30)	1.000
Comorbidities			
Asthma	418 (22.20)	488 (25.92)	**0.009**
Blood Loss Anemia	147 (7.81)	102 (5.42)	**0.004**
Cerebrovascular Disease	722 (38.34)	725 (38.50)	0.947
Chronic Kidney Disease	365 (19.38)	347 (18.43)	0.479
Chronic Pulmonary Disease	1050 (55.76)	1302 (69.14)	**<0.001**
COPD	943 (50.08)	1204 (63.94)	**<0.001**
Congestive Heart Failure	152 (8.07)	170 (9.03)	0.322
Coronary Artery Disease	604 (32.08)	704 (37.39)	**<0.001**
Depression	1274 (67.66)	1385 (73.55)	**<0.001**
Diabetes	781 (41.48)	724 (38.45)	0.062
Hypertension	1448 (76.90)	1475 (78.33)	0.309
Obesity	643 (34.15)	731 (38.82)	**0.003**
Osteoarthritis	739 (39.25)	831 (44.13)	**0.003**
Peripheral Vascular Disease	611 (32.45)	595 (31.60)	0.600

Variable	Non-Varenicline Users (N = 1,883)	Varenicline Users (N = 1,883)	P-value
90-Day Complications			
Infection	20 (1.06)	6 (0.32)	**0.011**
Wound Dehiscence	14 (0.74)	9 (0.48)	0.403
Surgical Site Complications	16 (0.85)	7 (0.37)	0.094
Hematoma	5 (0.27)	9 (0.48)	0.422
Anterior Fusion	31 (1.61)	11 (0.58)	**0.003**
Posterior Fusion	28 (1.49)	9 (0.48)	**0.003**
6-Month Complications			
Delayed Union	27 (1.43)	8 (0.42)	**0.002**
2-Year Complications			
Pseudoarthrosis	24 (1.27)	22 (1.17)	0.882
Fracture Sequelae	81 (4.30)	52 (2.76)	**0.013**

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